Modern human dispersal on the southern plain of Eastern Europe

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Summary. During August 2013, new field research was conducted at Shlyakh, an open-air, stratified Paleolithic site located in the southern plain of Eastern Europe near the city of Volgograd. The research was designed to establish a firmer chronology for the main occupation layers, which contain a Levallois blade and point industry that—while properly classified as Middle Paleolithic—might represent an archaeological proxy for modern humans. New stratigraphic profiles were recorded, and several square meters of occupation area were excavated. Sediment samples were collected for various analyses, including radiocarbon, OSL, cryptotephra, and soil micromorphology. The results indicate that the Levallois blade and point industry at Shylakh probably dates to 35,000–45,000 cal BP and may indeed represent a modern human presence on the southern plain, given both its age and contents. The analyses also contributed to a better understanding of site formation processes at Shylakh. Although unplanned in the original proposal, the research team obtained new dates on two other major Middle Paleolithic sites located on the Desna River (central plain of Eastern Europe).

Research Goals: 2013 Project. The overall objective of the proposed research was to test the hypothesis that a Levallois point and blade industry is present after 50,000 cal BP on the southern plain of Eastern Europe, offering a parallel to developments in south-central Europe. The south-central European industry is a credible proxy for anatomically modern humans (AMH) with apparent ties to the Emiran/Initial Upper Paleolithic (IUP) industry of the Levant, and may represent the first movement of AMH into Europe. The open-air site of Shlyakh provides the most suitable place in Eastern Europe to test this hypothesis, because it contains a well-studied Levallois point and blade assemblage with similarities to the south-central European assemblages, and previous research suggests that it may be at least roughly contemporaneous to the latter.

Shlyakh: Background and Previous Research. The open-air site of Shlyakh is located in the province of Volgograd (112 km N/NW of the city of Volgograd), Russian Federation, about 13.5 km NE of the Don River (see Figure 1). Shlyakh is found on the steep bank of Panika Ravine, in an area characterized by undulating steppe, incised by ravines and small valleys. P. E. Nehoroshev conducted excavations at Shlyakh (discovered in 1988) during 1990–1991 and additional field investigations with L. B. Vishnyatsky in 1998–2001 (Nehoroshev and Vishnyatsky 2002), exposing a total area of 236 m^2 (Nehoroshev 2009: 111).

The artifacts are buried in loams, sandy loams, sands, and gravels that represent an unconsolidated bed of Quaternary deposits up to 5 meters thick. The Levallois point and blade assemblages are found (with isolated faunal remains) near the base of the sequence (Layers 8 and 9), while overlying layers contain small Upper Paleolithic assemblages with bladelets. Earlier efforts to date the site yielded inconsistent results, although it appeared that Layers 8 and 9 might be relatively young for a Middle Paleolithic assemblage (Nehoroshev 2006).

Field Research at Shlyakh: August 2013. On 6 August 2014, Hoffecker and Holliday flew to Moscow and travelled by train to Bryansk, where—by prior arrangement—they met up with Nehoroshev, Vishnyatsky, and Ocherednoi, who were finishing up field research at the Middle Paleolithic site of Khotylevo 1 on the Desna River. Two charcoal samples from this site were received for radiocarbon dating, and Hoffecker subsequently received additional charcoal samples from Khotylevo 1, as well as bone samples from another Middle Paleolithic site on the Desna River (Betovo). Hoffecker and Holliday participated in a soils conference organized by the Russian Academy of Sciences with field trips to Kursk and Kostenki during 10–16 August, and then traveled with Ocherednoi to Frolovo, meeting again with Nehoroshev and Vishnyatsky, to begin field research at Shlyakh (located south of Frolovo). By prior arrangement, the research team operated out of a tourist camp (*Donskaya volnitsa*) on the Don River, about 15 km from the site.

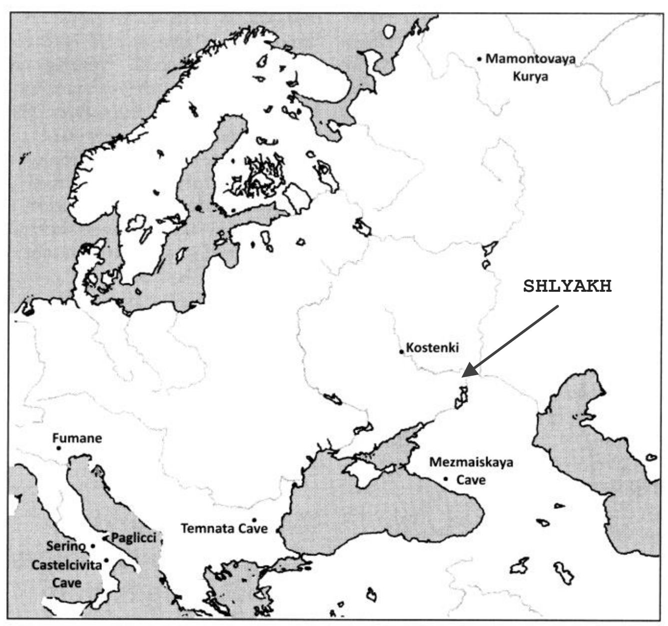

Figure 1. Location of Shlyakh on the southern plain of Eastern Europe.

