C. R. Palevol 18 (2019) 465–478

Contents lists available at ScienceDirect

Comptes Rendus Palevol

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Human Palaeontology and Prehistory (Prehistoric Archaeology)

The open-air Paleolithic site of Mirak, northern edge of the Iranian Central Desert (Semnan, Iran): Evidence of repeated human occupations during the late Pleistocene

Le site paléolithique de plein air de Mirak, en bordure nord du désert central iranien (Semnan, Iran) : preuves d'occupations humaines successives pendant le Pléistocène supérieur

Hamed Vahdati Nasab[a,*,1], Gilles Berillon[b,*,1], Guillaume Jamet[c], Milad Hashemi[a], Mozhgan Jayez[d], Somaye Khaksar[e], Zohreh Anvari[f], Guillaume Guérin[g], Maryam Heydari[g], Mohammad Akhavan Kharazian[a,b], Simon Puaud[b], Stéphanie Bonilauri[b], Valéry Zeitoun[h], Noémie Sévêque[i], Javad Darvishi Khatooni[j], Asghar Asgari Khaneghah[k]

[a] *Department of Archaeology, Tarbiat Modares University, Tehran, Iran*
[b] *UMR7194 MNHN–CNRS–UPVD/Département Homme et Environnement, Musée de l'Homme, Palais de Chaillot, 75016 Paris, France*
[c] *GéoArchÉon/UMR CNRS 8591, Laboratoire de géographie physique, 75016 Meudon, France*
[d] *Research Institute of Cultural Heritage and Tourism (RICHT), Iranian Center for Archaeological Research (ICAR), Tehran, Iran*
[e] *Department of Anthropology, University of Minnesota, 55455 Minneapolis, USA*
[f] *Faculty of Social Sciences, University of Tehran, Tehran, Iran*
[g] *IRAMAT-CRP2A, Université Bordeaux Montaigne, Maison de l'Archéologie, Pessac, France*
[h] *UMR 7207, CR2P–CNRS–MNHN–Université Paris 6, Sorbonne Universités, Université Pierre-et-Marie-Curie, Paris, France*
[i] *Laboratoire Géosystèmes, UMR 8157 CNRS, Université Lille-1, Villeneuve-d'Ascq, France*
[j] *Geological Survey of Iran, Tehran, Iran*
[k] *Institute of Research and Social Studies, Faculty of Social Sciences, University of Tehran, Tehran, Iran*

ARTICLE INFO

Article history:
Received 18 December 2018
Accepted after revision 20 February 2019
Available online 22 April 2019

Handled by Marcel Otte

Keywords:
Iranian Central Desert
Middle and Upper Paleolithic
Mirak
Late Pleistocene
Semnan

ABSTRACT

The northern edge of the Iranian Central Desert has provided valuable evidence of terminal Pleistocene human settlements. Mirak constitutes one of the largest open-air lithic scatters in the region, consisting of eight natural mounds. Fieldwork was initiated in 2015 by the joint Iranian-French program at Mirak 8. Preliminary results have demonstrated at least three successive phases of human occupation during the MIS3: an upper layer with clear Upper Paleolithic affinities and a maximum age of 28 ky, a lower layer with clear Middle Paleolithic affinities that dates around 47 ky, and an intermediate layer with mixed characteristics that can be seen as an intermediate Paleolithic phase which dates between 28 ± 2 and 38 ± 2 ky. At the time when Upper Paleolithic cultures originated in the Zagros Mountains, cultures with clear Middle Paleolithic affinities persisted nearby along the northern edge of the Iranian Central Plateau.

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* Corresponding authors.
E-mail addresses: vahdati@modares.ac.ir (H.V. Nasab), gilles.berillon@mnhn.fr (G. Berillon).

