Paleopedological tracers of the Late Pleistocene cryogenic environments in Europe and Western Siberia

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Abstract

Cryolithogenesis interacts with the pedogenetic processes forming a set of specific features in the solid matrix of soils. These features are preserved in the buried paleosols where they could be used as indicators (direct and indirect tracers) of the past cryogenic environment. MIS3 paleosols in the center - north of European Russia (Upper Volga basin) and Western Siberia (Middle Ob' basin) and MIS2 paleosols in low Austria are represented by hydromorphic profiles with gleyic colour pattern and sometimes Histic horizons. Conspicuously, they are developed in the well-drained geomorphic positions, where modern soils are non-gleyic. We suppose that the presence of permafrost in the Late Pleistocene was responsible for water logging and generation of reductomorphic soil environment. Macromorphological signs of cryoturbation and micromorphological evidences of coarse grain sorting and platy microstructure due to ice lens development provide additional direct indicators of cryogenic environment.

Keywords: cryogenesis, paleosols, gley, permafrost, late Pleistocene.

Introduction

Identification and reliable interpretation of the witnesses of the past permafrost development (proposed as a special branch of geosciences – cryotrassology) is of major important for reconstructing past terrestrial environments of the former cold periods. Such indicators/tracers of those events as pseudomorphs after repeated ice wedges, cryoturbations in sedimentary layers, solifluction features, lenses of segregation ice etc. are reliable but not ubiquitous direct markers.

However besides these direct evidences, soil systems could provide indirect indicators of the past cryogenic conditions. Certain pedogenetic processes although not necessarily linked to permafrost, are strongly influenced or modified in its presence. In particular icy permafrost layers could cause water saturation and thus switch on the hydromorphic soil forming processes: accumulation of peat and gleyzation in the mineral horizons, in the geomorphic positions and substrates where otherwise well-drained non-gleyic soils are formed. Therefore, we propose to use the indirect pedological indicators/tracers of former permafrost in order to complete the information about its spatial distribution and chronostratigraphic occurrence.

Materials and Methodology

We carried out comparative analysis of the late Pleistocene gleyic paleosols discovered: within the alluvial and lacustrine sequences in the center - north of European Russia (Upper Volga basin) and Western Siberia (Middle Ob' and Taz basins), and in Upper Austria in the classical loessic sequences. Correlation and pedogenetic interpretation of the studied profiles was carried out on the basis of macro- and micromorphological characteristics and radiocarbon datings of the paleosol organic materials, sometimes supported by luminescence dates of sedimentary strata

Results and Discussion

Recently well-developed paleosols formed during the MIS3 were discovered to the north from the Eurasian Loess Belt, in the north of European Russia, Upper Volga basin (Rusakov, Sedov, 2012) and North-Western Siberia, Middle Ob' basin (Sheinkman et al. 2016), and recently – in the Taz basin. The paleosols are developed within the Late Pleistocene alluvial and lacustrine sequences and produced radiocarbon dates from its organic materials within the time interval of 50–25 Ka BP (Fig. 1).

They represent hydromorphic profiles with Histic horizons or materials and gleyic colour pattern. In thin sections numerous specific ferruginous pedofeatures (concentric nodules, mottles, stripes) as well as abundant poorly decomposed plant fragments were (Fig. 2).

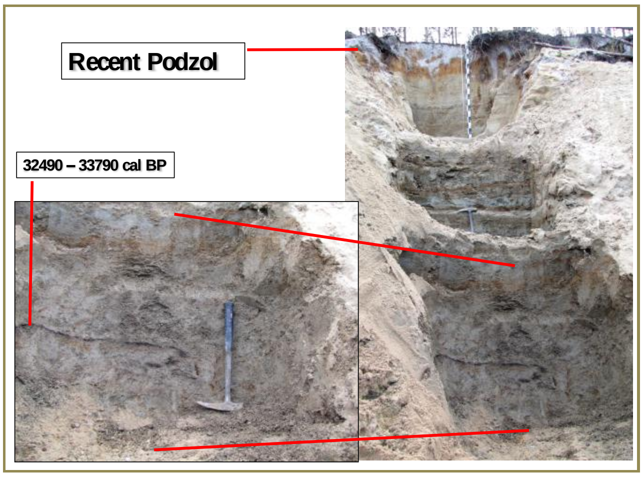

Figure 1. MIS3 gleyic paleosol in the alluvial section Belaya Gora (Vakh river, Middle Ob' basin)

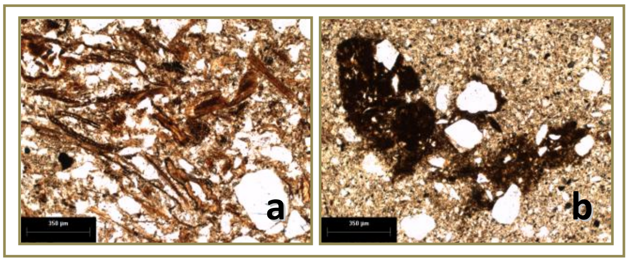

Figure 2. Micromorphology of MIS3 gleyic paleosol in the middle Ob´ basin: a – plant tissue fragments, b – ferruginous nodules. Plain polarized light.

Conspicuously they are developed in the well-drained geomorphic positions, where modern soils (Podzols and Luvisols) have only weak surficial redoximorphic (stagnic) features. These paleosols differ from synchronous Cambisols and Chernozems formed within loess sequences to the south.

In the Late Pleistocene loessic sequences of Germany and Austria strongly gleyed soils (known as Tundragley or Naßboden) correspond to the strata, developed during MIS2 including MIS3/MIS2 transition (Terhorst et al. 2015). Again, they are formed in the elevated landsurfaces providing good drainage on porous calcareous loess which hampers gleyzation. Indeed earlier (MIS3) and later (Holocene) soils of the same sequences are non-gleyic Cambisols and Luvisols. Additional evidences of permafrost in these soils are provided by morphological features of horizon fragmentation and mixing by cryoturbation and solifluction. Also in thin sections signs of cryogenic structuring, grainsize sorting, mixing of organic and mineral materials and deformation of plant debris and pedofeatures by frost processes are observed. Similar interpretation of the MIS2 incipient gleyic paleosols in the West German loessic sequences was proposed earlier by Antoine (2009).

In all presented cases we attribute strong gleization to permafrost rather than to deep seasonal freezing because only constantly frozen icy layer in the bottom of the profile could provide watter-logging and anoxic conditions throughout the year including the warmest season (when maximal microbial activity and thus gleyzation could take place). According to this interpretation we classify these paleosols as Reductaquic Cryosols. From the described spatial/temporal occurrence of the cryogenic gleyic paleosols we deduce the following: 1) Our data on gleyic MIS3 paleosols in the Upper Volga and Middle Ob' basins together with the findings of similar MIS3 gleyic paleosols in Kolyma lowlands (Zanina et al. 2011) point to a continuous zone of Reductaquic Cryosols in the Northern Eurasia during the Middle Valday/Karga interstadial (Sedov et al. 2016). This zone shifted several hundreds of km to the southwest towards the Central Europe during the MIS3-MIS2 transition. This was conditioned by the southward extension of permafrost in the beginning of the MIS2.

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