



Divnogorie pedolithocomplex of the Russian Plain: Latest Pleistocene deposits and environments based on study of the Divnogorie 9 geoarchaeological site (middle reaches of the Don River)



S.A. Sycheva^a, A.N. Bessudnov^b, A.L. Chepalyga^a, T.A. Sadchikova^c, S.N. Sedov^d,
A.N. Simakova^c, A.A. Bessudnov^{e,*}

^a Institute of Geography RAS, Moscow, Russia

^b Lipetsk State Pedagogical University, Lipetsk, Russia

^c Geological Institute RAS, Moscow, Russia

^d National Autonomous University of Mexico (UNAM), Mexico City, Mexico

^e Institute for the History of Material Culture RAS, St.-Petersburg, Russia

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ABSTRACT

Latest Pleistocene fossil soils and deposits have been described in the geoarchaeological site Divnogorie 9 (the Middle Don drainage basin) under the name of Divnogorie pedolithocomplex. For the first time, a soil-sediment series with 2–3 levels of soil formation has been described in the forest-steppe of the Russian Plain and dated to the Bølling–Allerød interval (BØ–AL). That was the last soil formation of Pre-Holocene time. The soils are weakly developed (immature), of meadow and buruzem genesis. They formed for a few hundreds of years in periglacial steppe environments, under forest-steppe vegetation. The lower soil (attributed to Bølling) is dated at 13.5–14 ka cal BP and defined as a weakly developed Petrocalcic Skeletic Colluvic Siltic Chernozem. Under coniferous-broadleaf forests the middle soil is described as Umric Calcaric Colluvic Siltic Leptosol and dated at Dryas-2. The uppermost soil dated at Allerød is weakly developed Skeletic Calcaric Colluvic Siltic Cambisol formed under coniferous-broadleaf forest-steppe. The data obtained made possible reconstructions of the Late Glacial climates and landscapes. The underlying sediments are the deposits of Divnogorie paleo-lake. The deposits include seven bone-bearing horizons with Late Upper Palaeolithic lithic tools. They are dated to the interval 17–14 ka Cal BP.

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1. Introduction

The Bølling–Allerød interval (BØ–AL) was noted for extremely unsuitable conditions for soil development (Velichko, 2002). In particular, two features of the period should be marked as especially unfavorable: climatic characteristics (low temperatures and insufficient moisture supply) and a brevity of the intervals when the soil formation was possible (that resulted in discontinuity of soil evolution). During that period, no “normal” (mature, with fully developed profile) soils could develop. The leading role belonged to relief-forming processes. New drainage networks developed, and intensified erosion and deposition processes, which suppressed soil

forming processes (Sycheva, 1997, 2006b, 2006c). The soils dated to the Latest Pleistocene warmings (Bølling and Allerød) are of small thickness and weakly developed, occurring in the eolian deposits (dunes) at the periphery of the last ice sheet in northern Germany, Poland, Baltic countries, Belarus and in northwest Russia (Velichko, 2002; Starnberger et al., 2009; Jankowski, 2014). In other regions of the Russian Plain, the soils dated to the Late Glacial occur only occasionally and are most often related to archaeological sites found on low terraces or slopes in river valleys (Aleksandrovskiy, 1983, 2004; Gugalinskaya and Alifanov, 2011). Most often, only one Allerød soil is described or a composite soil of Bølling–Allerød. The Late Glacial soils are still uncertain as to their stratigraphic position, genesis, rank, and history of evolution. The nomenclature and typology of the soils attributed to the BØ–AL interval on the Russian Plain have not been developed as yet, nor were stratotypes properly identified. The Late Glacial soils studies are of considerable

* Corresponding author.

E-mail addresses: sychevasa@mail.ru (S.A. Sycheva), bessudnov_an@mail.ru (A.N. Bessudnov), bessudnov_a22@mail.ru (A.A. Bessudnov).

importance not only for a detailed subdivision of the Late Pleistocene deposits, but they would provide a basis for paleoclimatic and paleoenvironmental reconstructions of the time marked by glacial to interglacial epoch transition, rapid changes in faunal assemblages and initial stages of human activities.

2. Purpose and objectives

The purposes of the studies may be stated as follows: to provide substantiation for recognizing the Divnogorie pedolithocomplex, and to determine its age, rank (order), and genesis. The studies of the Divnogorie complex of paleosols and deposits dated to final Pleistocene and occurring in the upper series of the sequence exposed in the Divnogorie 9 gave an insight into succession of natural events and made possible to estimate the environments of the Late Glacial warmings and coolings.

3. General characteristics of the Divnogorie 9 site

The studied region belongs to the archeological-paleontological site Divnogorie 9 located on the chalk plateau in the south of the Central Russian Upland (Fig. 1A). The site was discovered in 2004. It occurs in deposits on the right side of a large balka (small flat-bottom valley lacking perennial stream) at the right side of the Tikhaya Sosna River (a tributary of the Don R.) about 1.9 km

upstream of the river mouth. The studied site occurs at about 35–40 m above the water edge of the river (Bessudnov and Bessudnov, 2010; Bessudnov et al., 2012). The locality is noted for an extraordinary diversity of landscapes typical of the southern subzone of the Central Russian forest-steppe. The chalk plateau is at the right side of the Don R. and is bounded by river floodplains: that of the Don on the north and the Tikhaya Sosna on the west. The plateau slopes are heavily dissected by ravines and gullies opening into the river valleys and large balkas. The gullies are up to 60–70 m deep. In many of them, the longitudinal profile reveals a step indicative of at least two stages in their development: an incision and a subsequent infilling. Typical are gullies marked by a V-shaped cross-profile and very steep sides (up to 50°). They are cut into flattened floor of older, partly filled erosional landforms dated to the Late Pleistocene. One such gully, lately known as Divnogorie 9 Gully, appeared to cut into bone-bearing layers with considerable clusters of bones, mostly those of horses (Fig. 1B).

4. Stratigraphy and chronology

The stratigraphy of Divnogorie 9 geoarcheological site was described in more detail earlier (Lavrushin et al., 2010, 2011). In the sedimentary sequence, more than 14 m thick, there are two series distinguished: the lower lacustrine and the upper composed of paleosols and slope deposits.