[1] Hamed Vahdati Nasab and Gilles Berillon are both first authors.

https://doi.org/10.1016/j.crpv.2019.02.005
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Mots clés :
Désert central iranien
Paléolithique supérieur et moyen
Mirak
Pléistocène supérieur
Semnan

RÉSUMÉ

Le Nord du Désert central iranien fournit des preuves de présence humaine à la fin du Pléistocène. Mirak constitue l'une des plus grandes localités paléolithiques de plein air de la région, avec huit monticules naturels. En 2015, le programme conjoint franco-iranien a initié la fouille et l'étude pluridisciplinaire des dépôts et du matériel archéologique de Mirak 8. Les premiers résultats de trois saisons de fouilles indiquent la présence d'au moins trois phases successives d'occupation humaine pendant le MIS3 : un niveau supérieur d'affinités Paléolithique supérieur, avec un âge maximum de 28 ka, un niveau inférieur d'affinités Paléolithique moyen, autour de 47 ka, et un niveau intermédiaire avec des caractéristiques mixtes, vu comme un Paléolithique intermédiaire, daté entre 28 ± 2 et 38 ± 2 ka. À l'époque où les cultures du Paléolithique supérieur se sont différenciées dans le Zagros, des cultures avec des affinités Paléolithique moyen évidentes ont persisté juste à l'Est du Zagros, sur le pourtour nord du Plateau central iranien.

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1. Introduction

The wide area extending from the Zagros-Caucasus to Central Asia is historically acknowledged as a key region for understanding prehistoric human settlements, from the first human dispersal into Eurasia during the early Pleistocene to the upper Pleistocene (Zeitoun, 2016), including the transition from Middle Paleolithic to Upper Paleolithic cultures (e.g., Becerra-Valdivia et al., 2017; Coon, 1951; Heydari-Guran and Ghasidian, 2017; McBurney, 1964; Otte et al., 2009, 2011; Smith, 1986). However, despite the discoveries of numerous Paleolithic sites in this region and broad interest in the transition from Upper to Middle Paleolithic, to date, few archaeological assemblages have been obtained using accurate geological and chronological frameworks. These are mainly concentrated on the mountainous areas, especially the Zagros (Fig. 1) and dated to the MIS3 (see Becerra-Valdivia et al., 2017 for the current chronological framework). Some of them include: Shanidar (Solecki, 1955), Warwasi (Braidwood and Howe, 1961; Tsanova, 2013), Yafteh (Hole and Flannery, 1967; Otte et al., 2012), Gar Arjeneh (Hole and Flannery, 1967; Otte and Biglari, 2004), Ghar-e Khar (Shidrang et al., 2016; Young and Smith, 1966), Guilvaran and Kaldar (Bazgir et al., 2014, 2017; Roustaei et al., 2004), Ghār-e Boof (Ghasidian et al., 2017; Heydari et al., 2004). Other sites have been discovered in the Zagros and along its eastern fringes during the last decade. Most of these sites lack an adequate chronological framework, such as Mar-Tarik and Qaleh Bozi (Biglari, 2000; Biglari et al., 2009; Jaubert et al., 2008, 2009) as well as Zavyeh, Qaleh Gusheh and Holabad (Heydari-Guran et al., 2015). Several open-air sites have been discovered in the central Alborz and the northern edge of the Iranian Central Desert: the Upper Paleolithic site of Garm Roud (Berillon et al., 2007, 2016) dated to the end of the MIS3, and the surface sites of Mirak (Rezvani, 1990; Vahdati Nasab et al., 2013), Moghanak and Otchunak (Berillon et al., 2007; Chevrier et al., 2006, 2010), Delazian (Vahdati Nasab and Clark, 2014), and Chah-e Jam (Vahdati Nasab and Hashemi, 2016). The location and cultural affinities of these sites suggest that the northern fringes of the Iranian Central Desert could have constituted a corridor used during upper Pleistocene hunter-gatherer dispersals (Vahdati Nasab et al., 2013).