During 17–25 August, the research team worked at Shlyakh, excavating two new profiles and several square meters of occupation area at the site, as well as collecting various types of sediment samples for analysis. The locations of the new profiles (#21 and #22) are shown in Figure 2.

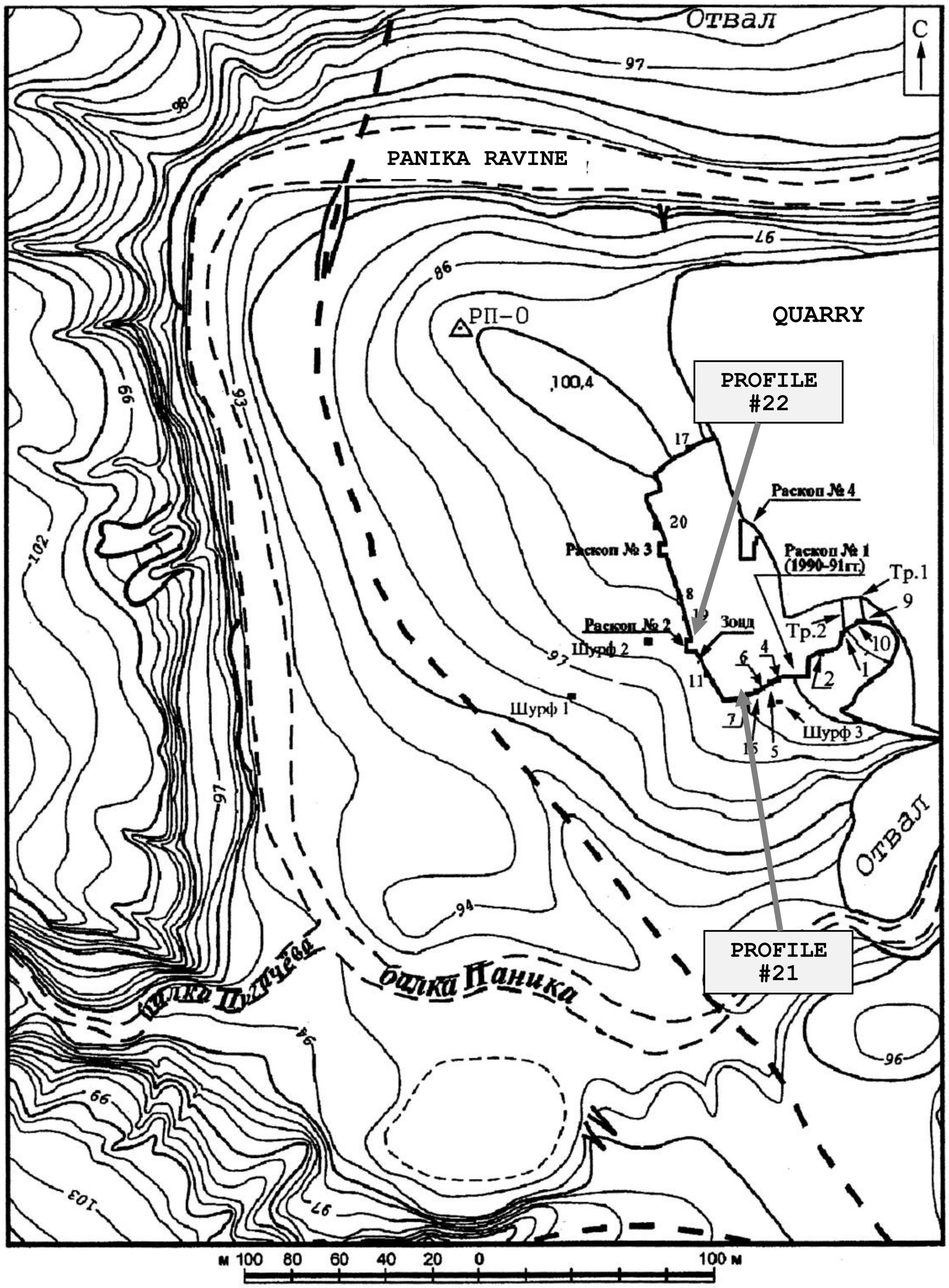

Figure 2. Map of Shylakh archaeological site and surrounding area, showing locations of new profiles (#21 and #22) (adapted from Nehoroshev and Vishnyatsky 2002: fig. 2).