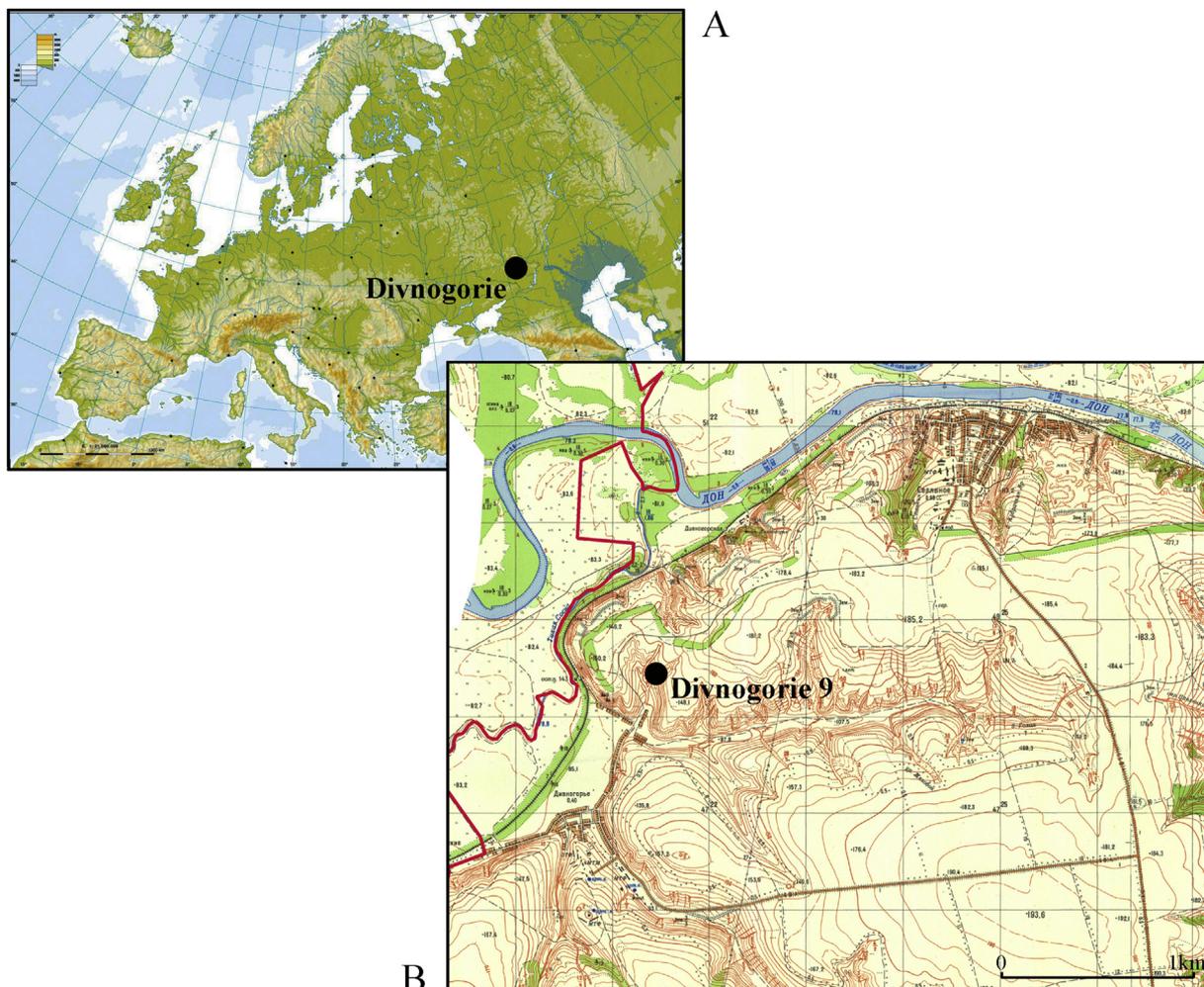


Fig. 1. A. Location of geoarcheological site Divnogorie 9 on the map of Europe. B. Topographic map of Divnogorie farmstead and the location of Divnogorie 9 site.

The lower series of 8–10 m thickness is essentially lacustrine layers deposited in the lowermost part of the gully where it enlarged and formed a lake. The deposits are thinly laminated calcareous silts interlayering with horizons of rubble and small-size blocks of chalk. Those layers were deposited by ephemeral streams and may be classified with proluvial or littoral lacustrine facies. At present, they occur at the base and compose most of the deposits filling the gully. They alternate with horizontally stratified lenses of small dammed water bodies (Lavrushin et al., 2010, 2011).

The lacustrine sediments containing 7 bone-bearing layers (levels) are dated by ^{14}C and AMS technique to the Late Glacial time (17.8–14.0 ka BP), within the limits of the Lascaux and Raunis interstadials (Table 1). They are overlain with calcareous silts giving way towards paleo-slope to scree and blocky deposits. Higher in the sequence there is a Divnogorie soil complex represented by two or three immature soils of B θ -AL age, alternating with deluvial loams. The upper soil is dated at Allerød. One more soil of Holocene age occurs at the top of deluvial calcareous loam (DR-3).

the animals were buried almost immediately after their death. The osteological collection recovered from all the bone-bearing layers amounts to more than 8000 bones, the absolute majority of them belonging to wild horse *Equus ferus*. There are occasional bones of arctic fox and wolverine.

A few long bones from layer 4 had been split in the old time – presumably, for the purpose to extract the bone marrow. A find of costal cartilage of horse with cut-marks strongly suggests the carcass was butchered at the site.

5.2. Paleobotany

The pollen analysis data allows reconstruction of changes in vegetation and climate during the Late Glacial, and also makes possible dating the studied sedimentary series. All the samples taken from the lower lacustrine series are dominated by grass and dwarf shrub pollen including abundant *Artemisia* and *Chenopodiaceae*. Pine is dominant among trees (Lavrushin et al., 2010, 2011)

Table 1
Radiocarbon dates of soil and bone-bearing layers in the Divnogorie 9 sequence.

Lab index	Context, material	^{14}C and AMS dates –(yr BP)	Cal BP	Source ^a
IGAN-4247	Charcoal from the top of the lower soil	12,060 ± 80	13,816–14 000 1.000	3
GIN-14547	"	11,880 ± 140	13,510–13 536 0.058	3
GIN-14548	Charcoal from the base of the lower soil	12,090 ± 100	13,817–14 043 1.000	3
LE-8137	Layer I, horse bones	11,400 ± 120	13,156–13 372 1.000	1
LE-8135	"	12,980 ± 180	15,165–16 078 1.000	1
LE-8136	"	13,150 ± 200	15,524–16 494 1.000	1
LE-8134	Layer II, horse bones	13,100 ± 200	15,267–15 328 0.056 15,471–16 389 0.944	1
AA-90650	"	13,430 ± 130	16,329–16 827 1.000	2
LE-8130	"	13,370 ± 240	15,881–16 810 1.000	1
LE-8131	"	13,560 ± 240	16,212–16 975 1.000	1
LE-8955	Layer III, horse bones	12,250 ± 350	13,813–14 894 1.000	1
GIN-13192	"	12,350 ± 200	14,032–14 685 0.885 14,712–14 815 0.115	1
LE-9250	"	13,820 ± 130	16,788–17 041 1.000	1
AA-90652	"	13,870 ± 140	16,814–17 094 1.000	2
LE-8956	Layer IV, horse bones	13 200 ± 300	15 507–16 641 1.000	1
GIN-14540	"	13,560 ± 320	15,943–17 003 1.000	3
AA-90653	"	13,830 ± 150	16,784–17 072 1.000	2
GIN-14541	Layer V, horse bones	12,600 ± 250	14,191–15 177 1.000	3
LE-8957	"	13,100 ± 500	15,092–16 715 1.000	1
LE-8932	"	13,270 ± 630	15,045–16 931 1.000	1
AA-90654	"	13,900 ± 140	16,832–17 120 1.000	2
GIN-14543	"	12,140 ± 300	13,667–14 631 1.000	3
GIN-14544	"	12,540 ± 470	13,899–15 556 1.000	3
LE-9620	Layer VI, horse bones	13,100 ± 600	14,932–16 805 1.000	3
LE-9619	"	13,800 ± 150	16,763–17 048 1.000	3
LE-8958	"	13,920 ± 175	16,853–17 114 1.000	1
LE-9102	"	13,940 ± 180	16,820–17 198 1.000	1
LE-9618	"	14,080 ± 190	16,928–17 408 0.152	3
AA-90655	"	14,430 ± 160	17,245–17 336 0.152 17,367–17 791 0.848	2

^a 1 – Bessudnov et al., 2012; 2 – Lavrushin et al., 2011; 3 – Bessudnov et al., 2013.

5. Paleontology, archeology, and chronology

5.1. Paleontology

The lacustrine sediments studied at Divnogorie 9 site yielded multileveled accumulations of horse bones, often including almost entire skeletons (Fig. 2), while flint artefacts are present in an insignificant quantity. That indicates that the site having served as a place of repeated killing and butchery of horse herds (Bessudnov et al., 2012; Bessudnov and Bessudnov, 2012).

There are seven levels of bone concentration found in the excavation. They are confined to light brown interlayers of lacustrine silt, locally separated with chalk blocks and debris lenses. The bones are well preserved and often undisturbed, which suggests

though it is rather scarce in pollen spectra (from 1–2 to 20 grains). Birch and spruce pollen are even rarer. Much more common are green moss and fern spores. A single grain of *Selaginella selaginoides* L. was found in the lacustrine sediments. That species is typical of stadial deposits farther north. The dammed lakes formed under conditions of unstable climate, the environments being distinct for the dominance of xerophytic vegetation and low temperatures (Lavrushin et al., 2010, 2011). The upper series, 3.1 m thick, was studied in the section 3/11, four pollen complexes (PC) having been identified in it (Fig. 3).

PC-1 characterizes the upper part of lacustrine-deluvial deposits (DR1) and the lower horizons of the lower paleosol (Bølling). The pollen spectra suggest a rather cool and humid climate, with coniferous spruce and pine forests seemingly having grown in the



Fig. 2. Accumulation of horse bones at layer 3.

river valley and near it. The pollen assortment in PC 1 is noticeably different from the younger PC1–PC5 in its higher proportion of spruce pollen. The sediments were deposited in water as indicated by the presence of algae and by homogeneity of the pollen assemblage composition.

PC-2 stage is marked by a sharp increase in the climate aridity. As may be concluded from the pollen composition, the environments were unfavorable for trees: dominant are meadow and steppe communities with only small patches of forest coenoses (mostly pine forests). The stage probably included a short-term cooling of DR-2.

PC-3 characterizes vegetation of the time when the upper paleosol developed (Allerød). The spectra contain spores of soil mushrooms, which confirm the soil genesis of the deposits. The region was dominated by forest-steppe. The vegetation displayed a mosaic structure, with pine-birch forests with small participation of nemoral elements (lime tree, hazel nut, oak, hornbeam), meadow steppes, and small areas of wetlands. Such landscapes indicate a certain warming of climate. The spruce proportion in forest communities was negligible. The forest area enlarged slightly.