In that chronocultural context, our interest focused on the open-air site of Mirak, which is located 16 km to the south of the outskirts of the city of Semnan (Fig. 2). First mentioned by Rezvani (1990), Mirak was officially surveyed in 2009 by one of the authors (HVN) as part of the Paleolithic Survey of the Iranian Central Desert Project (PSICDP) (Rezvani and Vahdati Nasab, 2010). This survey collected a large lithic assemblage from the surface of eight natural mounds with evident Middle Paleolithic affinities (flake-based blank production, an abundance of prepared and *chapeau de gendarme* platforms, a significantly high value for the Levallois index, the presence of tools typical of 'Mousterian' technology). Only scarce artifacts with Upper Paleolithic affinities were found at the site, which suggests either the presence of Upper Paleolithic techno-complex and/or the presence of transitional lithic industries at the site (Vahdati Nasab et al., 2013). Mound 8, though not the largest mound in Mirak, exhibits the greatest volume of lithic scatters on its surface and surroundings. Moreover, the presence of relatively dense archaeological material visible in spoil heaps around one of the clandestine looters' pits suggests that some archaeological deposits of Middle and Upper Paleolithic affinities were still *in situ*, buried, and protected by the mound.

Based on the foregoing, there was a need for a systematic excavation in this vicinity. Based upon our preliminary observations, Mirak appeared to be potentially very informative. Therefore, three seasons of excavation at Mirak 8 were conducted under the framework of joint Iranian-French collaboration (May–June 2015, July–August 2016, and October–November 2017). The following presents the preliminary results of these excavations, concerning the nature of archaeological deposits at Mirak, their cultural affinities, and their geological and absolute chronological framework. Finally, these original data provide new perspectives with regards to the human settlements of the region during the MIS3.

2. Results and discussion

2.1. The excavation and finds

The excavations at Mirak 8 exposed an area covering 36 m^2 in total, divided between three main sectors (Fig. 3):

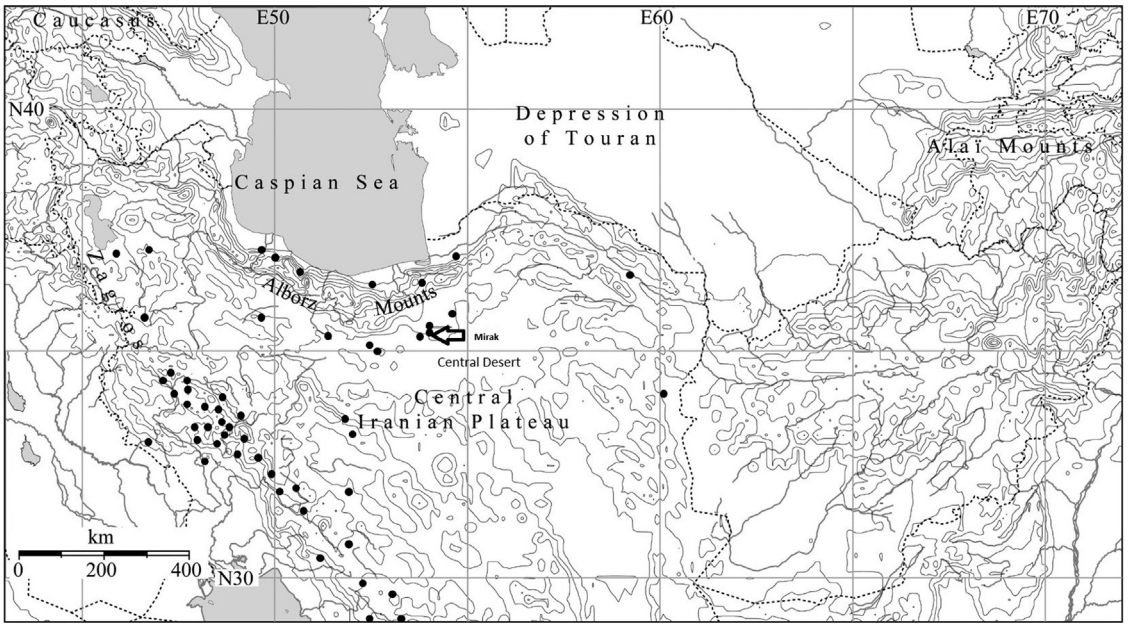


Fig. 1. Map of some of the major Paleolithic sites in the studied area.
Fig. 1. Carte des sites paléolithiques majeurs de la région d'étude.

