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Interactions in bones but not stone: Anomalous cultural transmission gaps in Romania's Middle to Upper Paleolithic Transition

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A R T I C L E I N F O

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A B S T R A C T

The Late Pleistocene archeological record shows emerging patterns of population turnover frequently associated with technological change between c. 50–40 thousand years ago. In Europe, this is thought to be related to indigenous population admixture and/or the diffusion of developing technologies by *Homo sapiens* resulting in a widely distributed spatiotemporal patchwork of industries with combinations of Middle and Upper Paleolithic traits. The Late Pleistocene record of Romania forms an anomaly in these scenarios. On the one hand, the country has important Pleistocene archives that preserve direct evidence of early modern humans with Neandertal genetic introgression. On the other hand, Romania shows no evidence of novel technology during the Middle to Upper Paleolithic transition. Here, we review the Late Middle and Early Upper Paleolithic archeological record of Romania supplemented with new radiocarbon ages and excavation data to clarify the validity of this current archeological interpretation. We conclude that while Neandertals and modern humans were in regional contact, raw materials eccentricities and incomplete empirical knowledge of past intergroup cultural transmission have obscured our ability to identify indicative material cultural signals indicating that current methods of understanding hybridized material culture are incomplete.

1. Introduction

Since the proliferation of the Single Origin Hypotheses, genomic data have refined models of human migration into Europe by establishing that populations of incoming modern humans admixed with indigenous hominins c. 50–40 ka ago (Hajdinjak et al., 2018, 2021; Hublin et al., 2020; Prüfer et al., 2021). During this demographic turnover, short-lived novel technologies incorporating Middle and Upper Paleolithic elements are implicated in population turnover and/or the cultural intermingling of discrete hominin populations (Slimak, 2008; Hublin, 2015; Haws et al., 2020; Slimak et al., 2022). These technological packages, classified as either Initial Upper Paleolithic (IUP) or Transitional industries, are thought to be chronologically and regionally bound, manifest in a mosaic of spatiotemporal groupings such as the Bohunician, Bachokiran, Neronian, Lincombian-Ranisian-Jerzmanowician, Châtelperronian, Uluzzian and Szeletian among others (Jöris et al., 2022).

It is commonly thought that these traditions reflect early incursions and/or discrete encounter events (Svoboda and Bar-Yosef, 2003; Tostevin, 2013; Slimak et al., 2022). Yet, the features that bind these regional technologies under larger terms and their association with distinct hominin groups, let alone hybridization events or cultural contact, remains unclear. Additionally, the limits of absolute dating techniques create wide ranges in reliable ages and many assemblages are the result of legacy excavations for which stratigraphy remains unclear. Moreover, parts of Eurasia are devoid of IUP and Transitional industries even where stratified Late Pleistocene archeological assemblages are well-known and studied.

Romania is one such region where, despite over a century of research and dozens of stratified sites containing Middle and early Upper Paleolithic assemblages, no IUP or Transitional industries have yet been convincingly identified. This is anomalous because Romania contains highly resolved Quaternary sediments and some of the continent's best understood early modern human fossils remains which constitute the best evidence for local European interbreeding of Neandertals and modern humans (Fu et al., 2015; Hublin et al., 2020; Svensson et al., 2021). Romania also occupies a central location in the European landmass surrounded by regions in Bulgaria, Moldova, Ukraine, and Hungary that all contain both IUP and Szeletian assemblages. It

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additionally encompasses most of the Lower and Middle Danube Catchment that has been proposed as an important conduit for migrating humans and fauna throughout the Pleistocene (Conard and Bolus, 2008; Tostevin, 2013; Olson and Krug, 2020; Curran et al., 2021). Romania stands as an excellent location for testing hypotheses related to hominin replacement and demographic changes due to its juxtaposition of Early Upper Paleolithic sites containing advanced cave art and human footprints, together with Late Middle Paleolithic sites showcasing non-lithic components of transitional assemblages like bitumen and ochre usage (Cârciumaru et al., 2002, 2012; Onac et al., 2021).

To better understand Romania's inconsistent Late Pleistocene archeological record and the absence of Transitional and IUP industries, this paper reviews the Late Middle/Early Upper Paleolithic record in Romania and with the aims to:

- Compile archeological research in Romania's three geographic regions (Western Romania, the Romanian Carpathians, and Eastern Romania) to validate the absence of IUP and Transitional industries across varied ecotones;
- Provide new radiometric dates from Paleolithic sites that contribute to our understanding the Late Pleistocene chronology and site preservation;
- Describe new Late Middle Paleolithic archeological material from the stratified site of Româneşti-*Dumbrăviţa* I;
- Test hypotheses for the putative absence of IUP/Transitional industries and synthesize the results with the hominin record to propose scenarios that might explain patterns.

A clearer picture of the Late Middle to Early Upper Paleolithic transition in Romania has broader implications for human demographics in Europe and the ability of Late Pleistocene lithic assemblages to detect regional hominin interactions.

2. Background

2.1. Current definitions and past interpretations

In other parts of East-Central Europe, IUP assemblages are typically related to the Bohunician, an evolved Levallois technology aimed at serial production of elongated Levallois points' exhibiting bidirectional dorsal scars with facetted striking platforms (Tostevin, 2013; Škrdla, 2017). Regional Transitional assemblages on the other hand are typically linked to the Szeletian, a non-Levallois flake and blade production method thought to have potentially developed from a local Middle Paleolithic bifacial tool-making tradition (Adams, 1998; Kot, 2014; Nerudová and Neruda, 2017). Here, bifacial foliates are a hallmark though the most typical tool types are retouched sidescrapers and endscrapers (Svoboda et al., 1996, p. 110; Allsworth-Jones, 2004; c.f. Mester, 2021). Among Szeletian assemblages, the proportion of blades is higher than that of the often associated preceding Micoquian (Frick, 2020).

To date, Szeletian and Bohunician assemblages have seldom, if ever, been described in Romania despite multiple syntheses reviewing a century of archeological research (Mertens, 1996; Păunescu, 1998, 1999, 2000, 2001; Cârciumaru, 1999; Cârciumaru et al., 2007; Horvath, 2009; Anghelinu et al., 2012). There are no known IUP sites in Romania and in the surrounding countries, there are no sites where the IUP is overlain by MP as found elsewhere in Europe (Slimak et al., 2022). In part, this is because early radiometric ages relied on conventional radiocarbon methods that underestimated the Late Pleistocene chronology of lithic industrial succession, particularly when compared to Western Europe (Doboş, 2017; Doboş and Chu, 2019). This has led to an assumed contemporaneity between the Mousterian and the Early Upper Paleolithic between 36 and 32 ka BP and a presumed technotypological continuity between the Middle and Early Upper Paleolithic where the presence of Middle Paleolithic tools in the earliest Early Upper Paleolithic account for an 'inherited' tradition from the Middle Paleolithic industries (Chirica, 1995). When Transitional industries have been discussed among the Carpathian cave sites, these have primarily been chronological and/or environmental attributions as opposed to having been technologically defined (Cârciumaru, 1999; Cârciumaru and Anghelinu, 2000; Chirica and Borziac, 2009).

Related models have previously espoused that after 30 ka, a late surviving Mousterian evolved alongside multiple transitional technocomplexes comprised of the Brynzenian, Szeletian, the Mitoc and Corpaci facies, and the Prut cultures, that all featured a mixture of Middle Paleolithic and Upper Paleolithic techno-typological elements (Horvath, 2009). Accordingly, the Aurignacian and Gravettian levels of Ripiceni-*Izvor*, together with the sites of Bobuleşti VI, Brînzeni 1 (level 3), Gordineşti 1, Corpaci (level 4), were subsumed into a 'Prut Culture', placed around 27–26 ka BP where industries with bifacial artifacts and/or foliates, sidescrapers, endscrapers and burins were thought to have evolved beside the Aurignacian and the Gravettian (Noiret, 2004). However convincingly demonstrated, the pre-treatment procedures for many of the radiocarbon ages were determined prior to the 2000s suggesting that these dates should be considered with caution (Higham, 2011). New radiocarbon chronologies clearly indicate that such interpretations are incongruous with the current Late Pleistocene Paleolithic chronological framework where the Mousterian and other succeeding Transitional industries disappeared by 41.0–39.3 ka cal BP (Anghelinu et al., 2012; Higham et al., 2014; Higham and Heep, 2019).

2.2. Geography & paleoenvironment

To evaluate the Middle to Upper Paleolithic transition of Romania, it is important to review the geography and late Upper Pleistocene climatic data to understand the dynamic backdrop of early humans inhabiting the region (Müller et al., 2011; Pederzani et al., 2021). Romania lies at the crossroads of Central, Eastern, and Southeastern Europe delineated in part by the Danube and Black Sea. Geologically, it is bisected by the Eastern and Southern Carpathians, a subsystem of the Alpide belt creating three broad geographical, ecological, and historical regions that form a framework for this paper.