PC-4 vegetation was distinctive for enlarged areas of periglacial coenoses with *Pinus* sect. *Cembrae*, *Betula* sect. *Fruticosae*. Forests, somewhat reduced in area, were dominated by pines, with considerable proportion of small-leaved species. Stepped and tundra communities became wider distributed. Typical was a mosaic pattern in vegetation, open forests alternating with step-plicated meadows and wetlands. The climate continentality increased. Such changes in vegetation could be a response to the stadial cooling of the Younger Dryas (DR3).

5.3. Archaeology

The lithic assemblage throughout seven bone-bearing horizons is limited (slightly more than 100 items; Fig. 4). Single flint implements were found in each level, and the highest concentrations occurred in levels 4, 5 and 6. Level 4 had a lithic concentration which includes prismatic core, unifacial tool (Fig. 4–13) and refitted bladelets and flakes. The assemblage is represented by truncations (Fig. 4–4,5,7–9) and double-truncations (Fig. 4–3,10), backed bladelets (Fig. 4–1,2,6), burins on truncations (Fig. 4–12), end-scrapers (Fig. 4–11,14,15). The high percentage of tools (about 25%) is a characteristic feature for kill-sites. According to its technological features the artifacts are similar to those recovered from

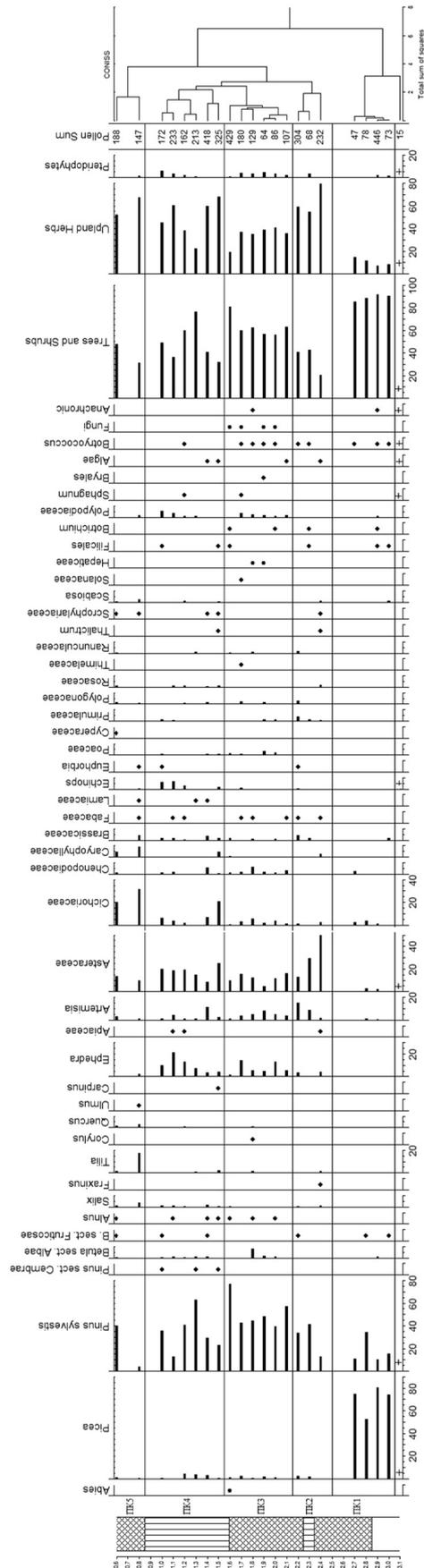


Fig. 3. Pollen diagram of samples from paleosols and sediments from section Divnogorie 3/11.

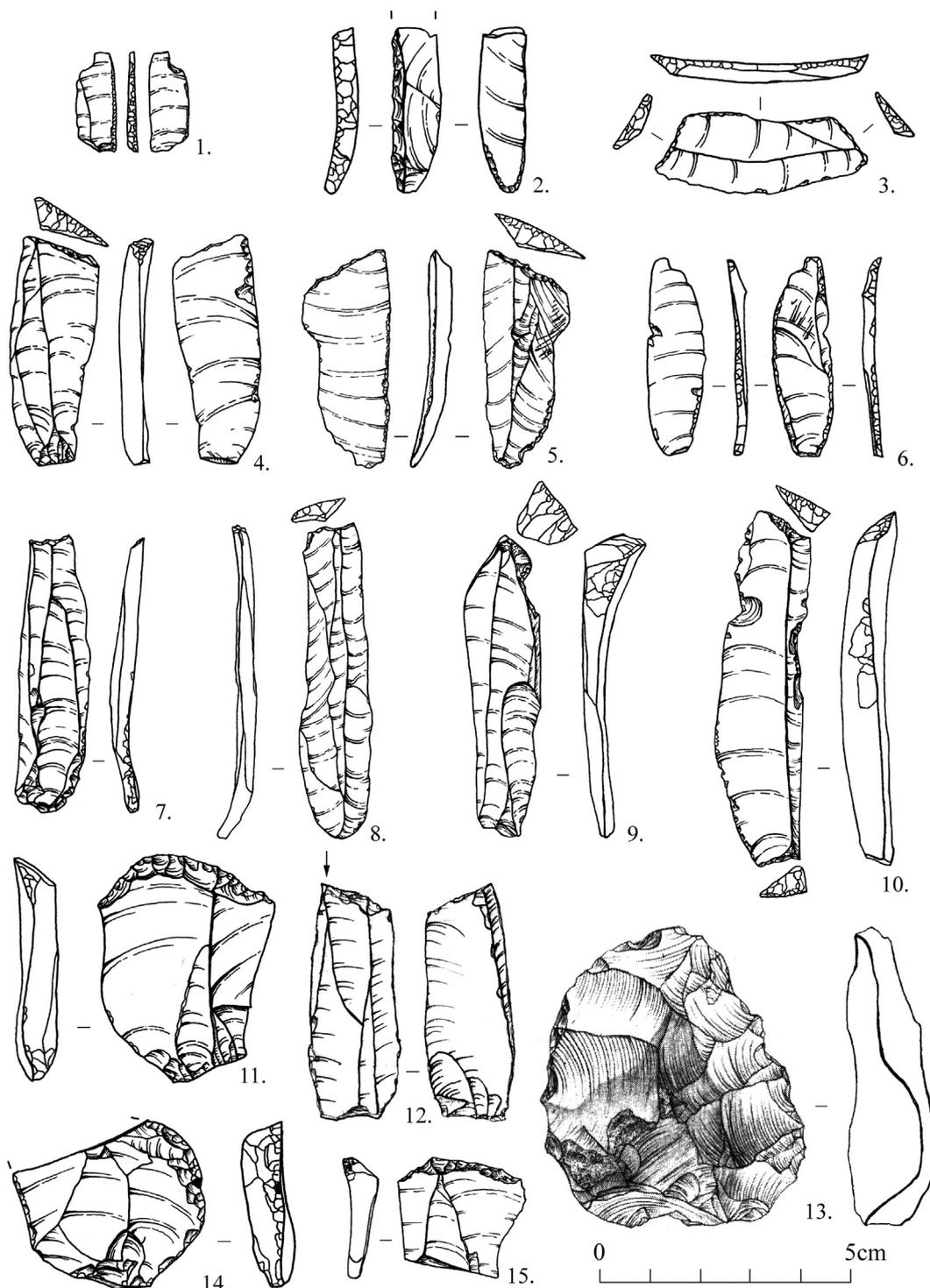


Fig. 4. Lithic assemblage from Divnogorie 9 (drawing by A.A. Bessudnov). 1,2,6 – backed bladelets; 3 – partially backed bladelet with double truncation; 4,5,7–9 – truncated blades; 10 – double-truncated blades; 11,14,15 – end-scrapers; 12 – burin on truncation; 13 – unifacially-worked tool (11,12,14 – level 2; 2 – level 3; 13 – level 4; 6 – level 5; 1,4,5,7,9,10 – level 6; 15 – lithological horizon 19; 3,8 – surface finds).

the Divnogorie 1 site and are associated with Eastern Epigravettian (Bessudnov and Bessudnov, 2010; Bessudnov et al., 2012).

5.4. Chronology

A series of radiocarbon dates was obtained in four laboratories. The dates of samples taken from the Divnogorie 9 sequence are

consistently older from the upper level to the lower one (Table 1). Insignificant inversion in dating is traced only to the third level, which could be explained by the errors of radiocarbon method. The dates from Arizona are probably the closest to the real age of bone-bearing level formation. The time interval of the deposition of the lacustrine series and mudflow material with bone-bearing layers I to VII is ~17.5–14.0 ka BP. Samples from the upper soil-deluvial

series (burnt layers) replaced downslope with the lower soil are dated by radiocarbon to the Bølling warming.