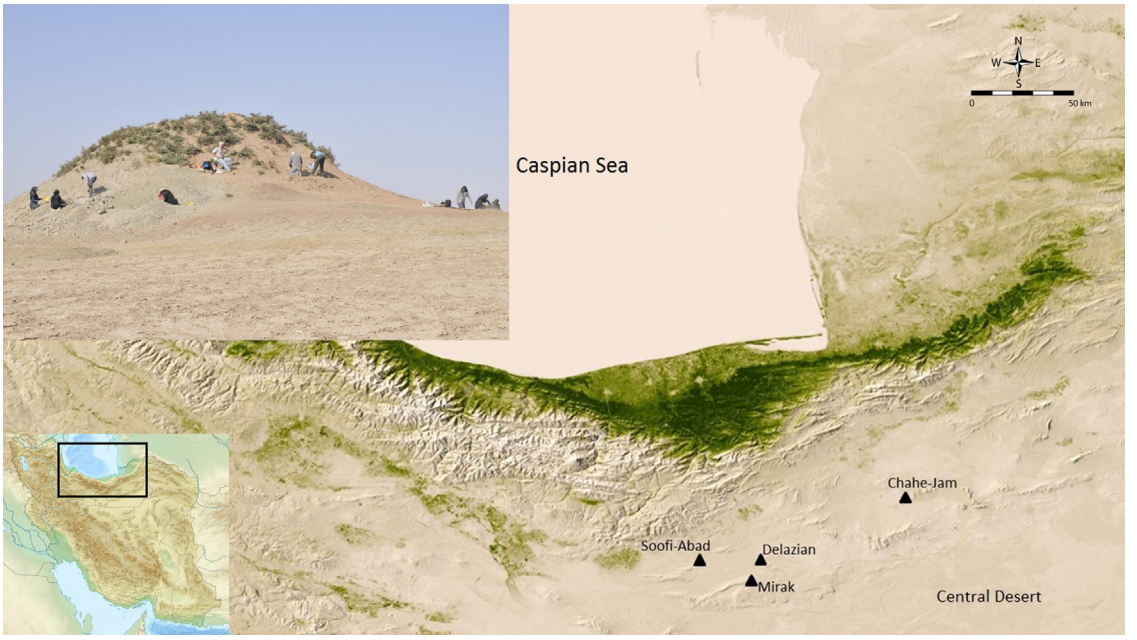


Fig. 2. Northern Iranian Central Desert and Mirak 8.
Fig. 2. Le Nord du Désert central iranien et la butte Mirak 8.

19 m^2 on the northern slope of the mound, 12 m^2 on the eastern slope and 5 m^2 on the southern one, delimited based on geoarchaeological prospecting. The excavation was carried out by squares with a surface area of 1 m^2 each, using both contextual and arbitrary level excavation techniques. The conventional depth of 5 cm was adopted for each arbitrary archaeological level, taking into account the depositional settings, and each excavated archaeological find was collected and referenced in the 3D frame of the mound. Dry and wet sievings of sediments were used when possible in order to sample micro-artifacts. The excavation exposed an excavated surface totaling 19 m^2 (north sector, 4 m^2; east sector, 10 m^2; south sector, 5 m^2).

The three campaigns of excavation yielded 6266 finds, including 2709 objects, precisely collected in the stratigraphic context and spread between 4 and 7 m below