West of the Carpathian arc is the eastern Carpathian (Pannonian) Basin (Fig. 1) composed of wetlands and loess-like sediments in the lowlands rising to the hilly Transylvanian Plateau (150–250 m above the valley floor). Western Romania currently has a wet temperate continental climate with patches of alpine biomes on the Transylvanian Plateau. Paleoenvironmental information is mostly inferred from loess and the number and types of embedded paleosols defined by rock magnetism, geochemistry, sediment properties (Zech et al., 2013; Schatz, 2014; Schatz et al., 2015; Schreuder et al., 2016; Obreht et al., 2019; Pötter et al., 2021a; Scheidt et al., 2021). Embedded mollusk shells, (Radaković et al., 2023), charcoal (Rudner and Sümegi, 2001; Willis and van Andel, 2004) and osseous remains (Jánossy, 2011; Pazonyi et al., 2014) infer a generic paleoenvironmental interpretation for Western Romania during MIS 3. These suggest that Western Romania experienced a relatively warmer and drier climate compared to its neighboring regions throughout the late Upper Pleistocene (Antoine et al., 2009; Buggle et al., 2013). Nonetheless, it is likely that Western Romania was still significant diverse varying between steppe-grasslands (Schatz et al., 2011) and steppe-forests (Feurdean et al., 2014; Kels et al., 2014).

The Carpathian Basin is delimited to the east by the Eastern and Southern Romanian Carpathians, a west-arcing range with metamorphosed rocks with a thin, Quaternary sedimentary cover. Within these, karstic limestone features have developed across the entire range, with over 8000 identified caves and abris (Goran, 2019). The Romanian Carpathians are currently a cool continental climate that transitions to an Alpine climate in the higher elevations. Speleothem stable isotope records from Ascunsă Cave (South Carpathians) and Tăuşoare Cave (East Carpathians) suggest that Greenland Stadial 12 (GS12) and GS10—at

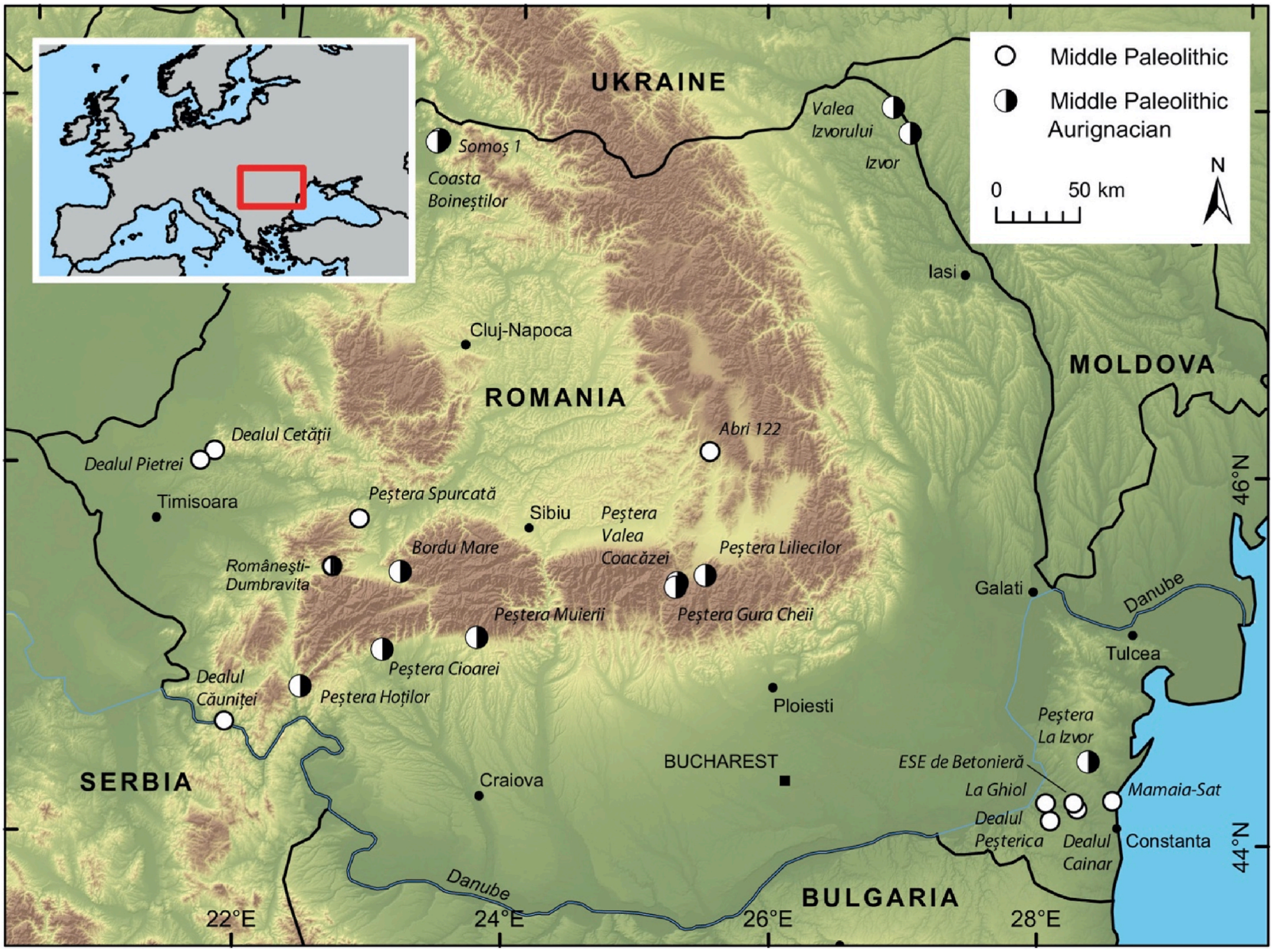

Fig. 1. Map of Romania and the key Late Middle Paleolithic/Early Upper Paleolithic sites.

44.3–43.3 and 40.8–40.2 ka—were prominent cold and arid intervals (Staubwasser et al., 2018) though the Carpathians remained largely unglaciated throughout (Urdea et al., 2022). This is additionally supported by MIS 3 Romanian cave bears which exhibit a large variation in their isotopic values that likely reflect ecological differences between cooler conditions and warmer climate associated with more open forests (Robu et al., 2019; Naito et al., 2020).

Outside of the Carpathian arc in Eastern Romania, the plains of Dobruja (southeast), Wallachia, Oltenia (south), and Moldova (east) form the western extension of the Pontic-Caspian Steppe. The region is predominantly defined by the Danube Delta, an extent of marshes, floating reed islets, and sandbanks (Krézsek and Olariu, 2021). Along the Black Sea coast, a range of limestone hills (200–300 m) contain small caves whereas to the North, the western fringes of the Moldavian Plateau, form lowland hills (c. 700 m) comprised of gritstones along the western bank of the Prut River. Eastern Romania is characterized by wet continental conditions that grades into a warm oceanic climate as it approaches the Black Sea coast. Here, complex loess deposits of the Lower Danube suggest Pleistocene similarities to the Western Romania that fostered steppic environments but that interstadials may not have been uniform in space or time (Fitzsimmons et al., 2012; Fenn et al., 2021; Pötter et al., 2021b). Although local paleoenvironmental proxy studies are largely lacking, mammoth dental microwear across the region suggest a mixed browsing/grazing diet throughout the Late Pleistocene indicating that steppic environments were coeval with forested environments (Haiduc et al., 2018).

Taken together, Romania currently encompasses a wide range of ecosystems which likely translated to a mosaic of contemporaneous biomes during the Late Pleistocene. While MIS 3 Europe is normally characterized as a period of climatic instability with dramatic alternations between milder and colder conditions at millennial or sub-millennial timescales (Van Andel, 2003; Weber et al., 2018), Romania and the surrounding regions may have been comparatively muted suggesting that it likely fostered attractive biomes to a range of hominins (Carvalho and Bicho, 2022).

3. Analysis: between the Middle and Upper Paleolithic in Romania

Among the hundreds of purported Paleolithic sites in Romania, most are small and poorly contextualized (Fig. 1). Sites range from several dozen to thousands of artifacts. Few sites show stratification across the Middle to Upper Paleolithic and secure radiometric dates are rare (Table 1). As a result, we selected only the stratified sites, supplementing their evidence with large surface assemblages (Supplementary Information 1). Given the geological and geographic heterogeneity of Romania, we discuss the Late Pleistocene in the three geomorphological regions presenting first a key reference site followed by other regional evidence, and finally compare evidence from neighboring extranational regions.

Table 1
Dates from Late Middle and Early Upper Paleolithic sites from Romania. 14C ages are calibrated to calendar years (calBP) with software program: OxCal, version 4.4 (Ramsey, 2009). Used calibration curve: IntCal20 (Reimer, 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon, 62).