6. Objects, methods and materials of the investigation

The objects of the studies are buried soils and deposits of the upper (soils and colluvium) and lower (lacustrine and mudflow) series exposed in the Divnogorie 9 gully (Fig. 1B). All the sections were excavated on the right (facing east) side of the gully. The gully is cut into the slope (10–15°) of the chalk plateau. There are outcrops of the solid rocks (chalk) on the slope. When exposed on the surface the rocks are subjected to intensive weathering and form sharp-grained debris 5 mm to 2–3 cm and to 10 cm.

The performed paleogeographic studies were multidisciplinary and included geological analysis of sediments, paleogeomorphological, paleopedological and paleobotanical studies as well as ^{14}C dating. When studying paleosols, in addition to granulometry analysis using the pyrophosphate technique by Kachinskiy, analyses included organic carbon measurement (Tyurin and Bascomb technique), determination of Fe, Mn, and Al oxides using techniques by Tamm, Jackson and Bascomb, as well as CO_2 of carbonates. In parallel, pollen and spore were analyzed in samples taken from the same or adjacent exposures (the archeological excavation and section 3/11).

7. Sediments of the Divnogorie paleo-lake

Lacustrine-proluvial and littoral (shallow-water close to the shore) deposits are exposed at the Divnogorie 9 site excavation at elevations of 9–14 m (Fig. 5a). The total thickness of the sediments amounts to 5 m, of which ~3 m are fine-grained (silts) interlayering with coarse non-sorted deposits of mudflows (Lavrushin et al., 2010). The deposits of the dammed lake exposed at the gully mouth occur over ~1 ha.

Typically, the lower series features sub-horizontal layers of rhythmically laminated clays and clay loams (lacustrine member) alternating with clay loam and loam with chalk fragments varying in dimension and roundness (proluvial member) (Fig. 5b). The rate of the series accumulation was rather high, 33 cm per 100 years (3.3 cm per year).

The lacustrine sediments are light grayish-white in color. The rock is compact, though weak and easily falls into crumbs, chalk-like, inhomogeneous, with distinct lamination. It is composed of fine-grained pelitomorphous material with rare inclusions of single grains and micro-lenses of fine sand (or coarse silt), no coarse inclusions were found. The texture is inhomogeneous. A fine (<1.0 mm) horizontal lamination is traceable, lighter calcareous laminae alternating with darker ones of silt and clay. When studied in thin sections under the microscope, the microlamination seems to be irregular even within one thin section. There are lens-like, pocket-like and pillow-like textures, as well as “whirl-like” (convolute) lamination displaying locally crumpled micro-laminae. The pockets are usually filled with coarser silt.

A probabilistic model of complicated texture similar to the above may be suggested as follows: silt particles settled on the surface of the liquefied unconsolidated sediment (clayey-calcareous suspension), and sank under their own weight downward, crumpling and distorting the micro-layers. Micro-landslides could occur locally, particularly if the material was deposited on an inclined surface.

No organic matter has been noted visually. C_{org} content is less than 0.1%. As granulometric analysis shows, the terrigenous material in the sediments is mostly fine silt (more than 90% of the clastic fraction) with insignificant admixture of very fine and fine sand (7% and 2.7%, respectively).

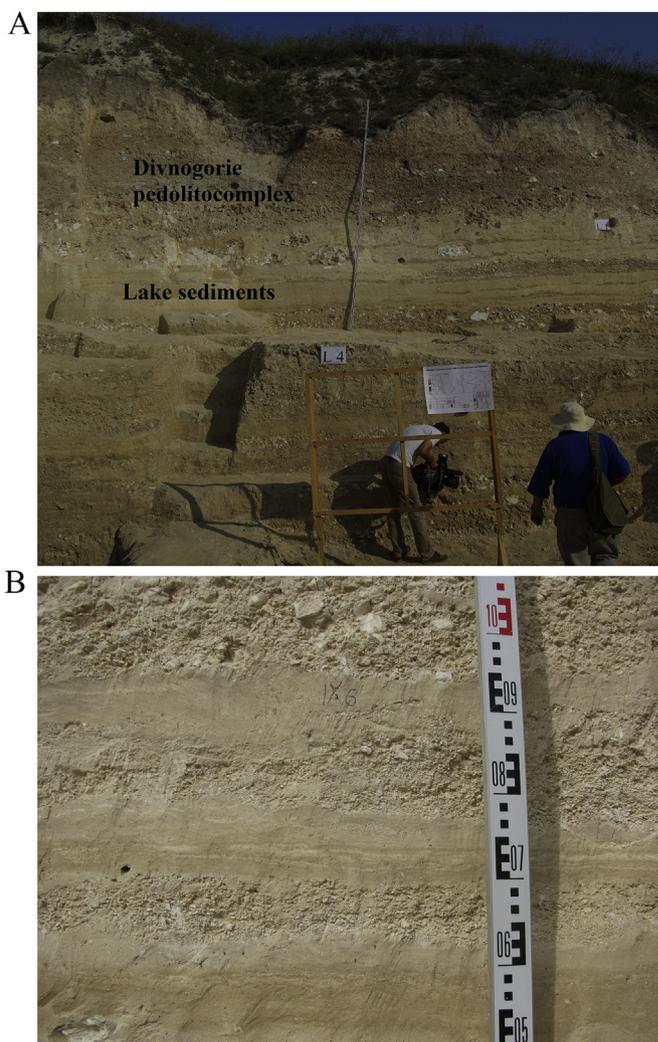


Fig. 5. a. General view of Divnogorie 9 cross-section (photo 2013). b. Lacustrine sediments.

The sediment, when washed (without dissolving in HCl), shows a considerable content of detritus limestone grains >0.5 mm and 0.5–0.25 mm in size, of flattened and rounded configuration. The chemical analysis showed the main oxides as follows: CaO – 35.52; MgO – 0.65%; MnO – 0.03%; FeO – 0%; CO_2 – 28.03%. Judging from those results, dominant in the carbonate group is calcite (CaCO_3 ~ 63.40%), the dolomite component is negligible (MgCO_3 – 0.29%), and no other carbonate were found.

The silt fraction composition was determined using X-ray diffractometry (XRD). A non-oriented powder specimen has a high content of calcite, a noticeable presence of quartz, and possibly smectite and mica (Fig. 6). In oriented samples, the presence and relative amount of clay minerals have been specified as follows: smectite > kaolinite > mica > chlorite (Fig. 7).

8. Paleosols

The paleosols of the final Pleistocene were studied in two sections in 2010 (1/10 and 2/10) and in one section in 2011 (3/11) (Fig. 5a).

Section 1/10 was located in the Divnogorie-9 excavation. It revealed two weakly developed paleosols (Fig. 8a). The Bfe horizon of the upper brown soil is inhomogeneous pale yellow (in the web version) – brown clayey loam, compact, with ooid microstructure,

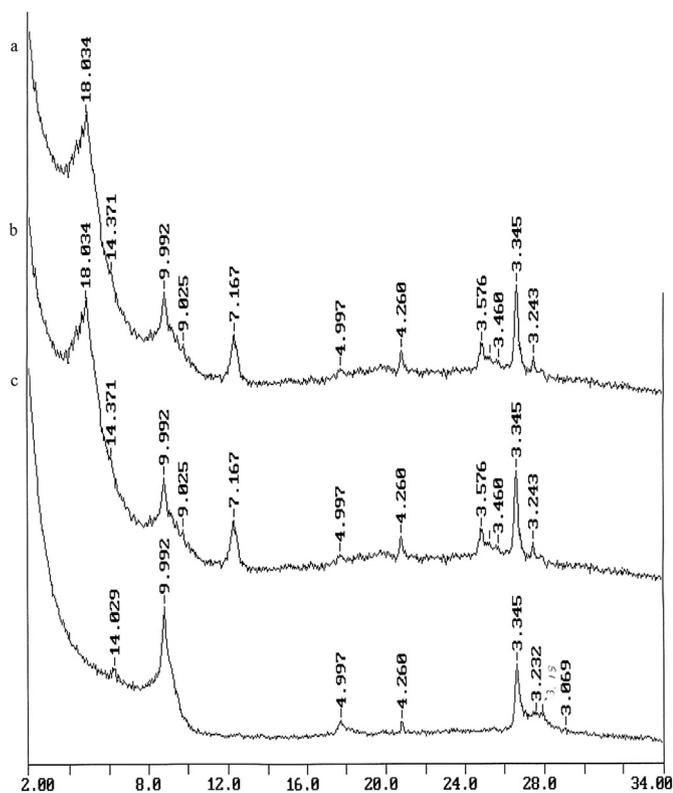


Fig. 6. XRD patterns of the oriented specimens: a – initial form; b – saturated with glycerine; c – heated at 550 °C.

and chalk fragments varying in size and roundness are present. Secondary carbonates occur as small concretions snow-white in color and 0.3–1 mm in diameter. The chalk fragments are covered with yellow-rusty patina.