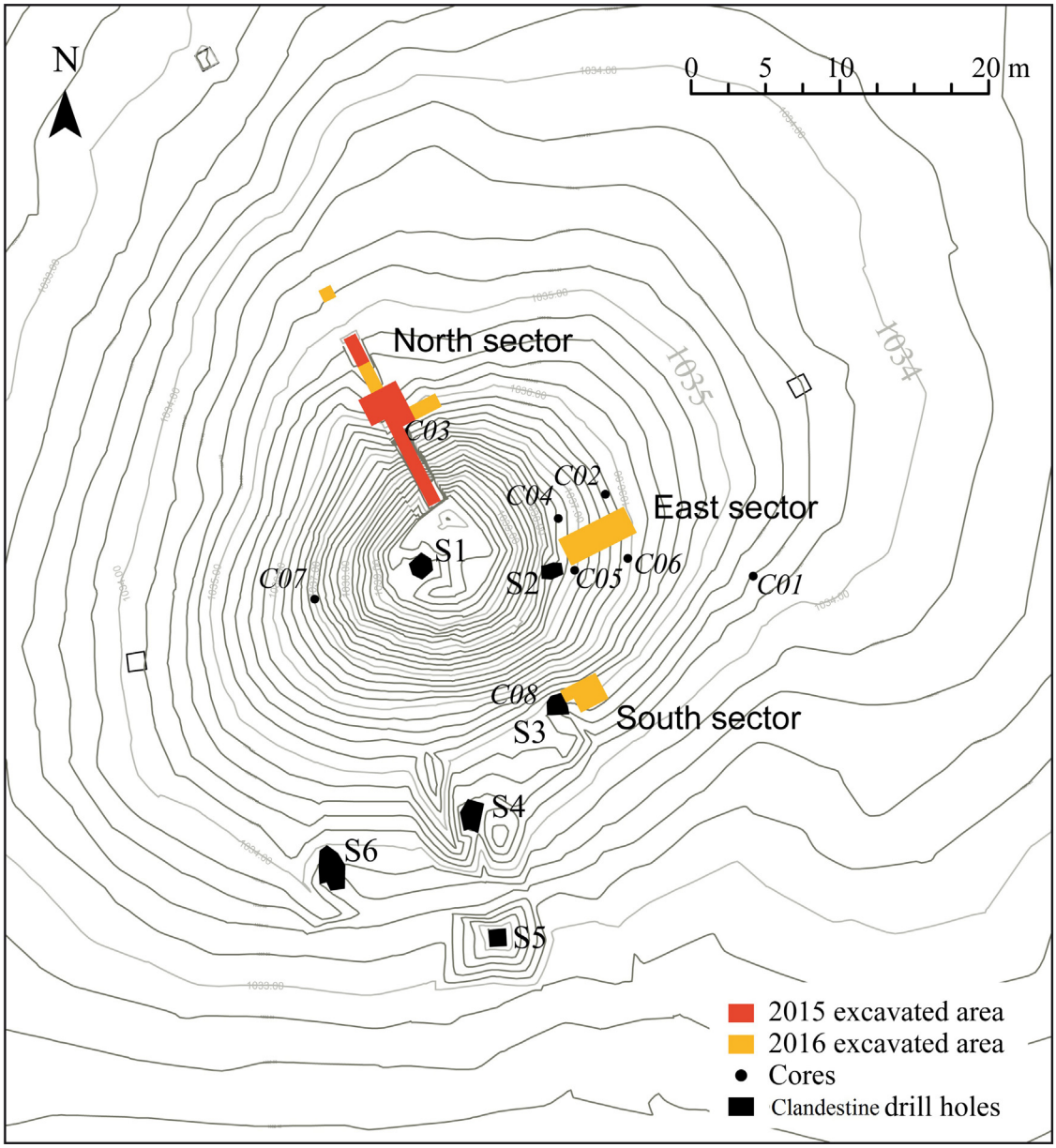


Fig. 3. Topographic map of Mirak 8.
Fig. 3. Carte topographique de Mirak 8.

the top of the stratigraphic sequence. These archaeological materials are mainly composed of lithic artifacts (see below), but rare and extremely altered fragments of bones and teeth of large mammals were also recovered; no sign of human intervention on these altered materials could be identified. The determinable teeth fragments belong to equids. No remains of small fauna were found either in excavation contexts or in the sieved sediments.

We focus here on the results of the excavation on the eastern trench, where the archaeological density appeared to be the highest. Three main successive archaeological concentrations were clearly identified in stratigraphic context (Layers 1–3) (Fig. 5).

2.2. Depositional setting and chrono-stratigraphic framework of Mirak 8

2.2.1. The Mirak stratigraphic sequence

Mirak is located in a dry mudflat (53°25'53" E; 35°28'10" N; ca. 1035 masl) that extends from Semnan's piedmont along the southern flank of the Alborz Mountains to the northern edge of the Iranian Central Desert, also known as *Dasht-e Kavir*. This area belongs to an elongated Quaternary drainage system, which is characterized by alluvial fans and sedimentary pediments, with widespread saline playa-lake systems downstream.