Detailed stratigraphic descriptions of the profiles were recorded by Holliday, and the sediments were sampled for radiocarbon dating, OSL, cryptotephra analyses, pedogenic carbonates, and soil micromorphology (thin sections). Smaller profiles also were recorded and other geologic data collected from the area around the site. In June 2014, Hoffecker travelled to St Petersburg to retrieve additional bone samples from Shlyakh to augment the radiocarbon chronology.

Site Geology. The Shlyakh site is exposed in late Pleistocene valley fill along *Panika Balka*, an entrenched tributary of the Don River (see Figure 2). This dry ravine is cut into Carboniferous rock which includes limestone (below) and shale with limestone (above). Quarrying of the limestone exposed the site, as the quarry activity encountered the edge of the ravine. The quarrying, in addition to destroying part of the site, also largely destroyed evidence illustrating the stratigraphic and geomorphic relations between the late Pleistocene valley fill and the valley itself. A very small remnant of the margin of the southeast valley wall with the valley fill inset against it is preserved at the southeast corner of the site. Of the sections exposed and examined in 2013, Profile #21 was closest to the valley margin and exposed both valley margin deposits as well as mainstream valley fill (see Appendix A). Profile #22 exposed mainstream valley fill.

The deposits preserved at the site are a remnant of valley fill that likely extended all the way across Panika Ravine. The modern drainage is an incised meander along the north and west margins of the ravine, which isolated the late Pleistocene deposits and their archaeology, along the east and southeast margins of the ravine, i.e., on the inside of the meander.

The basal valley fill is alluvial sand and gravel resting unconformably on shale and limestone of the Upper Carboniferous section. The basal strata include redeposited shales and clays of the Carboniferous bedrock. They were probably locally derived from the bedrock valley walls or the floor of the valley as "rip-up clasts." These deposits grade up into well sorted sands and limestone gravel typical of mainstream alluvium. The alluvial deposits, equivalent to Layers 9 and 10 in the profiles recorded earlier (e.g., Nehoroshev et al. 2003: 23), are up to ~1 meter in thickness across the exposures (see Appendix A).

Above Layer 9 are sands, silts, and muds, probably equivalent to Layers 7 and 8 in Nehoroshev et al. (2003: 22–23). These deposits are thicker (~1.5m) and more clearly bedded toward the east-southeast valley margin (Profile #21). Toward the valley axis (Profile #22) the deposits are more homogenized and somewhat thinner (~1.0 m). The thicker valley axis deposits include multiple, weakly expressed buried soils (b2 soil at 270-310 cm; b3 soil at 310-325 cm; and b4 soil at 338-360 cm in Profile #21). In the valley axis exposure these soils apparently merge to form the single b2 soil (at 265-327cm). These soils and sediments are indicative of a very low-energy, slowly aggrading floodplain system with some valley margin additions. The multiple buried soils and soil facies represent a pedocomplex. The Paleolithic occupants of the site represented in Layers 7 and 8 apparently were living on and around a generally stable floodplain landscape with minimal flooding (see Figure 3).

Above the pedocomplex is a zone of laminated sand, silt, and clay. Reddish to purple clay lenses nearer the valley margin are indicative of slopewash additions off of the valley wall bedrock. Otherwise the sediments are indicative of floodplain aggradation.