Locality–Site	Stratigraphic context depth	Sampling year	Material	Type	Lab-ID	14C age±1σ	Calibrated age (BP; 95.4% probability)	References
Baia de Fier-Muierii	Galeria Principală, Mousterian, 0.90 m		Bone	AMS	OxA 15554	30060 ± 280	34894-34153	Soficaru et al. (2006)
	Galeria Principală, Mousterian, −1.10–1.20 m	1950–1953	Bone	AMS	OxA 15530	40850 ± 450	44550–43074	Soficaru et al. (2006)
	Galeria Principală, Mousterian-1.40–1.60 m	1950–1953	Bone	AMS	OxA 16380	47500 ± 900	54945–48054	Doboş et al., (2010)
	Galeria Principală, Mousterian, −1.60–1.70 m	1950–1953	Bone	AMS	OxA 16381	40950 ± 450	44611–43111	Doboş et al., (2010)
	Galeria Principală, Mousterian −1.70–1.90 m	1950–1953	Bone	AMS	OxA 16382	42700 ± 550	46145–44471	Doboş et al., (2010)
	Galeria M, Mousterian, −1.40–1.50 m	1950–1953	Bone	CR	GrN 16997	42560 + 1310/-1120	48016–43236	Păunescu (2000), p. 313
	Passim – Muierii 2 human temporal		Human bone	AMS	OxA 16252	29110 ± 190	34177-33144	Soficaru et al. (2006)
	Passim – Muierii 1 human cranium		Human bone	AMS	OxA 15529	29930 ± 170	34682-34210	Soficaru et al. (2006)
	Passim – human scapula and tibia		Human bone	AMS	LuA5228	30150 ± 800	36509-32876	Olariu et al. (2005)
Boroșteni-Cioarei	Level O, Aurignacian, −0.95 m	1950–1953	Bone	CR	GrN 15045	25330 ± 240	30044–29155	Honea (1993)
	Level L, Mousterian, −1.60–1.70 m	1983	Bone	CR	GrN 13005	37750 ± 950	43369–40877	Honea (1986)
	Level J, Mousterian, −2.15–2.25 m	1983	Bone	CR	GrN 13001	43000 + 1300/−1100	48639–43855	Honea (1986)
	Level K, Mousterian, −2.15–2.25 m	1980s	Bone	CR	GrN 15052	47200 + 2900/-2100	Out of range	Honea (1993)
	Level J, Mousterian, −2.45–2.55 m	1980s	?	CR	GrN 15053	48900 + 2100/-1700	Out of range	Honea (1993)
	Level G, Mousterian, −2.75–2.95 m	1983	Bone	CR	GrN 13002	49500 + 3200/-1100	Out of range	Honea (1986)
	Level H, Mousterian, −2.75–2.85 m	1980s	Bone	CR	GrN 15054	48000 + 1800/-1500	Out of range	Honea (1993)
	Level E, Mousterian, −4.10–4.15 m	1980s	Bone	CR	GrN 15046	50900 + 4400/-2800	Out of range	Honea (1993)
	Level E, Mousterian, −4.25–4.35 m	1980s	Bone	CR	GrN 15048	51900 + 5300/-3200	Out of range	Honea (1993)
Cheia-La Izvor	Mousterian, −0.58 m	1956–1957	Bone	CR	GrN 16987	36810 + 790/-720	42445–40580	Păunescu (1999)
	Mousterian, −0.93m	1956–1957	Bone	AMS	RoAMS 1176.53	36506 ± 772	42359–40219	Doboş, Dumitrașcu (2022)
	Mousterian, −0.93 m	1956–1957	Bone	AMS	RoAMS 1177.53	37048 ± 823	42621–40651	Doboş, Dumitrașcu (2022)
Cuza Vodă - La ESE de betonieră	Level C Bottom, MP	2010	Loess	IRSL	EVA 1044b	121000 ± 19000	N/A	Iovita et al. (2014)
	Level C Top, MP	2010	Loess	IRSL	EVA 1043	54700 ± 7000	N/A	Iovita et al. (2014)
	Level B Bottom, MP	2010	Loess	IRSL	EVA 1044a	94700 ± 13900	N/A	Iovita et al. (2014)
Mitoc-Valea Izvorului	Loessic Limon level, LL2, MP	2004	Loess	OSL	MITOF 6	160000 ± 17000	N/A	Tuffreau et al. (2009a)
Nandru-Curată	Mousterian 2c (superior), −1.90–2.15 m	?	Bone	AMS	GrA 13948	40800 + 1050/-930	45497–42621	Păunescu (2001)
	Mousterian 2c, S1 1b, −2.74 m	?	Bone	AMS	GrM 25167	19670 ± 120	23910–23285	This study
	Mousterian 2a (superior), −3.00–3.15 m	?	Bone	CR	GrN 24221	44600 + 1900/-1500	54375–44473	Păunescu (2001)
	Mousterian 1b (inferior), S 3, -4.15–4.25 m (hearth)	?	Bone	CR	GrN 24222	45200 + 4200/-2700	Out of range	Păunescu (2001)
Nandru-Spurcată	Mousterian, mp 3, −0.70 m		Bone	AMS	GrM 25173	5475 ± 24	6308–6206	This study
	Mousterian, −1.30 m	?	Bone	CR	GrN 14622	30000 + 1900/-1500	39496–31175	Păunescu (2001)
Ohaba Ponor - Bordu Mare	Aurignacian + Musterian 4b, Cas 3 A, −0,20-0,50 m			CR	GrN 14627	28780 ± 290	34001-32111	
	Diluvium II, 9742 Corresponding to M IVa - Moust IIIe		Bone	AMS	Beta-507716	33740 ± 220	39355–37739	This study

(continued on next page)

Table 1 (*continued*)

Locality–Site	Stratigraphic context depth	Sampling year	Material	Type	Lab-ID	14C age±1σ	Calibrated age (BP; 95.4% probability)	References
	Mousterian 4a, C6, −0.89–1.02 m	1954/5	Bone	AMS	GrM 25174	27540 ± 120	31725–31210	This study
	Mousterian 3c, −1.32–1.47 m (hearth)	?	Burnt bone	CR	GrN 14626	45500 + 3500/-2400	Out of range	Păunescu (2001)
	Mousterian 3b, −1.48–1.55 m (hearth)	?	Charcoal	CR	GrN 12676	43600 + 2800/-2100	54800–43113	Păunescu (1989)
	Niv Mousterian 3d, square VI, −1.92 m	1954	Bone	AMS	GrM 25451	>42250	>44600	This study
	Diluvium III, 9753		Bone	AMS	Beta-507717	24240 ± 80	28718–28109	This study
	Sterile, above Mousterian 2, sqm VI, −2.74 m	1954	Bone	AMS	GRM 25176	42260 ± 500	45820–44323	This study
Peştera-Valea Coacăzii	Mousterian, −1.00–1.10 m	?	Bone	CR	GrN 16141	34400 ± 500	40778–38025	Păunescu (2001)
Peştera-Liliecilor	Mousterian	?	Bone	CR	GrN 14618	38700 ± 850	44090–41880	Păunescu (2001)
Râşnov-Gura Cheii	Mousterian 2b, −1.20–1.27 m (hearth)	1982	Charcoal	CR	GrN 11619	29700 + 1700/-1400	38778–31147	Păunescu (1984)
	Mousterian 2 b, −1.20–1.27 m (hearth)	?	Charcoal	CR	GrN 14620	28900 + 2400/-1800	40530–29832	Păunescu (1999)
	Mousterian 2 a + Mousterian 2b, −1.40–1.60 m	?	Bone	CR	GrN 13008	30450 ± 300	35422–34348	Păunescu and Abassi, (1996)
	Mousterian 2 a, −1.52–1.62 m (hearth)	?	Bone	CR	GrN 13009	33300 ± 900	40400–36172	Păunescu (1989)
	Sterile below Level Mousterian 1, −1.90 m	?	Charcoal	CR	GrN 13010	44900 + 1800/-1500	54424–44653	Păunescu (1999)
Ripiceni-Izvor	Aurignacian 2B, S2, −2.30 m		Bone	AMS	GrM 25161	19145 ± 50	23160–22935	This study
	Aurignacian 2A/1B, S2, −2.75 m		Bone	AMS	GrM 25162	8278 ± 24	9412–9135	This study
	Aurignacian 1A, S2, −3.55 m		Bone	AMS	GrM 25163	18190 ± 50	22291–22017	This study
	Aurignacian 1A/Mousterian 6?, S2, −4.20 m		Bone	AMS	GrM 25165	17545 ± 50	21385–20980	This study
	Mousterian 4 (Micoquian), −6.70 m (hearth)	1964	Charcoal	CR	Bln 810	28780 ± 2000	39935–29806	Păunescu (1984)
	Mousterian 5 (Micoquian), −6.80–6.88 m (hearth)	1977	Charcoal	CR	GrN 9210	40200 ± 1050	45164–42363	Honea (1981)
	Mousterian 4 (Micoquian), −7.10 m	1977	Charcoal	CR	GrN 9207	43800 ± 1050	48633–44597	Honea (1981)
	Mousterian 4 (Micoquian), S2, −7.20 m	1972	Bone	AMS	OxA 24046	>45500	N/A	Doboş, Trinkaus (2012)
	Mousterian 4 (Micoquian), −7.30 m	1977	Charcoal	CR	GrN 9208	44800 ± 1200	50735–44949	Honea (1981)
	Mousterian 4 (Micoquian), −7.30 m (hearth)	1977	Charcoal	CR	GrN 9209	42500 ± 1200	47916–43221	Honea (1981)
	Mousterian 3, −8.00 m (hearth)	1964	Charcoal	CR	GrN 11230	46400 + 4700/-2900	Out of range	Păunescu (1984)
	Mousterian 3, −8 m (hearth)	1964	Charcoal	CR	GrN 11571	45000 + 1400/-1200	51633–45102	Păunescu (1984)
	Mousterian 3, −8.20 m (hearth)	?	Charcoal	CR	GrN 14367	46200 ± 1100	52272–46155	Păunescu (1993)
	Aurignacian 1B, S2, D11, −4,10 m	1964	Charcoal and ash	CR	Bln 809	28420 ± 400	33818–31641	Păunescu (1984)

3.1. *Western Romania*

Late Pleistocene findspots in Western Romania are concentrated in the open-air hilly regions between the Carpathian Arc and the Western Romanian Carpathians likely due to a thick Late Pleistocene loess cover in the lowlands. Of these, Româneşti-*Dumbrăviţa* I is the only large, stratified site traversing the Middle-to-Upper Paleolithic. Early excavations reported a small quartzite-based assemblage regionally attributed to the Quartzitic Mousterian. Later excavations dated the depth below the lowest protoaurignacian level to 54.6 ± 6.4 ka ago (Rom-86-222-1; Schmidt et al., 2013) though few artifacts from this level were recovered (Sitlivy et al., 2012).

