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# The development of deep soil processes in ancient kurgans of the North Caucasus

A.L. Alexandrovskiy [a,*], S.N. Sedov [b], V.A. Shishkov [a]

[a] Institute of Geography, Russian Academy of Sciences, Staromonetny 29, 119017 Moscow, Russia
[b] Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D.F., Mexico

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ABSTRACT

In the past four thousand years, Luvisols with a clearly differentiated profile have developed on kurgans of the Bronze Age under beech and oak stands in humid climatic conditions of the foothills of the North Caucasus. The great height of the kurgans (up to 10 m) and their homogeneous composition (the kurgans were constructed of Chernozemic soil and are underlain by Chernozem) make it possible to study the direction and rate of pedogenetic and diagenetic processes acting at a considerable depth. In these kurgans, the profiles of Luvisols are underlain by the carbonate-illuvial horizon that has been shaped by illuviation processes acting for about 4000 years. The major part of this horizon lies at the depths of 110–350 cm, though carbonates penetrate as deep as 9 m along the deep earthworm burrows. At this depth, they occur within the noncalcareous mass of the lower part of the kurgans' bodies and in the upper part of the underlying Chernozem. At the depth of 5–9 m, in the kurgans and in the buried Chernozem, gypsum and iron pedofeatures (nodules and red-brown films on ped faces) have appeared. Humus-clayey infillings are present in some of the earthworm burrows at this depth. The formation of such a deep profile with the carbonate-illuvial, gypsiferous, and ferruginated horizons is related to the local bioclimatic conditions characterized by high precipitation and the growth of forest vegetation. Deep washing of the soil with atmospheric precipitation is combined with the manifestation of illuviation processes and alteration of the soil mass at a considerable depth. The mineralization of humic substances and some alkalization of the soil mass also take place in the deep horizons. However, these processes may occur at different depths independently from the illuviation processes and can be attributed to the group of diagenetic processes.


## 1. Introduction

Archeological objects in general and, particularly, ancient kurgans are of great interest for researchers studying the development of soils with time (Gennadiev, 1990; Goldberg and Macphail, 2006; Limbray, 1975). Every year, many kurgans are being excavated in Russia; their age may reach 6000 years. Thus, there are great opportunities to gain considerable and representative material on the soil evolution. Paleosol studies of kurgans in Russia were initiated long ago (Krishtofovich, 1914). Most of them are aimed at the study of soils buried under the kurgans to reconstruct the environmental conditions of the Holocene (Demkin, 1997; Ivanov and Demkin, 1999). The soils formed on the kurgans of different ages are also studied to gain knowledge about the stages of soil formation and the character and rates of pedogenetic processes (Gennadiev, 1990). An important advantage of using kurgans as study object is that archeological data on them allow us to obtain relatively exact dates for the soils formed in kurgan bodies and the soils buried under them directly in the field. Soil development with time can also be studied on various natural formations, such as moraines of mountain glaciers and various terraces (Stevens and Walker, 1970).

Kurgans, especially high kurgans, represent valuable objects for the study of deep soil processes. At present, different methods and approaches are used to study them, including geomorphological, chemical, physical, mineralogical, and other methods (Birkeland, 1999; Graham et al., 1994). It should be noted that the results gained even with the most precise methods cannot be unambiguously interpreted, because natural deposits (fluvial or eolian) usually have a layered character and their vertical heterogeneity may complicate the interpretation of factual data (Muggler and Buurman, 2000).

More definite data on the development of deep profiles of soils and weathered mantles on ancient surfaces are available for tropical and subtropical regions (Gracheva et al., 2001; Vidic, 1998; Thompson, 1981). It is generally believed that the development of such profiles requires long time spans (tens and hundreds of thousand years).

The study of deep soil processes in temperate regions involves additional difficulties because of the relative youth of the deposits. Thus,

* Corresponding author. Tel.: +7 495 9590028, +7 915 3627417 (cell); fax: +7 495 99590033.
E-mail addresses: alexandrovskiy@mail.ru (A.L. Alexandrovskiy), serg_sedov@yahoo.com (S.N. Sedov), vshishkov@yandex.ru (V.A. Shishkov).

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the study of weathering processes was performed for the gravelly moraine deposits (Zamotaev and Chernyakhovsky, 1996). The authors demonstrated that the depth, at which definite features of alteration (weathering) of gravelly material derived from gneissic rocks are present, reaches 7–12 m. The period of action of these processes encompasses not only the Holocene but also the entire Late Pleistocene. In more southern regions, in the subtropical zone of Georgia, a stronger alteration of andesite-basaltic gravels was observed at a considerable depth. During the first stages of weathering, sandy material was transformed into clayey material, and alteration crusts appeared on gravels. On ancient sea terraces (ca. 500 ka), deep weathering processes transformed gravelly material into reddish clay (Chernyakhovsky, 1973).

The alteration of soil material in deep horizons is of great interest for studying the problems of the Earth critical zone that includes the soil proper (A, B and C horizons) and the loose sediments (Wilding and Lin, 2006). The latter may have a considerable thickness and are usually perceived as horizons slightly altered by the pedogenesis, "little affected by pedogenic processes" (Richter and Yaalon, 2012). At the same time, many researchers noted that soil processes extend to a great depth, up to 10 m (Glinka, 1931), or even more (Harrison et al, 2011). Wyssotzky (1934) studied the processes related to the dynamics of soil moisture in chernozems and concluded that the descriptions of standard soil pits are insufficient for these purposes. He examined the profiles of many meters in thickness and argued in favor of the "deep-soil" pedology.

