QUANTITATIVE RECONSTRUCTION OF HOLOCENE CLIMATE CHANGES BY MINERALOGICAL ANALYSIS OF PALAEOSOLS IN THE STEPPE REGIONS OF EAST EUROPE

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The steppe soil belt of Eurasia, which includes the northern Caucasus, the low Volga basin, the southern Urals, and northern Kazakhstan, was investigated in this multidisciplinary study. Properties of palaeosols, as natural environmental recorders in the steppe belt, were compared with the sequence of environmental events. The work has shown that integrated mineralogical, magnetic methods can be used to obtain quantitative estimates of past climate, especially rainfall, changes, through both time and space.

About 6000 years ago, a new type of burial ceremony—erecting of a soil hill over a grave pit—appeared among steppe the tribes of the Eneolith epoch. Such archaeological monuments, known in Russian scientific literature as khourgans, are typical attributes of the southern Russian steppe landscape. Some burial complexes consist of several dozens or over hundreds of barrows, created within the Bronze Age (IV–II millennia B.C.), the Early Iron Age (I millennia B.C. – 4th century A.D.) and the early and developed stages of the Middle Ages (5th–14th centuries A.D.). Due to the well established chronological sequence of archaeological cultures it is possible to define the time of creation of the barrows quite precisely (from 200–300 to less then 50 years).

Understanding of palaeoclimate requires interdisciplinary work combining mineralogical, magnetic, pedological, microbiological and archaeological data. In this study, quantitative estimates of palaeoclimate changes through Holocene time were developed from analysis of the modern soil sequences, archaeologically buried soils. Soils can "record" information on solid phase mineral and retain this information in situ upon burial. Soil minerals are conservative part of soils, but furthermore they reflect the stage of soil development and the landscape-climatic situation at the moment of construction of the archaeological monument. Based on our previous work, we consider as most important the magnetic and mineralogical properties of the palaeosols, their humus content in the upper soil horizon, the depth of easily soluble salts, carbonates and their clay mineralogy.

Most recently, use of soil magnetite content as the basis of a quantitative climofunction (of rainfall) has been established for the area of the Russian steppe (Maher et al., 2002, 2003; Alekseev et al., 2003; Zavarzina et al.; 2003). Magnetic data, XRD, Mossbauer spectroscopy and analysis by electron microscopy show that the source of the enhanced magnetic susceptibility values in the Russian steppe soils is ultrafine-grained magnetite-maghemite. There is a strong statistical correlation between modern rainfall and the pedogenic magnetic susceptibility across the Russian steppe. This climofunction was then applied to the palaeosols of our study area to determine palaeorainfall. Hence, palaeorainfall can be calculated for each climate stage recorded in archaeologically buried soils.

The rate of formation of secondary ferrimagnetic minerals in soils is connected with the flux of Fe from primary Fe-bearing minerals. That is a function of the intensity and duration (time) of weathering. Once formed, Fe-oxides may be the subject to continual modification in an approach toward equilibrium with the changing soil environment. The investigation of sets of buried soils (a chronosequences spanning cca. 5000 years) from the steppe region does not confirm the fact that time is the main factor responsible for pedogenic enhancement of ferrimagnetic minerals concentration. Duration of the weathering determines the total pool of iron released from silicates and involved into formation of soil Fe-oxides in the connection with climatic conditions.

The obtained data allow to conclude that climate in the steppe soil belt of Eurasia over last 5000–6000 years had the cyclic character with alternation of humid and arid epochs of different degree and duration.

References

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