The most recent excavations recovered 26 artifacts from this lowest find horizon (GH4) where two main raw materials were observed; coarse-grained striated quartzite (2 cores; 1 flake; 2 debitage) and an inhomogeneous milky quartz (3 flakes and 1 bladelet; 8 debris) in a layer directly below the rich protoaurignacian level (Chu et al., 2022). While some smaller Banat flint artifacts (1 flake, 3 bladelets, 5 debris) corresponding to the upper layers were found at the same depth, no quartzite artifacts were found in the upper layers and the former are the result of downward movement.

The newly excavated assemblage is difficult to ascribe to a formalized technocomplex and there was no observed spatial organization (Fig. 2). Nonetheless, a stark change in raw material corresponds to a change in typotechnology. While the upper layers (GH1–3) focus on lamellar production, GH4 exhibits unipolar cores with extensively cortical flakes removed with internal percussion on cortical platforms of local river cobbles (Fig. 3). The corresponding 48 artifacts recovered by

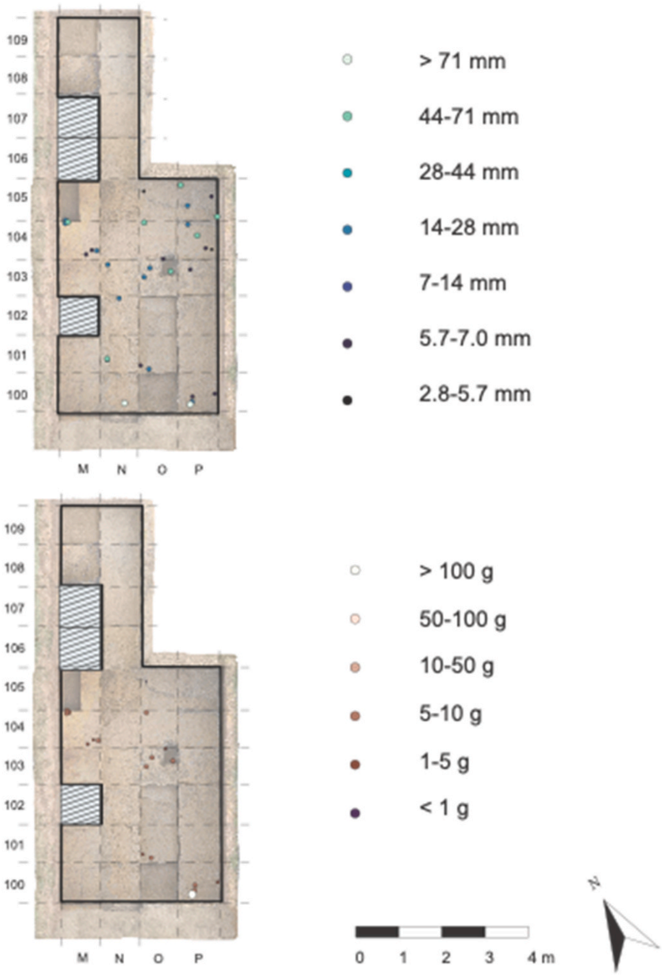

Fig. 2. Top-down orthophoto (final excavation depths) of the 2016–19 excavations at Româneşti-*Dumbrăviţa* I with lithic artifacts projected from: GH4 (Mousterian). (**top**) Lithic size distribution; (**bottom**) lithic weight distribution; (background is transparent to facilitate viewing of artifacts).

Mogoşanu of the same raw materials in previous excavations comprised eight tools including sidescrapers and unifacial choppers (Mogoşanu, 1978). No artifacts show obvious signs of retouch or use though reddish hues suggest that they may have been heated (Ciornei et al., 2020). The absence of leaf points or elongated Levallois artifacts production indicates that they cannot be ascribed to either the Szeletian or IUP industries.

To the north, near the Transcarpathian Ukrainian border, Western Romanian multi-stratified open-air sites demonstrate the same stratigraphic trend as Româneşti-*Dumbrăviţa* I with low density Middle Paleolithic assemblages being followed by richer Early Upper Paleolithic assemblages. At Boineşti (i.e., Coasta Boineştilor), the Middle Paleolithic assemblage from Level D (IRSL; 35 ± 5 ka) comprises c. 350 mostly jasper artifacts of which formal tools are mostly sidescrapers. Nonetheless, artifact refits demonstrated that some of the artifacts have been reworked into the two upper Aurignacian levels during the Holocene as confirmed by the IRSL ages of these layers (Bitiri, 1972; Păunescu, 2001; Dobrescu, 2008; Tuffreau et al., 2013).

At the nearby twin sites of Remetea Somoş I and II, both exhibit MP, Aurignacian, and Gravettian levels (Bitiri, 1972; Dobrescu and Tuffreau, 2013). Both Middle Paleolithic assemblages are comprised of c. 200 lithics, mostly worked in opal and the few formal tools are mostly sidescrapers. At Remetea Somoş I, three bifacial artifacts were also reported (two triangular and one oval) though none of which exhibit characteristics of leaf points that could be of any age and their exact provenance is unclear.

At Zăbrani-*Dealul Pietrei,* three MP levels were identified, with assemblages ranging from c. 100–400 lithics. Across the assemblage, cores are well represented and tools (>20%) are primarily sidescrapers, notches and denticulates. In all assemblages were simultaneously used the flint and the quartzite, despite the local abundance of flint and other fine-grained raw materials. The age of the occupations was estimated to the early Last Glacial (Tuffreau et al., 2007, 2009b).

Gornea-*Dealul Căuniţei* (i.e.,Ţârchevişte) revealed only a single MP level comprised of c. 150 artifacts in fine-grained rocks (e.g., porphyry, chalcedony, flint); among the tools, the sidescrapers are predominant. Due to the elevated Levallois component, the assemblage was assigned to the typical Levallois Mousterian (Mogoşanu, 1978; Păunescu, 2001).

A Middle Paleolithic layer containing 980 lithics primarily made of quartzite, including 67 formal tools like sidescrapers, was discovered at the open-air location of Cladova - *Dealul Cetăţii* in far western Romania. Among the findings were three quartzite foliates and nine bifacial artifacts, mostly oval-shaped (seven in quartzite and two in rock crystal). This assemblage has been associated with the Mousterian of Acheulean Tradition. The superimposed Aurignacian level of c. 100 primarily flint artifacts was dated with conventional radiocarbon to (29.3–27.2 ka cal BP[1]; Boroneanţ, 1991) leading to suppositions that it may indeed be Gravettian (Cârciumaru et al., 2019). Similarly, Pescari-Livadiţa reported a single MP level, with a small lithic assemblage where sidescrapers dominate. The discovery of a Neandertal phalanx was reported, but there is no published analysis on it (Terzea, 1979; Păunescu, 2001).

While Western Romania shows evidence for an early Upper Paleolithic and a Middle Paleolithic, both are recovered from shallow open-air sequences where stratigraphic reworking is often common due to landscape instability and erosion (Chu et al., 2019). Nonetheless, there are no known sites that preserve substantial assemblages of both. Though detailed technological studies and absolute ages are mostly absent for most assemblages, extant typological reports do not give any indications for transitional or IUP assemblages.

3.2. *The Carpathians*

The most comprehensive Late Pleistocene sequence in the Romanian Carpathians is Bordu Mare Cave (i.e., Ohaba Ponor). The first excavations were carried out 1923–1929, though the majority was excavated in 1954–1955 by C. S. Nicolăescu-Plopşor with some subsequent small-scale investigations (Breuil, 1925; Nicolăescu-Plopşor et al., 1957; Păunescu and Abassi, 1996). There, four Mousterian levels (I–IV, from bottom to the top) were found below an Aurignacian level (Fig. 4). The Middle Paleolithic assemblages vary from less than 100 (Mousterian I, II) to c. 1700 (Mousterian III) primarily quartzite artifacts (Nicolăescu-Plopşor, 1957; Păunescu, 2001) hailing from a total excavated surface of ca. 110 m^2. Though sediments were not systematically wet-sieved, six hearths and three Neandertal phalanges were also reported in Mousterian III though the later have since been lost impeding any further verification (Gaál, 1928). The superimposed level, comprised of 18 lithics including a retouched blade, a burin, and a possible bone point fragment/borer has been attributed to the Aurignacian, though no direct ages have been able to confirm this.

Our redating of the site, based on faunal samples from previous excavations by Roska and Nicolăescu-Plopşor, indicate that the upper Mousterian levels are between 39.4 and 31.2 ka cal BP while the lower levels suggest ages of at least 44.3 ka cal BP (Table 2). The further ages we obtained from the Roska's earlier excavations were more widely provenienced and the anomalously young date from Diluvium III, which should be older than that of Diluvium II, corroborate earlier indications of disturbances in the upper layers (Anghelinu and Niţă, 2014).

Other Carpathian caves have revealed similar stratigraphic patterns.

[1] All Radiocarbon ages presented in this paper are calibrated with IntCal20.