The soil is separated from another lower-lying soil with pale-yellow silt loam with large blocks of chalky rock. The burnt inter-layer wedges out within this area, and the brown-gray color appears indicative of the humus presence, most pronounced in the middle part of the layer. The horizon A of the lower weakly developed soil is clay loam, pale yellow–light gray, with poorly rounded debris.

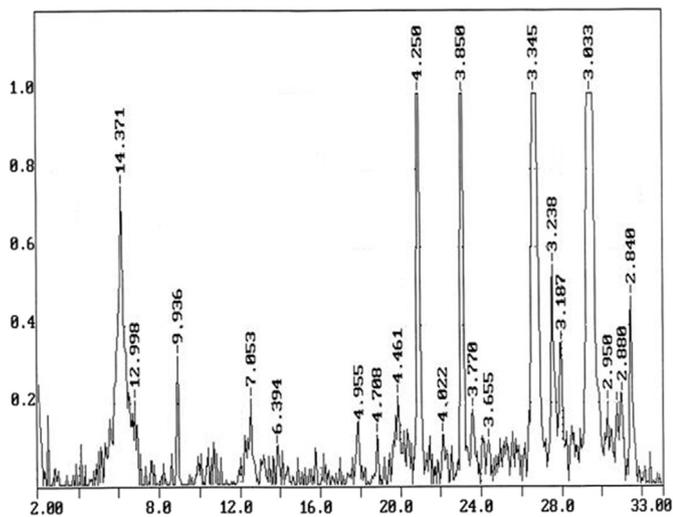


Fig. 7. XRD pattern of powder-triturated lacustrine specimen.

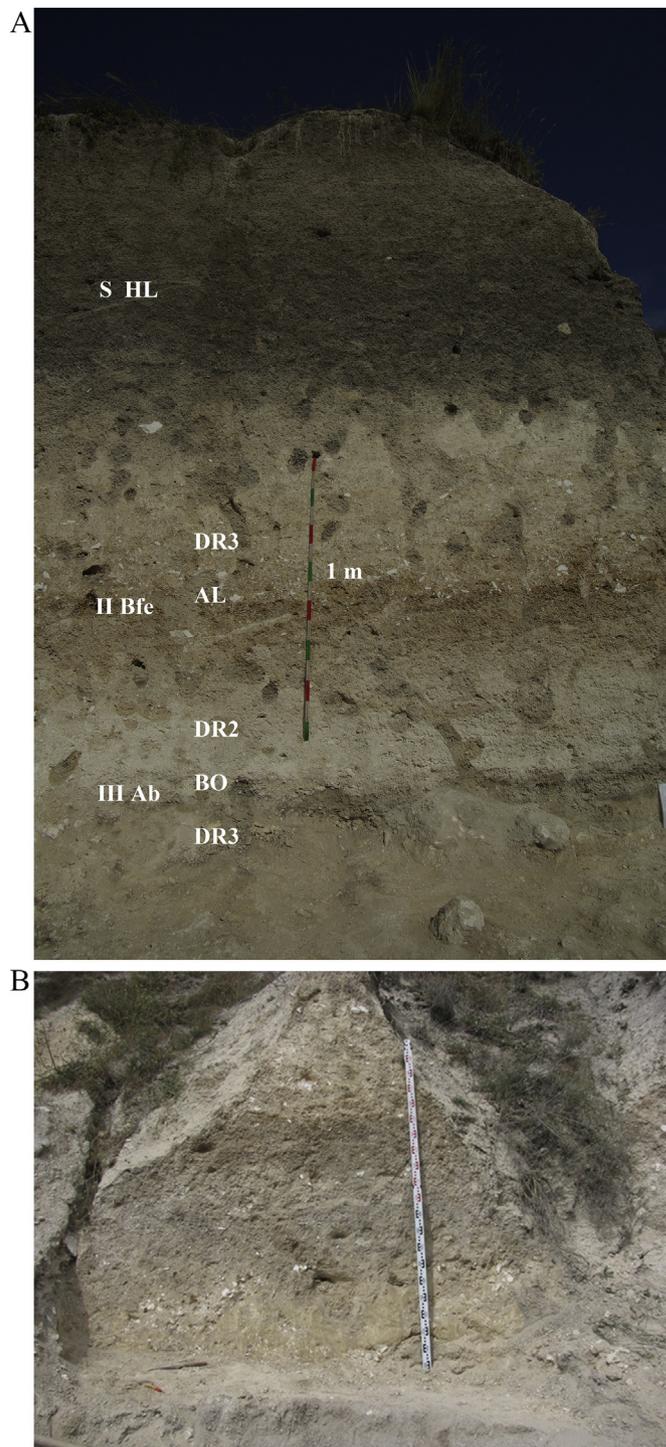


Fig. 8. a. The Holocene soil and Divnogorie pedolithocomplex, section 1/10 (photo 2013). b. The Divnogorie pedolithocomplex, section 2/10 (photo 2010).

In section 1/10 the granulometry of both soils and intermediate loam is dominated by fine silt (more than 40%), with silt being present in considerable proportion (Table 2). That suggests a similar origin of all the three layers, presumably formed by slope or deluvial (sheetwash) processes. The upper buried soil (Bfe horizon) shows a somewhat higher proportion of silt. That horizon does not differ from others in C_{org} , (Table 3) percentage of carbonates is slightly less, while that of Fe, Al, Mn oxides is a little higher. That suggests traces of weak activity of some elementary soil-forming processes, such as carbonate leaching, ferrugination, and gleying.

Table 2
Granulometric composition of soils and sediments in the Divnogorie 9 sections.

Soil sediment	Unit	Horizon	Depth cm	Fraction size. mm						
				1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01
Divnogorie 9, section 1/10										
dl 1	2		0	0.5	5.0	20.4	14.3	42.7	17.2	74.2
S 1	3	II Bfe	30	0.6	3.3	22.0	15.5	43.5	15.2	74.2
			55	0.4	3.5	23.3	16.3	39.8	16.7	72.8
dl 2	4		80	0.8	6.6	20.5	13.7	41.2	17.2	72.1
Divnogorie 9, section 2/10										
dl	2		60	1.1	6.5	19.3	13.5	37.3	22.3	73.1
			75	1.7	12.3	20.6	13.9	35.5	16.3	65.7
S 1	3	II Bfe	95	0.8	4.3	24.1	13.8	38.9	18.2	70.9
S 2	4	III Ab	115	2.8	11.1	22.7	12.1	34.8	16.4	63.3
	5	Bk	135	2.9	12.6	21.6	13.2	33.3	16.4	62.9
S 3	6	IV A	150	0.4	3.9	25.0	12.8	35.8	22.1	70.7
			165	0.7	7.2	22.6	14.7	37.1	17.7	69.5
			185	0.6	6.6	24.1	13.2	35.3	20.2	68.7
I	7		215	0.1	1.2	7.4	9.1	47.2	35.0	90.3
			220	0.0	0.7	6.7	10.3	48.8	33.5	92.6
Divnogorie 9, section 3/11										
S HL	1	AU	10	0.8	11.2	37.3	10.2	25.7	14.7	50.7
			40	0.6	9.1	32.2	11.0	26.3	20.7	58.1
		AB	70	0.3	7.6	28.6	10.8	28.5	24.4	63.6
dl 1	2	Bk	95	0.1	0.1	35.3	16.6	26.9	21.1	64.6
			125	0.1	3.3	28.0	12.6	38.0	18.0	68.6
S 1	3	II Bfe	150	0.0	0.4	16.3	13.4	48.4	21.5	83.2
dl 2	4		170	0.1	0.6	22.0	12.5	42.5	22.3	77.5
			180	0.2	1.3	24.4	12.4	39.5	19.8	74.0
PS	5	III	213	0.2	11.0	25.4	12.9	30.9	17.7	63.6
dl 3	6		230	0.7	7.8	26.0	13.7	34.1	25.9	65.7
S 3	7	IV AJ	255	0.1	0.2	21.4	11.4	41.1	25.2	78.2
I	8		275	0.1	6.3	19.3	9.7	39.5	10.0	74.4

Table 3
Divnogorie 9. Chemical characteristics of soils and sediments.