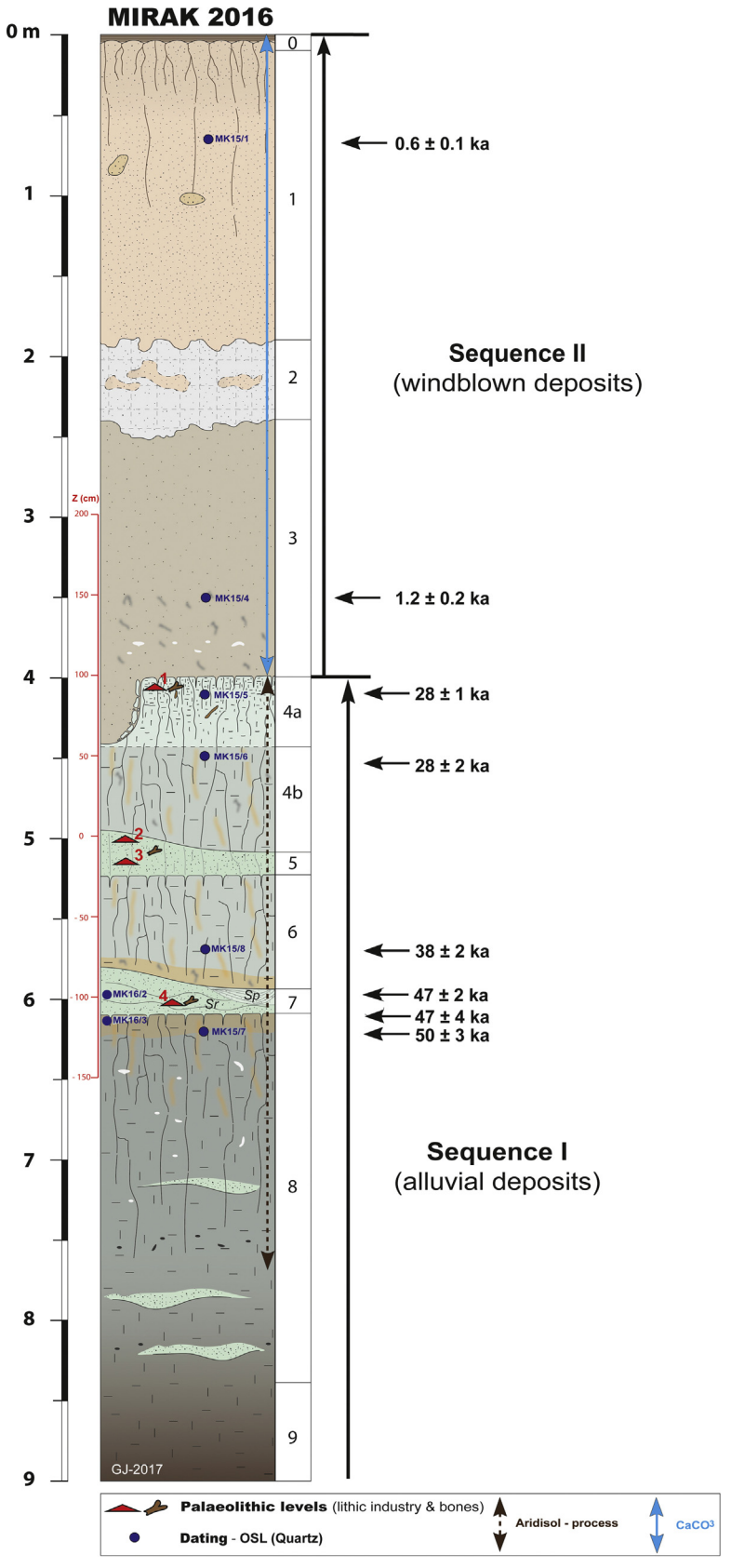

MIRAK 2016
0 m
1
2
3
4
5
6
7
8
9
Z (cm)
200
150
100
50
0
-50
-100
-150
MK15/1
MK15/4
MK15/5
MK15/6
MK15/8
MK16/2
MK16/3
MK15/7
0
1
2
3
4a
4b
5
6
7
8
9
0.6 ± 0.1 ka
1.2 ± 0.2 ka
28 ± 1 ka
28 ± 2 ka
38 ± 2 ka
47 ± 2 ka
47 ± 4 ka
50 ± 3 ka
Sequence II
(windblown deposits)
Sequence I
(alluvial deposits)
Sp
Sr
GJ-2017
Palaeolithic levels (lithic industry & bones)
Dating - OSL (Quartz)
Aridisol - process
CaCO3

Table 1
Summary of quartz OSL and feldspar post-IR IRSL data.
Tableau 1
Données OSL du quartz et post-IR IRSL du feldspath.