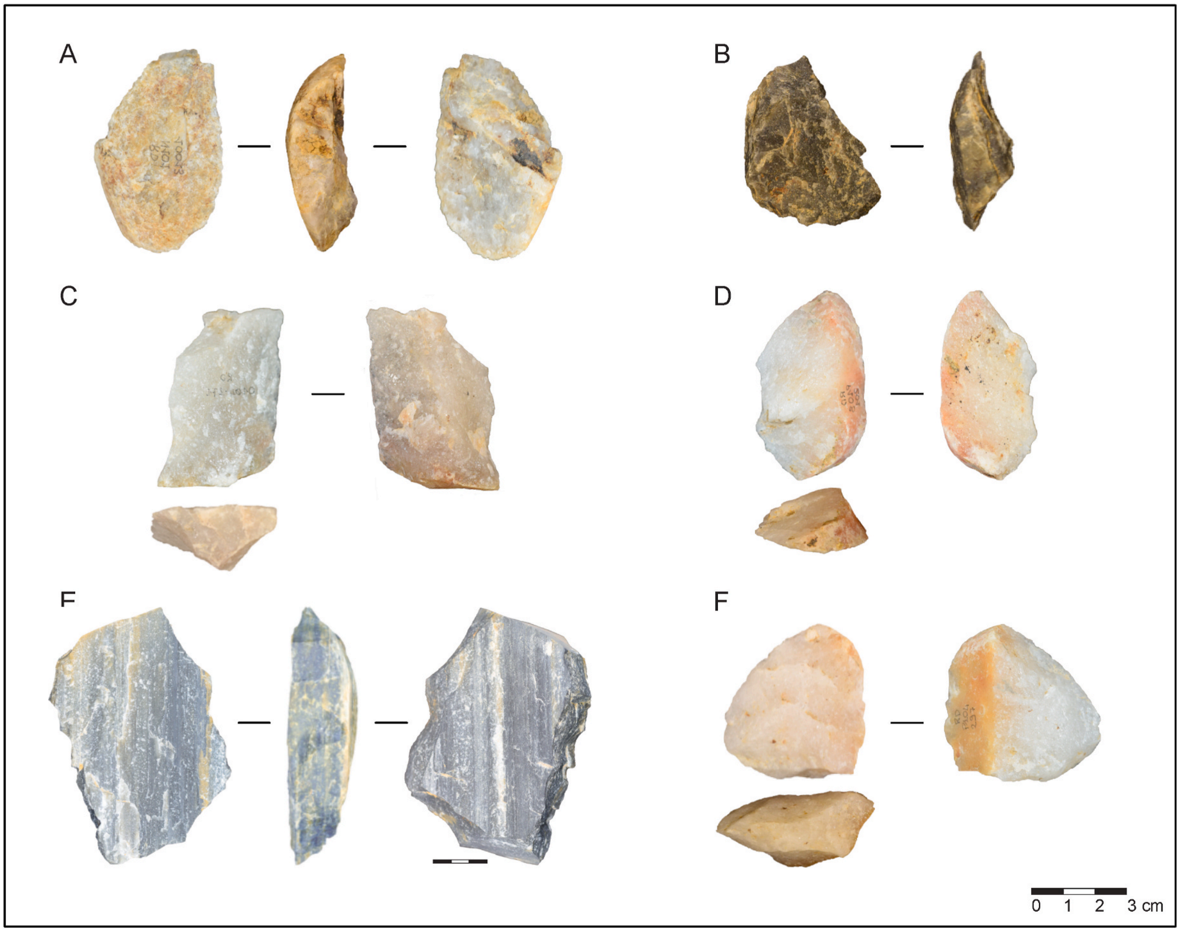

Fig. 3. Middle Paleolithic artifacts from Româneşti-*Dumbrăviţa* I, GH4 from the 2016-19 excavations (Chu et al., 2022).

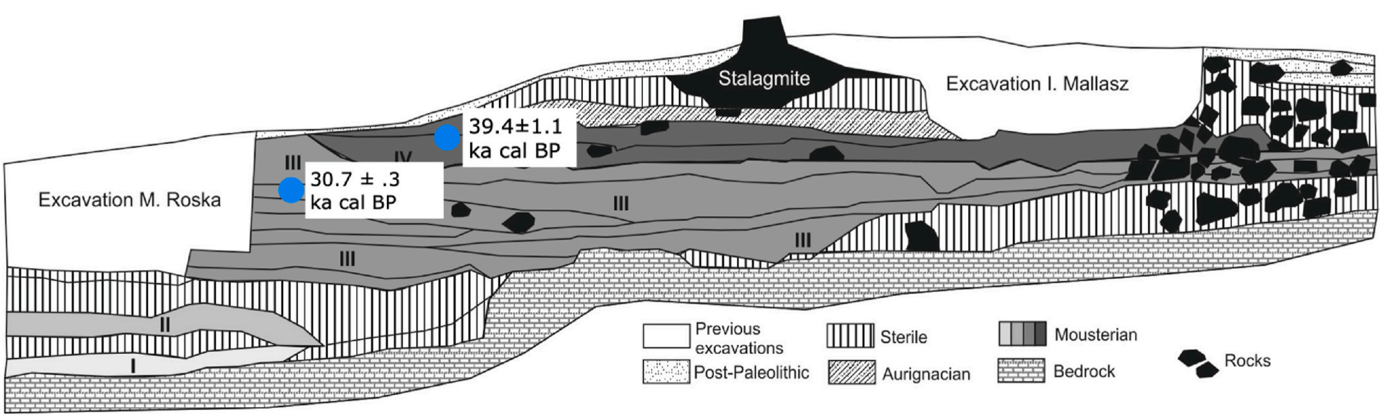

Fig. 4. Composite profile from Bordu Mare (Ohaba Ponor) showing previous excavations by Roska, Mallasz and Păunescu. Location of the newly reported radiocarbon ages are marked(Redrawn from Păunescu, 2001).

At Peştera Cioarei, Middle Paleolithic layers (c. 42.5 ka cal BP; conventional; Cârciumaru, 2000) are overlain by Aurignacian and Gravettian levels. The Middle Paleolithic assemblages, ranging from a several to several hundred lithics, are dominated by coarse-grained quartzite and granite pebbles (<10 cm) alongside 21 other finer grained metamorphic and magmatic raw materials. Here, coarse-grained raw materials were constrained to a "Pontinian-like" knapping technique, whereas other raw materials were employed using discoid and Levallois methods (Cârciumaru et al., 2002). The few formal tools/cores and toothmarks on the corresponding faunal assemblages suggest that the cave was primarily used as a carnivore den and that reduction was performed outside the cave (Cârciumaru, 1995, 2000; Patou-Mathis, 2000).

The Quartzite Mousterian layer of Peştera Hoţilor features c. 150 lithics, among which c. 25 are formal tools, mostly comprised of side-scrapers and notches. The superimposed Aurignacian assemblage (31 ka cal BP) consists of 19 mostly flint lithics including blade-tools and two prismatic cores (Mogoşanu, 1978; Păunescu, 2001). Peştera Liliecilor (i. e. Peştera Mare) has a Mousterian assemblage (c. 43 ka cal BP) comprised of 44 mostly quartzite lithics and the Aurignacian one 173

Table 2
New radiocarbon ages from Romanian Middle and Upper Paleolithic sequences.

Sample Name	Lab-ID	Dated material	%C	%N	C: N	δ13C (‰; IRMS)	δ15N (‰; I RMS)	F14C	±1-sigma	14C Age (yrBP)	±1-sigma	Calibrated age (BP; 95.4% probability)
Ripiceni-Izvor 2.3 m	GrM-25161	collagen	40.8	14.8	3.2	−19.57	6.13	0.0922	0.0006	19145	50	23160–22935
Ripiceni-Izvor 2.75 m	GrM-25162	collagen	42.7	15.3	3.3	−20.86	6.80	0.3568	0.001	8278	24	9412–9135
Ripiceni-Izvor 3.55 m	GrM-25163	collagen	39.7	14.6	3.2	−21.42	1.87	0.1039	0.0008	18190	50	22291–22017
Ripiceni-Izvor 4.20 m	GrM-25165	collagen	43.0	15.6	3.2	−20.90	3.35	0.1126	0.0008	17545	50	21385–20980
Nandru Curata SI B1 2.95 m	GrM-25167	collagen	42.7	14.3	3.5	−22.08	5.74	0.0864	0.0006	19670	120	23910–23285
Nandru Spurcata SI sqm 3 0.7 m	GrM-25173	collagen	43.8	15.7	3.2	−21.80	7.12	0.5058	0.001	5475	24	6308–6206
Bordu Mare C6 0.89–1.02 m	GrM-25174	collagen	47.8	17.4	3.2	−19.47	4.02	0.0324	0.0005	27540	120	31725–31210
Bordu Mare sqm 6 1.92 m	GrM-25451	collagen	46.8	15.4	3.5	−21.39	6.76	0.0039	0.0008	>42250		>44600
Bordu Mare sqm 6 2.74 m	GrM-25176	collagen	41.0	14.9	3.2	−19.68	9.47	0.0052	0.0005	42260	500	45820–44323
Bordu Mare 9742	Beta-507716	collagen	42.3	15.0	3.3	−21.9	4.1	0.0150	0.0004	33740	220	39355–37739
Bordu Mare 9753	Beta-507717	collagen	41.85	14.8	3.3	−20.9	6.3	0.0489	0.0005	24240	80	28718–28109

lithics (Nicolăescu-Plopşor et al., 1961).