Soil. sediment	Unit	Horizon	Depth cm	C _{org.} % Tyurin	C _{org.} % Bascomb	CO ₂ % carb.	Fe ₂ O ₃ % Jackson	Fe ₂ O ₃ % Tamm	Al ₂ O ₃ % Tamm	MnO ₂ % Tamm	Fe ₂ O ₃ % Bascomb
Divnogorie 9 1/10											
dl 1	2		0	0.17	0.084	37.98	0.17	0.045	0.058	0.006	0.014
S 1	3	II Bfe	30	0.13	Indet.	37.92	0.21	0.045	Indet.		
			55	0.21	0.060	36.46	0.26	0.054	0.084	0.010	0.021
dl 2	4		80	0.43	Indet.	37.92	0.17	0.039	Indet.		
Divnogorie 9 2/10											
dl 1	2		60	0.25	0.104	33.61	0.33	0.087	0.098	0.015	0.023
			75	0.31	0.148	36.37	0.24	0.059	Indet.		
S 1	3	II Bfe	95	0.51	Indet.	30.29	0.49	0.105	0.125	0.021	0.027
S 2	4	III Ab	115	0.61	0.188	35.50	0.28	0.057	Indet.		
	5	Bk	135	0.48	Indet.	37.20	0.20	0.032	0.057	0.008	0.015
S 3	6	IV A	150	0.61		34.76	0.37	0.044	Indet.		
			165	0.73	0.239	31.68	0.56	0.062	0.091	0.013	0.018
			185	0.56	Indet.	31.43	0.38	0.074	Indet.		
I	7		215	0.21	0.088	31.99	0.36	0.081	"		
			220	0.18	0.077	31.26	0.35	0.075	0.082	0.015	0.021
Divnogorie 9 3/11											
S HL	1	AU	10	3.69	Indet.	34.1	0.37	Indet.			
			25	3.23		34.4	Indet.				
			40	3.51		35.0	0.39				
			55	2.19		36.5	Indet.				
		AUb, zoo	70	1.63		36.9	0.34				
			85	1.44		37.3	0.28				
dl 1	2	Bk	95	0.99		37.3	0.21				
			125	0.32		39.0	0.18				
			150	0.21		37.0	Indet.				
S 1	3	II Bfe	160	0.24		34.0	0.37				
			170	0.21		32.1	0.39				
dl2	4		195	0.23		32.5	Indet.				
PS	5	III	213	0.36		29.0					
dl 2	6		230	Indet.		37.0	0.27				
S 2	7	IV A	245	0.47		36.1	Indet.				
			255	0.47		35.5	0.28				
I	8		265	0.19		32.7	0.28				

In section 2/10, located 10–15 m upstream in the gully from the Divnogorie 9 excavation (Table 4), the lower part of the slope is opened as well as the bottom of a shallow linear hollow on the side of the gully developed after the paleo-lake had been drained (Fig. 5a). The upper series is best represented here. It includes three Late Glacial soils separated with deluvial and scree deposits (Fig. 8b). The upper soil (horizon Bfe) is analogous to the upper one in 1/10 section, though it is better pronounced here than upslope. The middle fossil soil occurs in a micro-depression. The lower one is thickest of all, humified, with a horizon abundant in mole burrows. It is developed on the lake sediments (the parent rock). In common with the upper soil it is brown and is traced in all the studied sections and other exposures in the gully.

Table 4
Morphological description of section 2/10.

Unit	Depth, cm	Description
1	AUb, zoo 0–10	Zooturbated horizon of the modern soil
2	dI1 10–85	Heavy loam, pale-yellow, heterogeneous, slightly compact; with rare pores; inclusions of angular chalk fragments, a few mm to 5–10 cm in size, with light yellow ferruginous coatings; the upper contact is sharp, uneven, disturbed by animal burrows; the lower boundary is even, sharp.
3	II Bfe 85–105	Silty loam, rusty yellow with yellowish hue, inhomogeneous, with granular texture, chalk fragments up to 60–70% of total volume, more rounded, with thick ferruginous coatings; abrupt transition to the lower unit, even boundary
4	IIIAb 105–130	Silty loam, grayish-brown, slightly humified, inhomogeneous, rather loose, vague crumb and granular structure, porosity increased in comparison with the upper unit; chalk fragments more abundant, more or less uniform in size, no large fragments, mostly flakes, thin, with sharp edges, not rounded, with thick brown coatings. Transition is distinct to sharp, boundary even.
5	dI2 130–150	Heavy clay loam, pale yellow, with small-size soft calcareous concretions and angular chalk flakes a few mm to 5–7 cm in size, with dark-yellow coatings; fine-grained matter in scarce; distinct transition, even boundary.
6	IVAJ 150–190	Silty clay loam, pale-yellow and gray, humified; proportion of fine matter is higher, chalk inclusions are fewer in number (mostly fragments of the same size – 3–7 cm). There are crumbs (1.0–1.5 cm) of gray loam, finely porous. The boundary is sharp and even.
7	l 190–240	Silty clay loam (clay), pale yellow, more homogeneous, abundant pores of varied size, fine pores predominant; occasional calcareous new formations; rare small-size chalk inclusions; the entire unit occur as a lens, there are fragments with pronounced stratification; irregular lower boundary.
8	pr 240–250	Pale yellow loam, granular; many large (5–15 cm) angular fragments of chalk, with ferruginous coatings; fossil bones of horses (the first level of bones occurrence).

All three identified layers are similar in granulometry (Table 2). Dominant is fine silt (more than 40%). The proportion of coarse silt is noticeable. All the data indicate a similar genesis of the deposits in all three layers (deluvial slope processes). Horizon Bfe in the upper soil is noted for a somewhat higher proportion of silt. The C_{org} content it does not differ from the others (Table 3), the amount of carbonates is slightly less, while that of Fe, Al and Mn oxides are a little higher. The composition suggests an insignificant participation of elementary soil-forming processes, such as carbonate leaching and ferrugination, as well as enhanced hydromorphism.

In the granulometric composition (Table 2), the series is distinctly divided into the lower lacustrine member (unit 7 – two lower samples), paleosols (units 3, 4, 6) and deluvial deposits (units 2 and 5). The lacustrine sediments feature a small content of coarse fraction (sand ~1%, coarse silt 7%) and prevalence of small-size fractions (silt more than 33–35% and fine silt 47–48%).

The upper soil-deluvial member is distinct for a noticeable increase in proportions of sand, coarse silt (by factor of 3–4), as well as medium-size silt, while fine silt and particularly clay are reduced. In turn, this member is divisible into 3 or 5 layers by the proportion of sand and coarse silt. Its middle part (unit 4) is the richest in sand, while in the lower part (unit 6) the sand proportion is lowest.

All three buried soils (units 3, 4, 6) are noted for humus presence (by Tyurin), the two lower in particular (Table 3). The highest content of organic carbon (C_{org}) is in the lower soil (unit 6) – 0.61–0.73%. In the middle soil (unit 4), it is also increased to 0.61. In the Bfe horizon (unit 3) it is noticeably higher than in overlying

deposits and amounts to 0.51%. The lowest proportion of humus is found in lake sediments (unit 7). It is somewhat higher in proluvial-deluvial deposits (unit 2). The humus content (determined by Bascomb technique, that is, dissolved humus) also indicates the soil formation (humus formation) process in the past in all three soils, best pronounced in the lower one. The C_{org} content in the pedogenic horizons is 2–4 times higher than in the lake sediments or in slope (proluvial-deluvial) deposits.

The carbonate content is rather high in all the samples, both from soils or other deposits. That is not surprising, as all are products of chalky rock weathering and redeposition. It is slightly lower in paleosol humus horizons and in lacustrine sediments (30–31%), and higher in proluvial-deluvial deposits (up to

33–36%). Unit 5 resembles the carbonate horizon of the middle paleosol, with carbonate content rising to 37%.

All the three soils of the Divnogorie pedolithocomplex (and the upper one in particular) are distinct for increased content of Fe oxide determined using various techniques (by Tamm, Jackson, and Bascomb). The upper paleosol showed higher contents of Al and Mn oxides (by Tamm technique). In the lacustrine unit, and in the upper sample in particular, there is also a higher Fe oxide value, possibly as a result of soil-forming processes. The least content of Fe oxide is recorded in proluvial-deluvial deposits (units 2 and 5).

There are two lenses of charcoal accumulations in the upper 2 m of deluvial deposits. The charcoals were dated by radiocarbon and yielded ^{14}C dates rather close to each other ($11,880 \pm 140$; $12,060 \pm 80$; $12,090 \pm 100$, Table 1). Downslope on the gully side the charcoal lenses pass into immature meadow soil heavily disturbed by burrowing animals. There is another soil upslope, represented by a brown ferruginized horizon. The paleosols are overlain by deluvial loam which served as parent rock for the Holocene Chernozem, the latter, in turn, being overlain with humified pedosediment.

The Divnogorie 3/11 section is 70 m downslope of the Divnogorie-9 excavation at a distance of 70 m (Table 5). The results of granulometric and chemical analyses of the paleosols are not so informative as those on the analogous soils of the previously discussed section (Tables 2 and 3). That might be due to a higher rate of sedimentation closer to the gully mouth. The upper paleosol is noted for increased Fe_2O_3 content, while the lower one for higher C_{org} .