Sample	Quartz OSL					Feldspar post-IR IRSL			
	Depth[a] (m)	*n*	D_e (Gy)	Dose rate (Gy·ka^{-1})	Age (ka)	*n*	D_e (Gy)	Dose rate (Gy·ka^{-1})	Age (ka)
MK15/1	0.65	20	1.2 ± 0.2	2.18 ± 0.05	0.6 ± 0.1	15	4.4 ± 0.3	2.51 ± 0.07	1.7 ± 0.1
MK15/4	3.5	18	2.9 ± 0.4	2.39 ± 0.04	1.2 ± 0.2	15	7.6 ± 0.3	2.72 ± 0.07	2.8 ± 0.1
MK15/5	4.1	25	92 ± 4	3.29 ± 0.07	28 ± 1	15	118 ± 4	3.62 ± 0.09	32 ± 2
MK15/6	4.55	25	95 ± 6	3.37 ± 0.06	28 ± 2	14	116 ± 3	3.70 ± 0.08	31 ± 1
MK15/8	5.70[b]	25	135 ± 6	3.60 ± 0.05	38 ± 2	14	197 ± 4	3.93 ± 0.07	50 ± 2
MK15/7	6.2	25	159 ± 6	3.16 ± 0.09	50 ± 3	14	249 ± 9	3.49 ± 0.10	71 ± 4
MK16/2	−1.10	19	123 ± 4	2.63 ± 0.08	47 ± 2	15	193 ± 8	2.99 ± 0.08	65 ± 4
MK16/3	−1.18	20	156 ± 11	3.32 ± 0.10	47 ± 4	15	454 ± 52	3.68 ± 0.10	123 ± 17

Notes. 'D_e' is the average equivalent dose and 'n' is the number of the measured aliquots.
[a] Compared to the top of the stratigraphy.
[b] MK15/8, sampled in S2 at 4.60 m below the top of the S2 stratigraphy.

Geomorphological fieldwork has revealed a pedo-sedimentary succession represented by a 9-m-thick alluvial-aeolian record made up of two main sequences (Sequence I: alluvial basal complex; Sequence II: wind-blown deposits) (see Fig. 4 for the synthetic stratigraphy and description). Sequence I can be divided into six lithostratigraphic units from the base upwards (Units 9-4; thickness: ca. 5 m). Horizontal bedding of silty clays (Units 8, 6 and 4) were observed in the stratigraphy. This stratigraphic column also includes at least two bodies of very fine sands (Units 7 and 5) and a deflated horizon (Unit 4a); these three units contain the three main archaeological assemblages (3 to 1 respectively). Sequence I accumulated on a pediplain that was flooded repeatedly as a consequence of shallow sheet flooding and channel overflows. Indeed, horizontal bedding prevails in the very fine sand units (Units 7 and 5), but current ripple marks and internal planar cross bedding occur as well (lithofacies Sr and Sp according to Miall 1996). The whole units are distinguished by intense post-depositional weathering, resulting both from the repetition of decreases in the level of the water table and increases in the rate of evaporation, as evidenced by Fe–Mn concretions, iron hydroxide precipitates, calcareous nodules, gypsum crystals, and desiccation cracks. These features are associated with the development of 'Aridisol horizons' (Bk, By) (USDA, Soil Survey Staff, 2014). The upper limit of this alluvial pedocomplex is marked by a major discontinuity, which corresponds to the contemporary deflation surface of *Dasht-e Kavir*. Sequence II of Mirak 8 mound can be divided into four lithostratigraphic units from the base upwards (Units 3–0; thickness: about 4 m). The first part of this sequence consists of calcareous aeolian sand deposits (Unit 3) reworked by a hydromorphic horizon (Unit 2) topward. The uppermost part of Sequence II is composed of another aeolian sand deposit (Units 1 and 0) affected by the development of an entisol (USDA).