The larger Peştera Muierii (i.e. Peştera Muierilor) yielded c. 5000 mostly quartzite artifacts (Soficaru et al., 2006; Alexandrescu et al., 2010; Doboş et al., 2010). Though wholly unstratified, a multiphasic occupation is nonetheless assumed due to the volume and diversity of artifacts (Gheorghiu et al., 1954; Nicolăescu-Plopşor, 1957; Păunescu, 2000). Here, Middle Paleolithic artifacts have been classified as Charentian Mousterian (Păunescu, 2000) and the small flint (N = 36) assemblage may account for a single discrete short-term, logistic occupation (Doboş et al., 2010). A further assemblage of c. 60 Aurignacian lithics, together with three bone points, have been subsequently lost inhibiting any further radiometric ages or verification. The human fossils (34 ka cal BP) when confronting these ages to the series of ages from *Galeria Principala*, which range from c. 34.5–45 ka, appear to be contemporary with the end of the Middle Paleolithic occupation/the Early Upper Paleolithic occupation.

At the Nandru caves, Peştera Curată has two Middle Paleolithic levels (c. 150 lithics) containing mostly quartzite sidescrapers, notches and naturally backed knives. For the upper level, an AMS age indicates c. 44 ka cal BP, however our new date from a lower part of the same level indicates an age of c. 23.5 ka cal BP, most likely accounting for intrusions or poor proveniencing (Table 2). In the lower Middle Paleolithic level, conventional ages indicate an age of c. 49 ka cal BP (Nicolăescu-Plopşor et al., 1957; Nicolăescu-Plopşor and Zaharia, 1959; Păunescu, 2001). The neighboring Spurcată Cave has a smaller assemblage: 29 mostly quartzite lithics, of which 22 are formal tools including five quartzite bifacial artifacts and a flint foliate which were initially assigned to the Szeletian (Nicolăescu-Plopşor and Zaharia, 1959) but later assigned to the Mousterian by Păunescu, without even discussing the alleged Szeletian character of the industry (Păunescu, 2001). A conventional radiocarbon age indicates an age of c. 35 ka cal BP (Păunescu, 2001); though our recently dated faunal sample from our upper part of the Middle Paleolithic level was dated to c. 6 ka cal BP, suggesting some reworking of the site (Table 2).

Two Middle Paleolithic levels at Gura Cheii Cave contained dozens of mostly quartzite lithics with sidescrapers. One conventional radiocarbon age from the upper Middle Paleolithic level indicates an age of c. 38 ka cal BP. The lower Upper Paleolithic assemblage, comprising c. 50 lithics in flint, includes a few endscrapers and retouched blades and was assigned to the Aurignacian while a superimposed upper Gravettian level was dated at c. 27 ka cal BP (Nicolăescu-Plopşor et al., 1962; Cârciumaru et al., 2008, 2010). Nearby Peştera-Valea Coacazii yielded a Middle Paleolithic layer with c. 30 lithics, mostly in quartzite, and few sparse artifacts assigned to the Aurignacian and Gravettian. A conventional radiocarbon age indicates c. 39.5 ka cal BP for the Mousterian layer (Păunescu, 2001; Cârciumaru et al., 2010).

At Merești - *Abri 122*, recent research has yielded retouched flakes and blades, sidescrapers, endscrapers, unifacial and bifacial points. Unlike the majority of the unmodified quartzite blanks, formal tools are mainly made of lydite/opal and basalt/andesite. Albeit the archeological material appears scattered throughout the entire vertical span, two main clusters of lithics are apparent in the newly surveyed profile bracketed between c. 174–99 ka (Cosac et al., 2018; Veres et al., 2018, 2019).

The only transitional-like assemblages in the region have been described at Ceahlău-Cetățica I where blades alongside bifacial artifacts have been described as Aurignaco-Szeletian (Nicolăescu-Plopşor, 1957; Nicolăescu-Plopşor and Zaharia, 1959). However, the Szeletian (Nicolăescu-Plopşor et al., 1961), has little to do with the industries found in the three aforementioned caves, which aside from the bifacial artifacts (N < 7), feature a high percentage of flakes. The bifacial artifacts from the lower level of Ceahlău-Cetățica I were either assigned to the Aurignacian (Păunescu, 1999) or to a Late Mousterian/Early Upper Paleolithic industry (Steguweit et al., 2009) though an Early Gravettian attribution may also be likely (Schmidt et al., 2020).

The Carpathian cave sites appear technologically similar, most likely due to the primary focus on quartzite exploitation. Occasional bifacial artifacts and even foliates are nonetheless reported; Nandru-Peştera Spurcată stands as an exception, where from a small quartzite assemblage, over one fifth are bifacial points. Chronologically, the cave sites are dated in the window of 45–30 ka cal. BP, which might tally with a Szeletian presence, though they also encompass dates that would be include those of the Late Middle and Early Upper Paleolithic. Among these sites with bifacially shaped artifacts however, the accompanying assemblages are small or not clearly associated with other artifacts or dated charcoal samples; it is therefore difficult to ascertain on their own to what extent these are indicative of the Szeletian as the assemblages are small and the hallmark leaf point remains typologically poorly defined (Mester, 2018, 2021).

3.3. Eastern Romania

The site of Ripiceni-*Izvor* is by far the richest Paleolithic site in Romania. Comprised of 15 Paleolithic and one Mesolithic levels over a c.

11 m stratigraphic sequence, 4000 m^2 were excavated between 1961 and 1981 (Păunescu, 1993, 1999, Fig. 5). The lowest Mousterian levels (I–III) contain a Levallois component with sidescrapers, notches, denticulates and six 'atypical' bifacial artifacts. Upper Paleolithic tools are also present but account for less than 4% of the total artifacts. The subsequent Mousterian-of-Acheulean-Tradition levels (IV–V) contain over 35 k and 16 k pieces respectively including sidescrapers, notches and denticulates. Level IV contains 57 mostly plano-convex foliates though another 200 triangular, oval, and discoidal bifacial artifacts were also reported. Level V contains four foliates and 23 bifacial artifacts. Here, Upper Paleolithic tools are rare accounting for less than 3% within each assemblage. Mousterian Level VI, with an assemblage of 324 lithics comprises sidescrapers, notches and denticulates (c. one third of the formal tools) with no Upper Paleolithic tool types. No detailed technological analyses are available, partly inhibited by the curated nature of the assemblages during excavation.

The subsequent Aurignacian levels were separated by a 25–50 cm sterile layer. The four Aurignacian levels (Ia–IIb) feature assemblages between c. 1000–4500 lithics. The assemblages were assigned to the Aurignacian based on the presence of endscrapers (nosed, carinated) and burins (busked, angle). Moreover, a conventional radiocarbon sample on charcoal and ash indicated an age of c. 33.8–31.6 ka cal BP (Păunescu, 1984). These assemblages have an important Middle Paleolithic component among the formal tools, decreasing from c. 75% among older levels to c. 40% with the Upper Paleolithic tools' percentage increasing accordingly. All contain bifacial artifacts, accounting for 3–6% of the formal tools that have been interpreted as Szeletian leaf points (Kaminská et al., 2021). Still, bifacial artifacts occur in the overlying Gravettian layers, alongside Dufour bladelets and backed pieces suggesting sedimentary reworking, most likely from slumping from areas outside of the excavation area (Anghelinu et al., 2012).

Conventional radiocarbon ages bracket the Middle Paleolithic (Levels Mousterian III-V) between c. 49–43.5 ka cal BP (Mousterian V) and the Aurignacian IB to c. 32.5 ka cal BP. Unfortunately, the site was demolished by the construction of the Stânca-Costești Dam Lake rendering new excavations impossible and the ability to date previously excavated materials are limited. Fauna, rich in the Middle Paleolithic levels, is beyond the limit of the radiocarbon (Doboş and Trinkaus, 2012) and fauna is only represented by few fragments in the Upper Paleolithic levels. While burned lithics were reported in each level, they cannot be used for luminescence dating as there are no sediment sample for the dose-rate.

Our own dated samples from the Aurignacian levels (Levels Ia, IIa, and IIb) produced three ages 24.0–21.4 ka cal BP with another between 9.4 and 9.1 ka cal BP suggesting extensive post depositional movements in the upper layers (Table 2). Despite the nearly 2 m depth variability from which these artifacts were recovered, the ranges are all in close agreement though progressively older moving up the sequence suggesting that some of this may be due to bioturbation or progressive generations of regional landslides first triggered during the LGM by fluvial incision in the Moldavian Plateau (Niculiţă et al., 2019). The only available means for estimating the site age, albeit low resolution, is the location of the site on a low terrace of the Prut River, c. 10–15 m above the water course at the time of the excavation. The terraces of Prut River with elevations below 40 m are Upper Pleistocene in age (Moroşan, 1938; Păunescu, 1993, 1998) suggesting that the maximum age of the lowest levels cannot exceed the MIS 5d.