Table 5
Morphological description of section 3/11.

Unit	Depth, cm	Description
1	AU + AU _b , zoo 0–80	AU Humus accumulation horizon of chernozem soil. Loam gray with brownish hue, light, silty, with powdery-granular structure, loose. More intensely humified in the middle part of the unit. Noticeable admixture of chalk debris and crumbs a few mm to 1.5 cm in size. Heavily weathered, the debris disintegrated to crumbs less than 1 mm. Downward the rock is less weathered, proportion of chalk inclusions grows, as well as their size. The transition is noted by color, the boundary is even. AU _b , zoo Loam light-gray, silty, crumby-powdery, loose. Chalk debris decreases in amount. Recorded are secondary calcareous new formations seen as point-like whitish smears. Transition to the lower unit is sharp, marked by color, density and structure.
2	B _k 80–120	The boundary is irregular, distorted by animal burrows, dipping downslope by 20–30 cm (closer to horizontal than the present-day one). Light loess-like loam, whitish-yellow, white when dry, finely porous, compact, contains a sizeable amount of chalky inclusions. Noted are secondary calcareous new formations: films in biogenic pores, cutans in vertical fissures, light-yellow coating on the chalk debris. A few sub-units are distinguishable.
3	II B _{fe} 120–150	Unit 3. B _{fe} of the upper paleosol (Allerød). Loam whitish-brown, with yellowish hue. Abundant inclusions of chalky crumbs, their proportion increases downward. The boundary is even, accentuated by increased number of spots of humus and brown coating on chalk fragments.
4	dl 150–210	Medium loam, finely silty, brown, porous. Numerous chalk fragments widely varying in size. Inhomogeneous on micro scale, displays signs of being reworked by sheet and rill wash (oid texture). The transition is noticeable, the boundary is even.
5	III PS 210–215	Pedosediment. Loam slightly humified, gray-brown, with sand. Proportion of debris and rubble decreases. Spots and lenses of humified material indistinct in outlines occur at the boundary between brown and pale yellow layers.
6	dl 215–250	Light pale-yellow loam, porous, silty. Rubble of chalky rocks is present in abundance, smaller in size, with brown coatings. Gradual transition, seen by color, boundary indistinct.
7	IV A _J 240–260	Loam, pale-yellow to light gray, humified, powdery in texture, with abundant chalk crumbs and debris. Rare charred fragments of various origin. Occasional spots of brown loam. Chalk debris varied in size, with gray-brown coatings. The lower boundary is irregular, wavy, distorted by burrowing animals (the holes are 3–6 cm in size). The burrows are filled with material of horizon A.
8	C 260–280	Light whitish-yellow loess-like loam, finely porous. The boundary is sharp and even.
9	pr-I 280–480	Proluvial lacustrine series. Interstratified layers with rounded pebble, angular debris and fine clays, horizontally and lens-like stratified.

9. Interpretation

The structure and genesis of the sediments infilling the gully indicate that a small lake existed in the gully mouth. It was repeatedly filled with sediments and then reformed. It was used as a drinking site by horses and other animals that inhabited periglacial steppe on the waterless chalk plateau.

One of specific features of the Divnogorie paleo-lake is its occurrence at the gully mouth, on the slope. How and why it was dammed is especially interesting. One of possible variants is that this gully was dammed by an alluvial fan of the adjacent ravine. Such is often the case in thalwegs of linear erosional landforms. In the case under consideration, a considerable depth of the depression and periodically resumed high rates of sedimentation in the paleo-lake made it a trap for sediments and animal remains, with many bone-bearing beds.

The lake sediment composition, namely fine pelitomorphic carbonate material with admixture of silt and clay, suggests periodic erosion of surrounding chalky rocks and their redeposition at a rather short distance. Fine-grained material and good sorting of the sediments are evidence for a low dynamic medium (the water came as a weak surficial runoff, or shore ice melting, in the absence of currents). Fine horizontal lamination (<1.0 mm) and alternating calcareous and clayey laminae may be related to the seasonality in sedimentation. At cold seasons the calcite solubility is higher, so clay material was mostly settled. At higher temperature calcite is less soluble and precipitates in greater quantities.

The convolute lamination and lens-like inclusions of silt material suggest short-time intervals of coarser material coming into the basin. It may be attributed to occasional events of increased intensity of the slope (shore) erosion (possibly by meltwater). The practical absence of organic matter of plants (not in thin sections, nor by washing, nor by chemical analysis) strongly suggests a scarcity of vegetation.

The lake sediments were formed under conditions of thawing permafrost and solifluction on slopes. Those processes resulted in deposits similar to marine cryosuspensites described in the Khvalynian basin (Lavrushin et al., 2010). The sediments accumulated in the paleolake may be termed “lacustrine cryosuspensites”

(Chepalyga, 2012). There are identifiable sedimentation cycles of different duration represented by sediment members of various thickness: meter (possible corresponding to a cycle thousand years long), decimeter (century), centimeter (decade), and millimeter (yearly), not unlike the varved clays of the near-glacial areas. For a long time the gully served as a place of wild horse driving, killing and butchering, as indicated by numerous finds of flint tools and flakes in every bone-bearing layer, as well as by traces of cuts on the bones.

When the lake basin was largely filled with sediments and the dam could not hold the water in the gully and/or was eroded, a new stage began in the evolution of this unique object. In Late Glacial time, the dominant processes on slopes were sheet and rill wash, gravitational removal of products of the solid rock weathering, and development of debris taluses. The sheet wash gained in importance due to increasing rainfall as the glacial climatic system gave way to the interglacial one. At the colder intervals, the grass cover of periglacial steppe was scarce and practically did not protect the slopes from sheet erosion. In the warmings, however, the situation changed: herb and grass, occasionally shrubs and even trees, covered the gully slopes and floor. It was at those interphasals that soils developed.

The upper subaerial series displays immature soils alternating with talus debris layers and proluvial-deluvial loam. The rate of that series accumulation is somewhat less – 0.8 cm per 100 years, or 0.8 mm/year. The sequence is crowned with a well-developed soddy-calcareous soil (Rendzin) dated to the Holocene and overlain with agroglacial deluvial deposits.

There are three weakly developed paleosols distinguished in the most complete section of the upper colluvial series. All three soils and interlayering colluvial deposits form the Divnogorie pedolithocomplex, which is the latest Pre-Holocene soil formation. The upper initial paleosol is represented by the B_{fe} horizon. The profile of the middle immature soddy-calcareous soil includes two horizons: AB (25 cm) and B_{ck} (20 cm). The lowermost, thickest paleosol shows a profile A–C, with a thick A horizon (40 cm) and parent rock C represented by fine lacustrine silty clay loam.

All the three paleosols are different in genesis. The upper one is a weakly developed burozem – brown earth (Skeletal Calcaric

Colluvic Siltic Cambisol, IUSS... WRB, 2014), formed in periglacial forest environments. The middle paleosol is soddy-calcareous soil or Umric Calcaric Colluvic Siltic Leptosol (IUSS... WRB, 2014). The lower one is defined as immature meadow-calcareous soil (Petrocalcic Skeletic Colluvic Siltic Chernozem, IUSS... WRB, 2014). The lower and middle soils seemingly developed in periglacial forest-steppe.

All the ^{14}C dates (Table 1) obtained on charcoal recovered from the two burnt layers corresponding to the lower paleosol indicate the soil could be developed during the Bølling warming. The two upper paleosols have not been dated. Judging from the pollen data, they developed during the next warming, Allerød. The genetic differences of the two soils are attributable to the climatic variations within the Allerød, its first part being drier, and the second more humid (Sycheva and Golyeva, 2006).

All the soils are thin and poorly differentiated, probably due to short duration of their development (a few hundreds of years). Such soils may hardly be considered as interstadial (they are incomparable with paleosols of the Bryansk or Krutitsa interstadials). They are of a lesser rank, namely, interphasial. The soils are separated from each other by colluvial interlayers including fragments of charcoal, occasionally forming interbeds. Higher on the slope, soils are absent (probably, eroded). The presence of charcoal fragments and interbeds strongly suggests repeated fires. The latter destroyed vegetation and triggered sheet and rill erosion, thus putting an end to the soil formation (Sycheva, 1997, 2006).

10. Conclusion

As a result of multi-disciplinary paleogeographic studies the history of the Late Glacial environments (17.5–10 ka BP) has been reconstructed in detail. The following stages in the landscape evolution in the Don River valley (middle reaches) were identified: the Last Glacial maximum (LGM), the Late Glacial time (LGT), the Bølling and Allerød warmings (BO–AL), and the Holocene (HL).