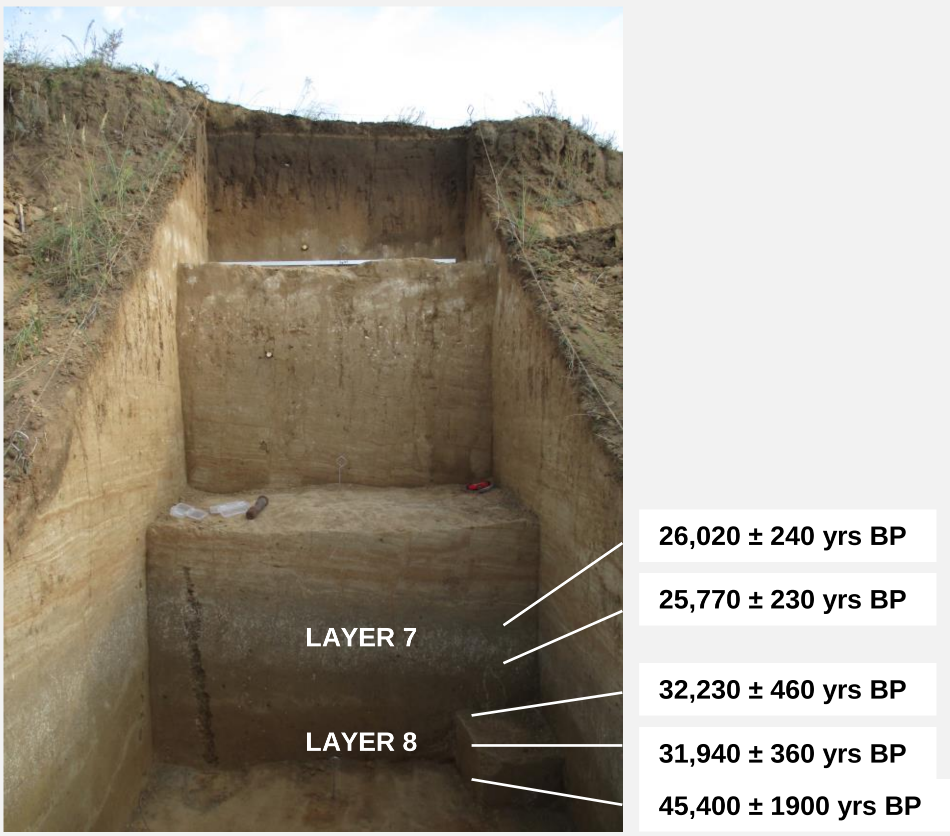

Figure 3. Stratigraphic profile (#21) exposed at Shlyakh (photographed by JFH August 2013). A description of the stratigraphy is presented in Appendix A.

The upper ~2 meters of the section in both Profiles #21 and #22 is composed of two layers of sandy loam. Each layer contains a well-expressed soil (the surface soil and the b1 soil). The massive fine-grained character of these deposits suggests eolian deposition. The layers may represent “sandy loess” with regional airborne silt mixed with the locally common sands.

A profile examined to the north of #21 and #22, and north of the main site area (#23), exposed similar stratigraphy, but compressed into a section of ~2.5 meters in thickness. This conforms to the data generated by the early work at the site, which showed that the thickest and most complete stratigraphic sequence was in the area of Profiles #21 and #22. The sequence thins to the north, on-lapping a bench or perhaps an older terrace cut on the bedrock.

Analysis of Soil Carbonates. Samples of pedogenic carbonates were collected from the buried soil horizons and analyzed for calcium carbonate and stable isotope values (see Table 1). The calcium carbonate values for samples PC-1 through PC-3 are typical for weakly expressed Bk horizons, while PC-4 and PC-5 are typical (higher above; lower with depth) for more developed Bk horizons. The low values in PC-6 and PC-7 indicate minimal weathering of the A horizon. All of the $d^{13}C$ values are indicative of mixed grasses. The more negative values (lower in the sequence) are also indicative of cooler conditions. A slight trend toward warming may be evident from the older samples (PC-4 through PC-6) to the younger ones (PC-1 through PC-3).

Table 1. Analysis of pedogenic carbonates from buried soils at Shlyakh.

Sample no.	soil/layer	depth	$\%CaCO_3$	$d^{13}C$	$d^{18}O$
PC-1	Bk (Layer 3?)	70–75 cm	6.37	-5.98	-7.79
PC-2	Bk (Layer 3?)	92–97 cm	10.69	-6.46	-8.42
PC-3	Bk (Layer 3?)	128–133 cm	13.99	-6.12	-8.34
PC-4	Btk1b1 (upper buried soil: upper level)	140–145 cm	21.07	-5.00	-7.75
PC-5	Btk2b1 (upper buried soil: lower level)	160–165 cm	14.21	-5.53	-8.01
PC-6	Akb2 upper (Layer 7)	274–284 cm	2.89	-7.81	-12.50
PC-7	Akb2 lower (Layer 7)	294–304 cm	2.43	-8.33	-12.97

Soil Micromorphology. Thin section samples were collected from the base of Layer 7 (at the contact with Layer 8) and the uppermost Layer 8 in Profile #22, and from the middle of Layer 8 in Profile #21, to search for microscopic evidence of human impacts in the associated soils, and to complement the field observations of the lithology. The samples were analyzed for soil micromorphology (Courty et al., 1989) by Paul Goldberg (Boston University, MA USA).