The nearby site of Mitoc-*Valea Izvorului*, an *in situ* evolution of Mousterian to Upper Paleolithic industries via a transitional industry was posited within the 4.30m loessic/sandy sequence where artifacts were found throughout (Bitiri, 1965, 1987; Bitiri and Cârciumaru, 1978; Cârciumaru, 1999). Here, Levallois debitage, side scrapers, notches, and oval bifacial artifacts were recovered alongside prismatic blade cores, endscrapers, chisels and borers. Recent re-excavations and radiometric

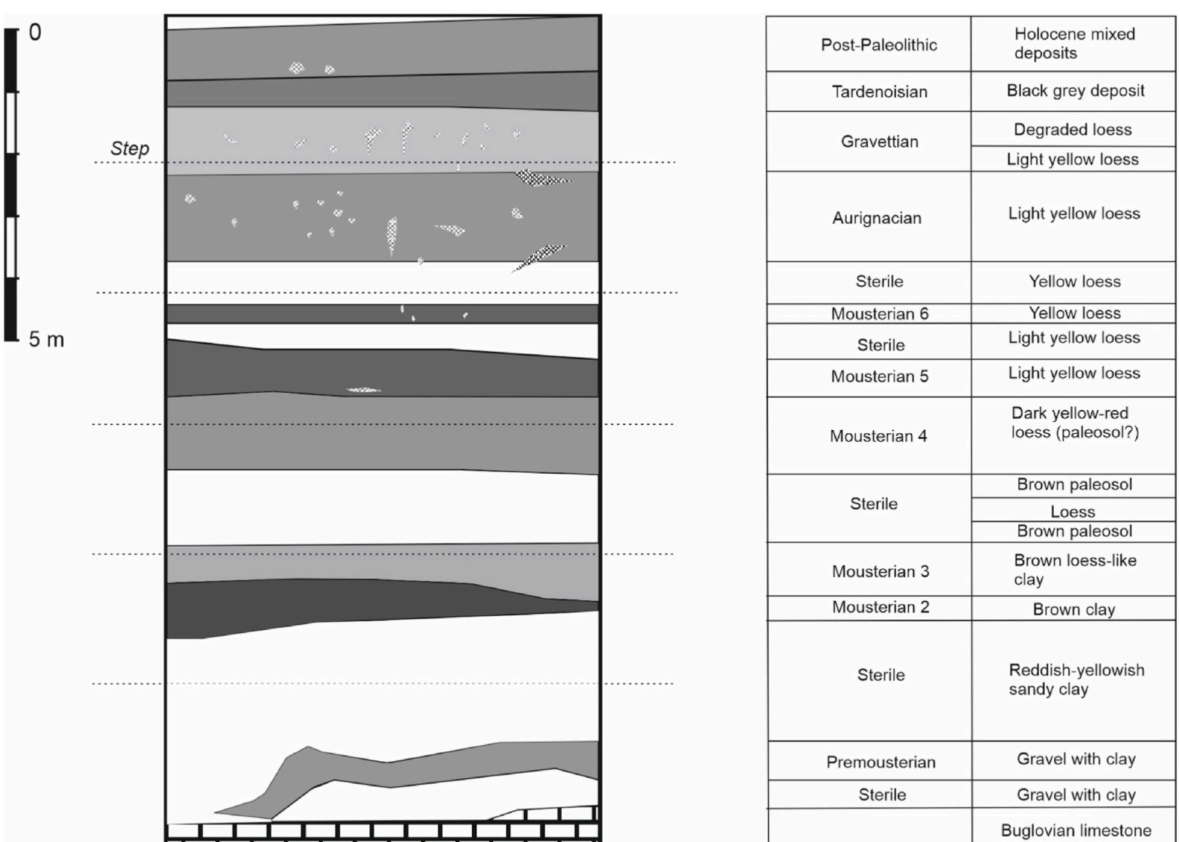

Fig. 5. Schematic stratigraphy from Ripiceni-Izvor (modified from Păunescu, 1993).

ages however, have demonstrated sedimentary reworking is responsible for the co-occurrence of Middle Paleolithic and Upper Paleolithic forms and that there is no transition industry in Mitoc - *Valea Izvorului* between the Middle Paleolithic and the Upper Paleolithic (Tuffreau et al., 2009a).

In Dobrogea, the eastern extension of Romania, the cave of Cheia-*La Izvor* encourages further doubt of transitional assemblages. The site yielded a total of 128 mostly flint artifacts in two levels comprising mostly formal tools (87%; Păunescu, 1999). Only a few artifacts (total unclear) were found at the bottom of a loessoid deposit that were assigned to the Aurignacian. The level immediately below was assigned to a late typical Levallois Mousterian typified by sidescrapers on Levallois and non-cortical flakes. A recent reassessment of the sites' assemblage has reconfirmed a Late Pleistocene age (42.4–40.6 ka cal BP) though has also demonstrated that the cave had been heavily bioturbated by animal denning that disturbed the archeological levels making it difficult to disentangle discrete assemblages (Doboş and Dumitraşcu, 2022).

Several MP sites are known from the province of Dobrogea, mainly consisting of surface collections: Cuza Vodă–*La ESE de betonieră*, Castelu–*Dealu Cainar*, Saligny–*La Ghiol*, Peştera–*Dealul Peşterica*, with collections ranging in size from c. 150 lithics to over 1000 (Cârciumaru and Păunescu, 1976; Cârciumaru, 1999; Păunescu, 1999; Fitzsimmons et al., 2020). The assemblages, mostly worked in flint, have variable Levallois indexes, and generally the formal tools are dominated by sidescrapers, notches, and denticulates. The only chronometric information available comes from the site of Cuza Vodă: in 2010 where a core in an industrial trench indicated an OSL age of between c. 95–55 ka ago (Iovita et al., 2014).

4. Discussion

Discussing the Late Pleistocene technological variability across Romania is clearly hampered by the low number of stratified sites, unclear stratigraphic proveniences, small artifact assemblages, and uncertain absolute ages. Nonetheless, what is clear is that Romania, to date, exhibits no unambiguous signal of IUP or Szeletian assemblages despite discrete proximity to numerous sites and evidence for hominin hybridization events.

There are three plausible hypotheses that could explain this scenario. The first suggests that the makers of such industries were present, however expressing signature typotechnological assemblages was inhibited by the availability of suitable raw materials; this is possibly exacerbated by the lack of technological analyses that may have inhibited their recognition, particularly among old excavations where stratigraphic information is largely lost. A second, less technical narrative, is that while Neandertals and modern humans co-existed in East-Central Europe, local territories did not overlap creating largely segregated communities that independently continued their own technological lithic traditions. A third possibility is that Modern human and Neandertal populations intimately interacted, however in Romania, these were not expressed in lithic technologies, or at least, our understanding of hybridized technological variation is inadequate to identify it archeologically.

4.1. Raw materials

An initial proposition for the absence of Szeletian or IUP is that industries produced by hybridized communities exist, but that their expression into signature reduction sequences or forms is obfuscated or modulated according to the dominance of quartzite among Romanian Paleolithic assemblages, affecting both flake production intensity and cores/tool reduction. Such a signal would suggest expedient technological behavior and low-investment technologies through the near-exclusive use of local raw materials coupled with reduction sequences that target low-levels of predetermined flakes and the scarce presence of simple retouched tools. While the excavations discussed in this context frequently lacked sieving and comprehensive technological analyses, the observation of a minimal occurrence of the Levallois technique in quartzite Middle Paleolithic assemblages from various periods in Romania, along with the scarcity of bladelets in Early Upper Paleolithic quartzite assemblages, implies a significant influence of raw materials.

Among quartzite-dominated assemblages, this can appear as technological homogeneity giving the false impression of diachronic continuity (Jaubert, 1997) that have been hallmarks of discrete regional techno-cultural traditions (Rankama et al., 2006; Garcia Garriga, 2011). Different raw materials may have elicited operational scheme modifications but not necessary implying a fundamental change of the conceptual scheme. When finer grained materials were available, even sporadically, formal technologies on these materials are similar to those identified in those territories with fine-grained raw materials (Barsky, 2013; Aubry et al., 2016; Gaspar et al., 2016; Rodríguez-Álvarez, 2016) during the late Middle Paleolithic (Daffara, 2018; Daffara et al., 2021). In places like Zabrani-*Dealul Pietrei* (Tuffreau et al., 2009b), quartzite was reduced using several techniques and more often modified into tools than blanks of other finer-grained raw materials.

Nonetheless, few transitional assemblages and IUP assemblages are made primarily from Quartzite. The fracture mechanics of Quartzite frequently inhibit the manufacture of blade-forms (Aubry et al., 2016) and in parts of Europe where quartzite dominates, modern humans readily produced a variety of Upper Paleolithic forms on flake-based industries alongside lower numbers of elongated blanks (Thacker, 2002; Pereira et al., 2012; Chu et al., 2020). Even among technologies employing bipolar technology (i.e., Bachokiran, Ulluzian) they are seldom manufactured on quartzite.

4.2. Multiculturalism

If Neanderthal populations in Southeastern Europe persisted until relatively late compared to other parts of Europe, as has been posited, they may have regionally impeded the influx of early modern human populations into uplands and restricted their early activities to river valleys (Alex et al., 2019; Mihailović, 2020; Borić et al., 2021). The low number or absence of early Upper Paleolithic artifacts in Romanian caves therefore intimates dissimilar mobility patterns by hominin groups that may be related to resource availability (Anghelinu and Boroneanţ, 2019) (see Table 3). The inverse trend at most open-air sites such as Româneşti-*Dumbrăviţa* I may also be evidence that modern human activity does not strongly map onto previous Neandertal occupations.

Under such models, Neandertals persisted primarily in upland refugium, a scenario congruent with past interpretations of the Romanian record, where the Middle Paleolithic may have lasted up to 36 ka ago (Honea, 1981, 1984, 1986; Mertens, 1996) though the radiocarbon chronology remains problematic. A similar scenario may be envisioned for Eastern Romania where Micoquian assemblages may have continued

Table 3
Lithic counts per excavated surface area of stratified MP/UP cave sites in Romania.

