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Petromagnetic Properties of Fallow Soils as an Indicator of the Organic-Matter Content

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Abstract—The magnetic properties of chernozem soils, dark and light gray forest soils, and sod-podzolic soils present in the Republic of Tatarstan have been researched and described using the petromagnetism method, coercive spectrometry, and X-ray phase analysis with the purpose of improving the soil monitoring system in relation to fallow and virgin soils. In the course of soil genesis, iron compounds undergo transformations and the magnetic parameters of the soil profile change in comparison with the parent rocks. It can be said that the magnetic profile reflects the pedogenesis processes. A statistically significant relationship between the humus content on the one hand and the susceptibility and intensity of remanent saturation magnetization (J_{rs}) on the other hand has been identified. A technique making it possible to separate the contributions of lithogenic and pedogenic magnetic minerals to the saturation remanence (J_{rs}) intensity has been developed on the basis of coercive spectrometry. In the studied soils, the pedogenic component primarily consists of the organogenic extracellular constituent of the magnetite–maghemite association, which is the best candidate to proxy in assessments of the humus concentration in soils at various depths with magnetic methods.

Keywords: coercive spectrometry, magnetic susceptibility, component analysis, magnetic analysis techniques, humus, pedogenesis, monitoring, virgin soil, fallow soil, magnetite

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INTRODUCTION

The research into magnetic properties of various soil types is relevant both for fundamental science (e.g., soil evolution) and for practical purposes (e.g., agroecological soil monitoring). It is known that magnetic properties of zonal soils change with the depth according to certain patterns. The magnetic susceptibility profiles of various soil types may have the shape of both eluvial–illuvial and accumulative curves (Babanin et al., 1995; Busorgina, 2002). By now, it is commonly accepted that pedogenesis in automorphic (aerobic) conditions normally increases the magnetic susceptibility of soils, most often by raising the concentrations of finely dispersed magnetite and maghemite in the soil mass (Evans et al., 2003; Geiss et al., 2006).

In the past, a comparative assessment of magnetic properties and some parameters of the degree of mineral weathering was performed with our involvement for virgin forest–steppe soils formed on initially vertically homogenous soft parent rocks (aleurite of the Kazanskian stage, Permian system and quaternary deluvial clay loam) (Fattakhova et al., 2015). It was established that, in the temperate climate, the formation of mature magnetic profiles in automorphic soils is a very lengthy process. At this stage, the formation of secondary magnetic minerals is actively ongoing in Holocene chernozem soils; the resource of primary ferriferous silicates less susceptible to weathering in their organic horizons is not depleted yet (Fattakhova et al., 2016).

The major part of the experimental data interpreted in the context of the formation of soil magnetic properties and the time dependence of this process were collected in the course of studies of soil chronosequences on river and marine terraces (Singer et al., 1992; Torrent et al., 2010) and chronosequences of modern and fossil soils on loess deposits (Maher and Thompson, 1995; Vidic et al., 2004). The application of coercive spectrometry makes it possible to significantly increase the range of studied soil objects and raises the informative value of magnetic methods. In fact, this method allows one to separately determine the inputs of the dia-/paramagnetic, ferrimagnetic, and superparamagnetic components into the magnetic susceptibility; concurrently, coercive spectrometry makes it possible to distinguish various components of the ferrimagnetic signal (Kosareva et al., 2015, 2015; Fabian et al., 2016).