1. LGM – 23–18 ka BP. The maximum cooling on the Russian Plain was marked by a deep regression of the Black Sea, over-deepening of river valleys and beginning of a new stage in the gully erosion. The linear erosional hollow at the Divnogorie 9 gully mouth was formed.
2. LGT – 17–14 ka BP, including the Lascaux and Raunis interstadials. A general decay of the ice sheet and rhythmical fluctuations of its margin, along with the permafrost thawing due to sudden warming were periodically accompanied with catastrophic flooding (Chepalyga, 2006; Chepalyga et al., 2013). Divnogorie paleo-lake formed as a result of the gully damming with an alluvial fan of the adjacent ravine. The linear hollow was gradually filled with lacustrine sediments and with material brought by the gully, including the cryosuspensites formed due to permafrost thawing. Seven levels of bone-bearing layers were formed, with bones of mostly horse, and flint tools attributed to the Late Upper Palaeolithic.
3. BO–AL, including two warm phases, Bølling and Allerød, and three cold phases, within the interval 14 to 10.5 ka BP. The paleo-lake is drying, and the Divnogorie pedo-lithocomplex formed including two (three in local macro-depressions) weakly developed paleosols separated with colluvial layers. The lower, best developed soil (Petrocalcic Skeletic Colluvic Siltic Chernozem) is dated to Bølling, the middle (Umric Calcaric Colluvic Siltic Leptosol) and upper (Skeletic Calcaric Colluvic Siltic Cambisol) ones are attributed to Allerød. The two lower soils were formed in periglacial steppe environments. The upper one, most probably, is forest periglacial soil. Not one of the soils corresponds to a periglacial paleosol rank. During the warmings,

and more so in their second half, areas of forest coenoses enlarged in the forest-steppe landscapes. During the Bølling, coniferous (spruce–pine) forests gained in area in the river valleys. In the second half of the Allerød, the vegetation became more diversified. Pine and birch forests with lime-tree, oak and hornbeam alternated with meadow steppes and wetlands. The upper Allerød soil marks an important paleoenvironmental event, the appearance of forest zone on the Russian Plain. That time was the most humid interval in the region under consideration.

4. HL. 10.5 ka BP to the present day. The landscapes are dominated by southern forest-steppe during the Holocene, Chernozems and Rendzina soils developed on eroded slopes.

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References

- Aleksandrovskiy, A.L., 2004. Phases and rates of soil evolution within river flood-plains in the center of the Russian Plain. *Eurasian Soil Science* 37, 1137–1146.
- Aleksandrovskiy, A.L., 1983. The Holocene Evolution of Soils in the East European Plain. Nauka, Moscow, 150 pp. (in Russian).
- Bessudnov, A.A., Bessudnov, A.N., 2010. New Upper Palaeolithic Sites Near Divnogorie in the Middle Don River. No. 2. *Russian Archaeology*, pp. 136–145 (in Russian).
- Bessudnov, A.A., Bessudnov, A.N., 2012. Upper Palaeolithic adaptation to surrounding landscapes in Divnogor'ye (Middle Don, Central Russia). In: Bronnikova, M., Panin, A. (Eds.), *Geomorphic Processes and Geoarchaeology: from Landscape Archaeology to Archaeotourism. International Conference Held in Moscow-Smolensk, Russia, August 20–24, 2012. Extended abstracts. Universum, Moscow-Smolensk*, pp. 41–44.
- Bessudnov, A.N., Bessudnov, A.A., Burova, N.D., Lavrushin, Yu.A., Spiridonova, E.A., 2012. Some results of studies of the Palaeolithic sites near Divnogorie in the Middle Don River during 2007–2011 yrs. *KSI A* 227, 144–154 (in Russian).
- Bessudnov, A.N., Sycheva, S.A., Bessudnov, A.A., Lavrushin, Yu.A., Chepalyga, A.L., Sadchikova, T.A., 2013. Geoarchaeological sites Divnogorie 9 and 1 (Paleosols and Sediments MIS 2). In: *Guidebook for Field Excursions of the XIIth International Symposium and Field Seminar on Paleopedology 'Paleosols, Pedosediments and Landscape Morphology as Archives of Environmental Evolution' (10–15 August, 2013, Kursk, Voronezh, Russia)*. IG RAS, Moscow, pp. 89–97.
- Chepalyga, A., 2006. Late glacial great flood in the Ponto-Caspian basin. In: *The Black Sea Flood Question: Changes in Coast Line, Climate, and Human Settlement*. Springer, Dordrecht, pp. 119–148.
- Chepalyga, A.L., 2012. The Great Flood History (Epochs of Catastrophic Floods) Based on Paleo-hydrological Reconstructions and the Bible Text Analysis. In: *Voprosy Geografii (Problems of Geography)*. Geographic-Hydrological Studies 133. Kodeks Publ, Moscow, pp. 361–389 (in Russian).
- Chepalyga, A., Gerasimenko, N., Glad'yevskaya, M., Kiosak, D., Pirogov, A., Chepalyga, P., 2013. Final Pleistocene and Paleolithic stratigraphy in the Dniester valley (the uppermost part of the Roksalyan section) and Budzhak. In: *Loess Mantle in the Northern Black Sea Region. Collection of Scientific Works. (XVIII Ukrainian-Polish Workshop, Roksalyan, 8–13 September, 2013)*. KAR-TROL Publ, Lublin, pp. 210–220 (in Ukrainian).
- Gugalinskaya, L.A., Alifanov, V.M., 2011. Mesostratigraphy of the Middle Valday loess-like loams as a marker of lower order ecosystem restructuring. In: *Proceedings of the VI All-Russia Conference on the Quaternary Studies. Geological Institute Kola Scientific Center RAS, Apatity*, pp. 145–147 (in Russian).
- IUSS Working Group WRB, 2014. *World Reference Base for Soil Resources 2014. World Soil Resources Reports No. 106*. In: *International Soil Classification System for Naming Soils and Creating Legends for Soil Maps*. FAO, Rome.
- Jankowski, M., 2014. Allerød paleocatena in inland dune. In: *XIII International Symposium and Field Seminar on Paleopedology (ISFWP)*. Guidebook for Field Excursions. Nicolaus Copernicus University, Torun, pp. 41–45.
- Lavrushin, Yu.A., Bessudnov, A.N., Spiridonova, E.A., Kuralenko, N.P., Kholmovoy, G.V., Bessudnov, A.A., 2010. Divnogorie (the Middle Don): natural events during the final Palaeolithic. *Quaternary Comm. Bulletin* 70, 23–34 (in Russian).
- Lavrushin, Yu.A., Bessudnov, A.N., Spiridonova, E.A., Kholmovoy, G.V., Jull, A.J.T., Hodgins, W.L., Kuzmin, Ya.V., Kuralenko, N.P., 2011. High-resolution Sequence of Local Natural Events in the Central Part of European Russia 15–13 kyr BP (^{14}C -age). In: *Geology Series 2. Voronezh State University, Vestnik*, pp. 26–39 (in Russian).

- Starnberger, R., Terhorst, B., Rähle, W., Peticzka, R., Haas, J.H., 2009. Palaeoecology of Quaternary periglacial environments during OIS-2 in the fore fields of the Salzach glacier (Upper Austria). *Quaternary International* 198, 51–61.
- Sycheva, S.A., 1997. Small Valley (Balka) System Evolution in the Climatic Rythm "glaciation – Interglacial Epoch". In: *Geomorfologiya (Moscow)* 2, pp. 100–110 (in Russian).
- Sycheva, S.A., 2006a. Long-term pedolithogenic rhythms in the Holocene. *Quaternary International* 152–153, 192–202.
- Sycheva, S.A., 2006b. Pioneer soils, cultural layers, and enclosing rocks of the Late Paleolithic site Kamennaya Balka II. In: *Cultural Layers in Archeological Monuments. Theory, Methods, and Practice of Studies. Proceedings of Scientific Conference. NIA-Priroda Publ, Moscow*, pp. 180–186 (in Russian).
- Sycheva, S.A., 2006c. Specific features of paleopedological and microfacies analyses of the surficial deposits of the Late Paleolithic sites. In: *Cultural Layers in Archeological Monuments. Theory, Methods, and Practice of Studies. Proceedings of Scientific Conference. NIA-Priroda Publ, Moscow*, pp. 56–75 (in Russian).
- Sycheva, S.A., Golyeva, A.A., 2006. Cyclic change of paleoenvironments as a mechanism of the Late Pleistocene loess formation in the Azov region. In: *Late Cenozoic Geological History of the North of the Arid Zone. Rostov-na-Donu. SSC RAS*, pp. 153–154 (in Russian).
- Velichko, A.A., 2002. *The Dynamics of Landscape Components and Inner Marine Basins of Northern Eurasia during the Last 130 000 Years. Atlas-monograph. GEOS Press, Moscow*, 232 pp. (in Russian).