In the temperate climate, recent Holocene and Late Pleistocene surfaces predominate; at these geomorphic positions, clearly expressed features of pedogenic alteration of the deep horizons are usually absent. However, along with the earlier noted features of the weathering of stony materials and gravels, there are also the features attesting to the deep penetration of root systems and to considerable changes in the water regime of the deep soil horizons (Harrison et al., 2011; Wyssotzky, 1934). At the same time, the age of such features may differ considerably, and the characteristic times of the corresponding processes (weathering) are rather obscure and may vary from the modern epoch to the Late Pleistocene. Thus, the rates of weathering processes remain uncertain.

In this context, large kurgan bodies of a relatively homogeneous initial composition and with clearly determined age represent unique objects offering possibility to study the character and rates of the development of not only the surface soil horizons, but also deep subsoil processes.

## 2. Materials and methods

The study area is located at the foothills of the northern macroslope of West Caucasus to the south of Maykop City under an oak-beech forest at elevations about 500–700 m a.s.l. (Fig. 1). The mean annual temperature reaches +10 °C, and the mean annual precipitation is about 800 mm. The parent material is brown loam with some admixture of sand. Carbonates occur at the depths of more than 1.5 m. The soils developed from loams are classified as Luvisols. Rendzinas are developed on the outcrops of calcareous bedrock.

At the Novosvobodnaya site, archeologists studied kurgans of the Early Bronze Age (the Maykop culture), whose radiocarbon age is about 4200–4700 BP (cal 4800–5500 BP). These kurgans are very large; their height is up to 10 m, and their diameter is up to 180 m. They are mainly composed of the material of the upper humus horizon of Chernozems. Typical Chernozems are buried under the kurgans. Their profile consists of the following horizons: dark-humus A horizon (40 cm) — transitional AB horizon (up to 80 cm) — Bk horizon (105–200 cm). Three kurgans are well preserved. Kurgans 26 and 27 reach 8 m in height and are protected from the destruction by pavement (rock blanket) composed of calcareous rocks. Kurgan 29 is lower (4 m) and is not protected by the calcareous rock blanket. All these kurgans consist of the material from the humus horizon of Chernozems. About 4000–3500 years ago, the forests spread down from the mountains to the foothills and piedmont plain as a result of an increase in humidity of the climate. The initial Middle Holocene steppe Chernozems degraded under forests and transformed into Luvisols. Soil carbonates were leached off, and the soils became acid. However, the lower part of the chernozemic humus horizon with krotovinas was partly preserved within the newly formed Bt horizon of the Luvisols.

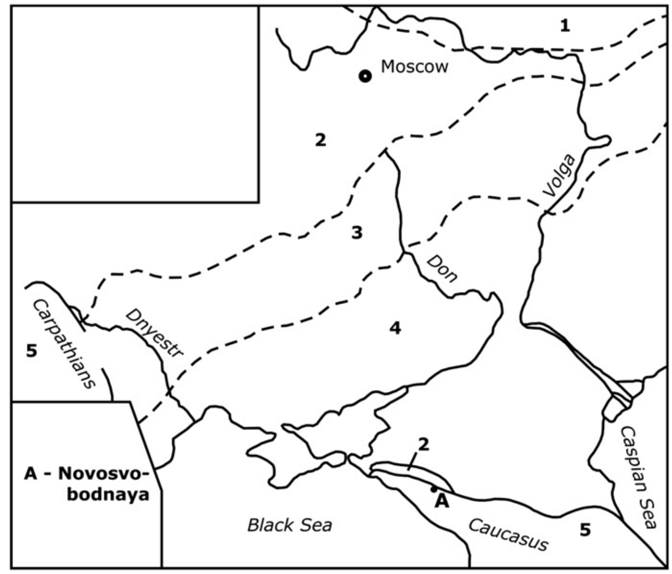


**Fig. 1.** Location of the Novosvobodnaya site and biomes: (1) taiga, (2) mixed and broad-leaved forests, (3) forest-steppe, (4) steppe, and (5) mountains (forests, meadows, etc.).

The initial Chernozems slightly changed by diagenesis were studied under the kurgans; they were compared with surface soil on the kurgans composed of different materials and also with background soils on neighboring territories unaffected by the kurgan construction.

A standard methodology for studying the surface and buried soil chronosequences was used (Ivanov and Aleksandrovskiy, 1987). In the field, morphological descriptions of the deep soil profiles and the soil sampling were performed from big archeological pits dissecting the bodies of kurgans 26 and 27 down to the buried soil surface. Soil analyses were performed by routine methods; the Corg content was determined by the Tyurin method (wet combustion, similar to the Walkley–Black method), the soil pH was measured with a potentiometer in the water soil suspension; the $CaCO_3$ content was determined by the acidimetric method (according to Kozlovskii), and the clay (<0.001 mm) content was determined by the pipette method in modification by Kachinskiy (1958). The $^{14}C$ age of humic acids was obtained using liquid scintillation counting. Thin sections from undisturbed samples were described in agreement with terminology suggested by Bullock et al. (1985). The submicromorphology of small fragments of the carbonate nodules was also studied under a scanning electron microscope (JEOL JSM-6610LV). Elemental analysis was performed by energy dispersive spectroscopy (EDS) INCAx-act from Oxford Instruments. Before the study, the samples were covered by a thin film of Pt alloy for creating electrical conductivity in a JEOL ionic coating chamber was used.

## 3. Results and discussion

The first results of the study of large kurgans at the Novosvobodnaya site were published earlier (Alexandrovskiy et al., 1999). Additional investigations made it possible to reveal new variants of the soil