In the field, Layer 7 was noted as calcareous based on reaction to dilute HCl, but no carbonate was observed in thin section. It was also identified as a mud (i.e., mostly silt and clay). Sand was common in thin section, which is probably a component of the loam. But the ubiquity of the sand in the thin section indicated that domains of sandier material are locally common. This bimodal lithology supports the interpretation of floodplain deposits as the source of the sediment. The thin section of upper Layer 8 confirms the field observation of non-calcareous soil. The lithology in the field was observed to be a fine sandy loam but the thin section sampled displayed finer (i.e., less sandy) sediment. Layer 8 is locally bedded and both this observation and the thin section analysis are indicative of sediment layering, characteristic of a floodplain.

The thin section from Profile #21, in conjunction with the field observations, also is indicative of a bimodal lithology typical of flood deposits. The thin sections provided no evidence of human occupation impact, and none was observed in the field. These data show that the human activity in Layers 7 and 8 was ephemeral, and consistent with the archaeological interpretations of lithic procurement without extended habitation or other signs of intensive occupation (e.g., Nehoroshev and Vishnyatsky 2000).

Cryptotephra Analyses. A column of sediment samples was collected from the lowermost 10 cm of Layer 6 through the uppermost 16-17 cm of Layer 9 in the hope of identifying traces of the CI Y5 tephra, which is a major chrono-stratigraphic marker (~40,000 cal BP) in southeastern Europe (Hoffecker et al. 2008). The samples were sent to Biagio Giaccio (Instituto di Geologia Ambiente e Geoingegneria CNR, Rome, Italy) for analysis, but no traces of volcanic tephra were encountered.

Radiocarbon Dating. New radiocarbon dates were obtained on soil organics from the upper and lower portions of Layer 7, and on bone from the main occupation layer (Layer 8). No charcoal has ever been identified at Shlyakh. The soil organics samples were collected by Holliday, and the bone samples all were obtained from earlier excavations (1990–1991). Sample preparation for the soil organics was performed at the INSTAAR Radiocarbon Laboratory (University of Colorado at Boulder), and ultrafiltration preparation was performed by John Southon on the bone samples at the University of California at Irvine (UC-Irvine). The AMS ages were obtained on all samples at UC-Irvine, and the results are listed in Table 2 (calibrations performed with the online OxCal 4.2 program [IntCal 13 calibration curve]). Also see Figure 3.

Table 2. Radiocarbon dates for Shlyakh 2013–2014.

LAYER	LAB No.	material	^{14}C age	calibrated age
Layer 7	CURL-17631	soil organics	26,020 ± 240 years BP	28,868–27,679 cal BC
Layer 7	CURL-17626	soil organics	25,770 ± 230 years BP	28,685–27,453 cal BC
Layer 8	UCIAMS #133290	bone	32,230 ± 460 years BP	35,675–33,171 cal BC
Layer 8	UCIAMS #143877	bone	31,940 ± 360 years BP	34,657–33,071 cal BC
Layer 8	UCIAMS #143876	bone	45,400 ± 1900 years BP	44,066 cal BC

Optical Stimulated Luminescence (OSL) Dating. Sediment samples for OSL dating were collected from the entire column of sediment in Profile #21 by Hoffecker and shipped to Steven L. Forman (Baylor University). OSL ages were obtained on quartz grains, except for sample #2 (UIC3554), which could not be calculated, and for samples #4 (UIC3548), #5 (UIC3549), and #10 (UIC3554), for which only minimum ages could be calculated. The results are presented in Appendix B.

Because the OSL ages obtained from the initial run of samples were consistently older than the radiocarbon dates (and inconsistent with the paleomagnetic chronology), Forman recalculated the dates with an alternate statistical model (finite mixture model). The results, however, were similar.

Artifacts. Although recovery of new artifacts was not a specific goal of the 2013 project at Shlyakh, the six square meters of excavated area (units Λ-35, Λ-36, K-35, K-36, E-7, and Ж-7 on the site grid) predictably yielded a modest assemblage from the main occupation layers (8 and 9), as well as some artifacts from Layer 7. The artifacts recovered in August 2013 are listed in Table 3.

Discussion and Conclusions. The main objective of the 2013 project at Shlyakh was to establish a more secure chronology for the archaeological remains, especially Layers 8 and 9, which contain Levallois blade assemblages. This objective was achieved, but the results were less decisive than had been hoped.