Site	Aurignacian artifacts/m^2	Middle Palaeolithic artifacts/m^2
Baia de Fier - Peștera Muierii	1.20	60.00
Băile Herculane - Peștera Hoților	1.36	11.07
Bordu Mare	0.16	18.12
Mare/Liliecilor	2.16	0.55
Peștera - Peștera Valea Coacăzii	0.20	1.16
Râșnov - Peștera Gura Cheii	0.27	1.24
Boroșteni - Peștera Cioarei	0	13.02
La Izvor	0	3.54
Nandru Spurcată	0	0.94

due to differential population dynamics. Here, the absence of Szeletian and IUP assemblages in combination with genetic mixture may be the result of multiculturalism/cultural pluralism, whereby groups within a larger society maintain their unique cultural identities and traditions. Rather than biological change, the Middle-to-Upper Paleolithic transition would therefore be primarily driven by large-scale climate changes effecting local ecologies rather than biological turnover (Riel-Salvatore et al., 2008).

Nonetheless, the recent ages of the Late Middle Paleolithic of Romania still rely primarily on conventional radiocarbon dates and must therefore be treated with caution (Doboş, 2017). The notion of the Southeastern Europe as a late Neandertal refugium may therefore be a simple relic of lower population density than in other regions of Europe (Pop, 2013, p. 2013; Dogandžić et al., 2014). The lack of sterile layers between the Middle Paleolithic and Early Upper Paleolithic at most stratified Romanian sites confirms this, but taphonomic studies of many of these sites remain inadequate to sufficiently confirm such broadscale notions.

4.3. Incomplete models of cultural transition

An alternative hypothesis is that models of biocultural expression among lithic technology is currently inadequate to address population dynamics. While the genesis of transitional and IUP industries are intensely debated, they remain poorly understood (Harrold, 2009; Kuhn and Zwyns, 2014). Typically, transitional assemblages are related to the arrival of modern humans in Eurasia (Zilhão and d'Errico, 1999; Hublin, 2015; Faivre et al., 2017) though their makers are uncertain. Under this model, Transitional industries result from cultural transmission—either through stimulus diffusion or as an adaptive response based on interaction/observation between Upper Paleolithic and indigenous (e.g., Neandertal) populations (Mellars, 2004; Tostevin, 2007). A recent focus of understanding Transitional industries has therefore been to identify the underlying mechanisms of cultural transmission rooted in an evolutionary framework.

Recently, it has been routine to interpret major transitions in the Paleolithic archeological record in relation to effective population size and interaction (French, 2016; Mihailović and Bogićević, 2016; Creanza et al., 2017; Greenbaum et al., 2018), connections that are generally supported by analytic/simulation-based models and laboratory-based experiments (Derex and Mesoudi, 2020). Late Pleistocene hominins likely had a multi-level social structure, with core single-male–(multi-) female units nested within larger social bands whereby cultural transmission was facilitated by both strong male-bonds and the movement of individuals between groups through bisexual dispersal (Grueter et al., 2012). Here, intermediate levels of population fragmentation would have maximized cultural accumulation (Derex et al., 2018) by hindering the transmission of cultural innovations, while allowing diverse traditions or technological solutions to emerge in distinctive parts of the social network. This way, past hunter-gatherer societies could have adapted culturally despite having low population density (Migliano et al., 2020).

Still, the past mechanisms that would have triggered this in Romania remain poorly understood as linking models and experimental results to archeological contexts is difficult because we do not have access to detailed knowledge of demographic changes, population structures, and the ways in which social networks were organized (Fogarty and Creanza, 2017; Fogarty et al., 2017; Aoki, 2018; Derex et al., 2018; Fernández-López de Pablo et al., 2022). The highest percentage of Neanderthal-modern human hybrid currently known is from the Peștera cu Oase (c. 10%) indicating recent social interaction. Additionally, specimens from Muierii and Cioclovina suggest that modern humans and Neandertals continued a high level of interaction for up to 10 ka among diverse population clusters (Fu et al., 2016; Svensson et al., 2021; Posth et al., 2023). Interestingly, other individuals from that period, such as Zlatý kůň from Czechia and Ust'Ishim from Russia, do not carry significantly more Neanderthal ancestry than other non-African groups (Fu et al., 2014; Prüfer et al., 2021) indicating lesser interactions between Neanderthals and early modern humans during their early presence across Eurasia; nonetheless, these remain regional hotspots of transitional and IUP industries (Zwyns, 2021).

It therefore seems plausible that genetic diversity could have spurred an increase in cultural differentiation and cumulative cultural evolution but the nature of these interactions and indeed if they even occurred regionally, remains unknown. Endogamous groups have undoubtably met many times in the Paleolithic past, and they have not always produced novel toolkits (e.g. Zhang et al., 2020). The variety of Transitional industries across Europe suggest that external stimuli also modulated their expression across the lithic record. Factors, such as ecological/-climatic variables (Fogarty, 2018) and social structure would have influenced cultural transmission both directly and indirectly, via their influence on population size and interconnectedness (Fay et al., 2019a, 2019b).

In terms of the IUP, it is still unclear to what extent it can be regarded as a transitional industry, at least in the sense of being linked to demic exchange (Kuhn, 2003, 2019). While the IUP could be consistent with *Homo sapiens* dispersals in Central and East Asia during the Late Pleistocene (Zwyns, 2021) its expanded definition has become too generic to be called a 'culture' in the usual sense however, the prehistoric relationship between the IUP assemblages of across Europe has yet to be established given its high variability in composition and duration (Kuhn and Zwyns, 2014) particularly considering the evolving nature of the IUP even in the Levant (Boaretto et al., 2021; Goder-Goldberger and Malinsky-Buller, 2022). There is currently no strong evidence to suggest that IUP assemblages index modern humans as we do not know which hominin(s) were responsible for producing the IUP assemblages in different regions.

The technological similarities of the IUP across Europe may be a consequence of diverse processes, including demic migration, cultural transmission, and technological convergence. More broadly, it forces us to consider whether the shared elements of material culture reflect common cultural descent or broad convergence. While in the Levant the IUP shows *in situ* development, in Europe, it appears to be exogenous and has been used to track a discrete hominin dispersal event (Tostevin, 2013; Slimak et al., 2022). However, it can also result from repeated convergence or parallelism. Levallois-like blade production may be a natural transition between Mousterian Levallois production and volumetric blade manufacture or an adaptive response or a combination of all three. Still, given what is known from genetic interbreeding, network social structure, and of current human primates, technological convergence remains an unlikely scenario.

While modeled dispersals suggest that IUP bearing hominins parsimoniously passed through the region (Kondo et al., 2018), they may have bypassed Romania though the wide distribution of the IUP suggests that ecology is less of a significant variable than among Transitional industries that appear to be more standardized across Western Eurasia (Tostevin and Škrdla, 2006; Zwyns, 2021). At present, our methods of detecting IUP cultures are strictly limited to stone tools as our understanding of how these relate to other artifact classes such as bone tools and personal ornaments remains limited (Martisius et al., 2022). The IUP is defined in terms of flaking methods though in the Romanian case, we typically only have stone tool typologies making it difficult to evaluate the likelihood of transmission or absence of transition in a single trait. Understanding variation within the IUP is therefore key to understanding if its spatiotemporal distribution is the result of cultural continuity (migration or diffusion) or convergence (Kuhn, 2019).

The scarcity and widespread distribution of IUP assemblages across Europe implies that sampling errors may influence the perception of hotspots or significant sites; this may be the case in Romania and new fieldwork always has the potential to unearth new sites. However, this situation also raises doubts about the definition of the IUP and its usefulness as an indicator of human populations. In Central Europe, the IUP is found in a stratigraphic position between the later Middle Paleolithic and the early Aurignacian, though it is infrequently present in extensive sequences. Conversely, in Western Europe, where it is regionally known as the Neronian, the IUP is found beneath Middle Paleolithic layers (Slimak et al., 2022).

Both cases raise the question, to what extent can we expect the complex demographic changes to be reflected in continental-wide technological patterns? They could either be the result of technological convergences suited to a specific task or a consequence of migration or diffusion. As convergence is unlikely based on the modeling and socio-psychological studies of the multilevel population structure of hominins showing that culturally diversity and interaction foster innovation.

5. Conclusion

Romania lies at the center of early hypothesized modern human dispersal routes across Europe and contact zones between Neandertals and early modern humans. Yet despite a technologically diverse Late Middle Paleolithic, a precocious Early Upper Paleolithic, and direct evidence of Neandertal and Modern human contact, Romania shows none of the commonly implicated hybridized cultural residues in the form of Szeletian or Bohunician assemblages. In places, this is obfuscated by unclear datasets and the particularities of the available raw materials, but the overall pattern suggests that such assemblages were simply absent or rare suggesting that current models of identifying cultural transmission among lithic assemblages remain incomplete, or at best, unidentifiable on a European-wide scale. The Romanian archeological record, like many locations in Western Eurasia during the Late Pleistocene, poses challenges to models of Late Pleistocene demographic changes, at least from a cultural point of view that can only be rectified by improving models of archaic cultural transmission or through falsification through new detailed technological analysis of new or recently excavated collections.

CRediT authorship contribution statement

Wei Chu: Writing – original draft. **Adrian Doboş:** Writing – review & editing. **Marie Soressi:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quascirev.2024.108546.

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