The primary source of uncertainty regarding the dating of Shlyakh at the start of the project was a series of luminescence ages on the sediments that ranged between roughly 100,000 and 225,000 years for Layer 8, and provided similar but somewhat younger estimates on Layers 7 and 9 (Nehoroshev 2006: 25). The new OSL ages obtained from the 2013 research were similar, however, and also yielded

Table 3. Artifacts recovered *in situ* from Shlyakh during 2013.[1]

Description	Layer 7	Layer 8	Layer 9
cores	2	3	5
flakes	9	44	28
blades	(3)	2 + (8)	8 + (5)
bladelets	(1)	(3)	-
points	1	-	-
side-scrapers	-	(1)	-
backed knives	-	-	(1)
end-scrapers	-	2	1
burins	-	-	1
borers	-	1	-
manuports	1	-	-
other	-	1	1
TOTALS:	17	65	50

[1] Fragments are in parentheses; surface finds excluded.

older-than-expected ages for the upper levels of the site (see Appendix B). At the same time, the cryptotephra studies failed to produce any traces of the CI Y5 tephra, which would have provided an independent chrono-stratigraphic marker (although potentially redeposited by stream action).

The chronology of the site has been strengthened, nevertheless, by the new radiocarbon dates, which—although run on two materials (soil organics and bone) and by several labs—yield consistent results and support the three earlier radiocarbon dates (all obtained on bone) (Nehoroshev 2006: 26).[1] Collectively, the dates indicate that the buried soil represented by Layer 7 dates to ~30,000 cal BP and appears to be contemporaneous with the b2 soil at Kostenki 1 (Holliday et al. 2007). The underlying Layer 8 yielded dates between 35,000–45,000 cal BP, and is contemporaneous to the occupation levels immediately above and below the CI Y5 tephra at Kostenki-Borshchevo. The position of the Laschamps Paleo-magnetic Excursion (Layer 9), which is widely dated at ~44,000 cal BP, supports the radiocarbon estimates.

The lithic assemblages from both Layer 8 and 9 are assigned to the Middle Paleolithic on the basis of technology and typology (Nehoroshev and Vishnyatsky 2000). The artifacts recovered during 2013 and listed in Table 2 are similar to those recovered during the earlier investigations. The chronology of the site indicates, however, that the artifacts are contemporaneous to those made by anatomically modern humans at Kostenki-Borshchevo (Hoffecker et al. 2008), while new dates on skeletal remains from both Western Europe and Siberia confirm the presence of modern humans by 45,000 cal BP (Higham et al. 2011; Fu et al. 2014). The emerging chronology of modern human dispersal in northern Eurasia suggests that the lithic assemblages at Shlyakh might have been produced by modern humans, despite their Middle Paleolithic character. This possibility is reinforced by the similarities between the Shlyakh industry and the Emiran/IUP of the Levant, which probably was made by modern humans.

In addition to the research at Shlyakh, project participants obtained new radiocarbon dates on two other major Middle Paleolithic sites of the East European Plain. The site of Khotylevo 1 on the Desna River near Bryansk, although once believed to date to MIS 5 on the basis of soil stratigraphy, yielded finite dates between 37,910 ± 1030 BP and 49,780 ± 3710 BP, as well as minimum dates of >45,650 BP, thus apparently older than Shlyakh, but also containing Levallois blades (Ocherednoi et al. 2014). Eight bone samples from the nearby site of Betovo dated to ca. 28,000–36,000 cal BP. These dates appear too young for a likely Neanderthal occupation, regardless of the technology and typology of the artifacts (which conceivably represent expedient tools, also found at sites occupied by modern humans).

[1] Dates obtained earlier from Layer 8 include a conventional estimate of >26,000 years BP (ΛE-5522) and AMS dates of 45,700 ± 3000 years BP (OxA-8307) and 46,300 ± 310 years BP (OxA-8306) (Nehoroshev 2006: 26).

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Appendix A: Shlyakh stratigraphic profile

Profile #21 (South wall)

Layer	Depth, cm	Soil Horizon	Description
	0-10	A	Sandy Loam, 10YR 4/3d, 3/3m; very weakly medium prismatic, moderately medium sub-angular blocky; non-calcareous; clear, smooth
	10-33	ABt	Sandy Loam, 10YR 4/3d, 3/3m; strong medium prismatic, strongly medium sub-angular blocky; thin, patchy clay films on ped faces; non-calcareous; clear, smooth
	33-42	Bt1	Sandy Clay Loam, 10YR 4/4d, 3/4m; strongly medium prismatic, strongly medium sub-angular blocky; thin, continuous clay films on ped faces; non-calcareous; clear, smooth
	42-56	Bt2	Sandy Clay Loam, 10YR 4/4d, 3/4m; strongly medium prismatic (but slightly weaker than above), strongly medium sub-angular blocky; thin, continuous clay films on ped faces; non-calcareous; clear, smooth
	56-73	Bw1	Sandy Loam, 10YR 4/4d, 3/4m; very weak medium prismatic, moderately medium sub-angular blocky; non-calcareous; very irregular lower boundary of horizon, locally bioturbated (~73cm = general upper depth on East wall)
	73-93	Bw2	
	73-135	Bk	fine Sand, 10YR 5/4d, 4/4m (carbonate = 8/2d, 6/3m); moderately medium sub-angular blocky; carbonate in irregular patches (not dense bodies, but areas of pervasive accumulation in three distinct horizontal zones: 73-83, 95-110, 125-135cm; a few up to 15cm across, a few up to 5cm thick, vary in distinctness); matrix calcareous; clear, smooth
	135-157	Btk1b1	Sandy Clay Loam, 7.5YR 6/4d, 6.5/4sm (clay films 5/4m, 5/4sm); strongly medium prismatic, strongly medium sub-angular blocky; thick, continuous clay films on ped faces; common 5-10mm carbonate bodies; matrix calcareous; clear, smooth
	157-180	Btk2b1	Sandy Clay Loam, 7.5YR 6/4d, 5/4m (clay films 5/4m, 5/4sm); moderately medium prismatic, strong medium sub-angular blocky; thin, continuous clay films on ped faces; few 2-5mm carbonate bodies; matrix calcareous; clear, smooth

	180-270	C	Laminated zone; upper 10-20cm indistinct due to wxing; 180-240 mostly 5-10mm thick lenses; a few 1-3cm thick; mostly 10YR 8/2d, 7/2m; 6/4d, 5/4m; 5/3d, 4/4m; some 7.5YR 6/4d, 5/4m; 5/4d, 4/4m); 240-270 has more thicker laminae (and generally reddish with the 7.5YR hues; redeposited Shlyakh beds?), mostly 2-3cm thick, a few up to 4cm, a few 5-10mm; note local faults and block faults; some bioturbation (1-3cm krotovinas) of underlying horizon; clear, wavy
7	270-280	Ab2	Clay Loam, 10YR 5/4d, 4/4m; weakly sub-angular blocky to massive; a few 1-2mm Mn-ox bodies; few fine carbonate bodies; calcareous; clear smooth
7	280-310	Akb2 (ABkb2)	Clay Loam, 10YR 6/3d, 5/3m; weakly coarse sub-angular blocky to massive; pervasive carbonate bodies & threads 1-2cm; calcareous; clear smooth
8			Upper non-calcareous silt lens on west & east wall dipping down to the north; to the south the lens rises and is obscured by Akb2; 10YR 6/3d, 6/4m; massive; clear, wavy
8	310-325	ABb3	Mixed, unwxd strong 8 & humified strong 8; Sandy Loam, 10YR 5/4d, 4/4m; fine strong crumbly structure; non-calcareous; clear, smooth.
8	325-334	C1b3	Unwxd strong 8; SL, 10YR 5/4d, 4/4m; massive to weak sub-angular blocky; non-calcareous; irregular wavy
8	334-338	C2b3	Middle non-calcareous silt lens, 10YR 6/3d, 6/4m; massive; clear, wavy
8	338-360	ABb4	Weakly wxd strong 8; Sandy Clay Loam, 10YR 5/4sm; weak sub-angular blocky; non-calcareous; irregular boundary due to bioturbation
8	360-370	C1b4	Loamy fine Sand, 10YR 6/4sm; massive; non-calcareous; clear, wavy
8	370-371	C2b4	Lower non-calcareous medium Sand lens; 10YR 6/3d, 6/4m; massive; clear, wavy
8? 9?	371-385		Sandy Clay Loam, 10YR 5/4d, 4/4m; massive; non-calcareous; clear, smooth
8? 9?	385-387		medium Sand, 7.5YR 4/6d, 4/4m; massive; common Mn-ox stains & bodies; clear, smooth
8? 9?	387-396		fine Sand, 10YR 3.5d, 5/4m; massive; gradual
8? 9?	396-408		fine Sand, 7.5YR 5/4d, 5.3.5m; mixed by bioturbation; abrupt, smooth

8? 9?	408-414		Clay with common rock fragments, 5YR 4/6 & 3/2m; massive; abrupt
8? 9?	414-420		medium Sand, 5YR5/8m; bedded; abrupt (down to 430cm on west wall)
10?	420-450		Gravel and cobbles of limestone & flint (thinner on west wall); 5YR 4/6m with some 3/2m Mn-ox stains & bodies and gley 2.5Y 5/6m mottling and in matrix; abrupt
Shlyakh Fm	450-470+		Clay, 2.5YR 5/6d, 3/6m

Measurements from historic surface below recent spoil
Laminae on East wall are horizontal; laminae on South wall dip gently West

Appendix B. Optically stimulated luminescence (OSL) ages on quartz grains (150-250 micron) for sediments from Shlyakh (9/11/2014)

Sample	Depth (m)	Laboratory number	Aliquots[a]	Over-Dispersion (%)[b]	Equivalent dose (Gray)[c]	U (ppm)[d]	Th (ppm)[d]	K (%)[d]	H_2O (%)	Cosmic dose (mGray/yr)[e]	Dose rate (mGray/yr)	OSL age (yr)[f]
Shlyakh OSL-1	0.83	UIC3545	28/30	22 ± 3	14.131 ± 0.81	0.6 ± 0.1	2.4 ± 0.1	0.44 ± 0.01	15 ± 5	0.18± 0.02	0.78 ± 0.04	18,280 ± 1720
Shlyakh OSL-2	1.57	UIC3554	5/30	non-calculable	non-calculable	0.7 ± 0.1	2.6 ± 0.1	0.56 ± 0.01	15 ± 5	0.18 ± 0.02	0.84 ± 0.04	non-calculable
Shlyakh OSL-3	2.15	UIC3547	35/40	20 ± 3	76.54 ± 3.91	1.8 ± 0.1	6.4 ± 0.1	1.12 ± 0.01	15 ± 5	0.17 ± 0.02	1.82 ± 0.09	42,070± 3665
Shlyakh OSL-4	2.93	UIC3548	23/50		>85 Gy	4.4 ± 0.1	7.7 ± 0.1	1.24 ± 0.01	30 ± 5	0.16 ± 0.02	2.19 ± 0.11	>39 ka
Shlyakh OSL-5	3.20	UIC3549	11/30		>75	3.8 ± 0.1	7.3 ± 0.1	1.10 ± 0.01	30 ± 5	0.15 ± 0.02	1.96 ± 0.10	>38 ka
Shlyakh OSL-6	3.42	UIC3550	31/40	29 ± 4	85.4.4 ± 6.73	4.0 ± 0.1	6.1 ± 0.1	0.88 ± 0.01	30 ± 5	0.15 ± 0.02	1.77 ± 0.09	48,170 ± 4905
Shlyakh OSL-7	3.75	UIC3551	35/45	28 ± 4	57.96 ± 3.56	1.2 ± 0.1	2.4 ± 0.1	0.50 ± 0.01	30 ± 5	0.14 ± 0.01	0.80 ± 0.05	72,255 ± 6610
Shlyakh OSL-8	3.95	UIC3552	27/30	27 ± 4	45.87 ± 2.60	0.6 ± 0.1	1.4 ± 0.1	0.15 ± 0.01	30 ± 5	0.14 ± 0.01	0.40 ± 0.03	116,120 ± 11,215
Shlyakh OSL-9	4.01	UIC3553	29/30	20 ± 3	53.07 ± 2.84	0.7 ± 0.1	1.4 ± 0.1	0.17 ± 0.01	30 ± 5	0.14 ± 0.01	0.44 ± 0.03	124,925 ± 11,625
Shlyakh OSL-10	4.32	UIC3554	27/30	23 ± 3	>77	2.5 ± 0.1	4.0 ± 0.1	0.57 ± 0.01	30 ± 5	0.13 ± 0.01	1.25 ± 0.06	>62 ka

[a] Aliquots used in equivalent dose calculations versus original aliquots measured.
[b] Value reflects precision beyond instrumental errors; value indicate low dispersion in equivalent dose values and an unimodal distribution.
[c] Equivalent dose calculated on a pure quartz fraction with about 200-500 grains/aliquot (~2 mm plate area) and analyzed under blue-light excitation.
(470 ± 20 nm) by single aliquot regeneration protocols (Murray and Wintle, 2003). Equivalent dose calculated using the Central Age Model (Galbraith et al, 1999) when overdispersion is ≤ 20% (at 1 sigma limits) and a Finite Mixture Model with an overdispersion between 29 and 27%.
[d] U, Th and K content analyzed by inductively-coupled plasma-mass spectrometry analyzed by Activation Laboratory LTD, Ontario, Canada.
[e] Cosmic dose rate calculated from parameters in Prescott and Hutton (1994).
[f] Systematic and random errors are included and reported errors are at one sigma; reference year for ages is AD 2000.

References

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