2.2.2. *Luminescence dating*

Samples for luminescence dating were collected: six samples were taken from the northern section of Sequences I and II and two samples from the lower part of the eastern section of Sequence I. Preliminary dating results, including analytical data, are listed in Table 1 and plotted in their stratigraphic position in Fig. 4 (see also Supplementary Material for details on the implemented procedure). OSL and post-IR IRSL measurements were performed on multi-grain aliquots (see SM for methodological details). Overall, the OSL ages are coherent with the stratigraphy and the inter-aliquot dispersion in equivalent doses for each sample is very low; this allows us to consider the OSL ages to provide accurate, reliable ages. As a result, the ages range from 50 ± 3 to 28 ± 2 ka in the Sequence I that contains the three primary archaeological deposits, with a maximum age of 28 ± 2 ka for Layer 1, dates between 28 ± 2 and 38 ± 2

Fig. 4. Synthetic stratigraphy of Mirak 8 in 2016 and location of the OSL/IRSL dating. 0. Topsoil with platy structure (*vegetalized surface of the mound*). 1. Light brown sandy silt with massive structure (*entisol developed on calcareous windblown deposits*). 2. Convoluted light-grey sandy silt including lenses of reworked wind-blown deposits (unit 1) (*hydromorphic horizon*). 3. Brown clayey silt with massive structure (*calcareous windblown deposits*). 4a. Pale green silty clay with polyhedral structure (*non-calcareous floodplain fines–hydromorphic horizon*). 4b and 6. Greyish green silty clay with prismatic structure and Fe–Mn oxide coatings (*non-calcareous floodplain fines*). 5 and 7. Pale green silty sand with current ripples (Sr) and internal planar crossbedding (Sp) (*shallow water deposits and minor channel fills*). 8. Dark greyish green silty clay with prismatic structure including Fe–Mn oxide coatings, very fine sands and small pebbles of grey sandstone (*non-calcareous floodplain fines and crevasse splay deposits*). 9. Dark brown silty clay (Sketch by G. Jamet). This synthetic stratigraphy was built up on the basis of the correlation between three vertical sections (North, East & South trenches) and 14 sediment logs from Auger surveys and clandestine holes.
Fig. 4. Stratigraphie synthétique de Mirak 8 (2016) et localisation des âges OSL/IRSL. 0. Sol arable à structure plate (surface végétalisée de la bute). 1. Silt sableux brun clair à structure massive (entisol développé sur des dépôts calcaires soufflés par le vent). 2. Silt sableux gris clair convoluté comprenant des lentilles de dépôts remaniés par le vent (unité 1) (horizon hydromorphique). 3. Silt argileux brun à structure massive (dépôts calcaires éoliens). 4a. Argile silteuse vert pâle à structure polyédrique. 4b et 6. Argile silteuse vert grisâtre à structure prismatique et revêtements d'oxyde de Fe–Mn. 5 et 7. Sable silteux vert pâle avec des ondulations de courant (Sr) et lits entrecroisés planaires internes (Sp) (dépôts d'eau peu profonde et remplissages mineurs de chenaux). 8. Argile silteuse vert grisâtre foncé, à structure prismatique, comprenant des revêtements d'oxyde de Fe–Mn, du sable très fin et de petits cailloux de grès gris (dépôts fins et craquelés non calcaires de plaine d'inondation). 9. Argile limoneuse brun foncé (dessin de G. Jamet). Cette stratigraphie synthétique a été construite sur la base de la corrélation entre trois sections verticales (tranchées nord, est et sud) et 14 diagraphies sédimentaires provenant de levés à la tarière et de sondages clandestins.

for Layer 2, dates between 47 ± 2 ka and 47 ± 4 ka for Layer 3 (samples MK 16/2 and MK16/3), which correspond to the Last Glacial cycle. The ages range from 1.2 ± 0.2 to 0.6 ± 0.1 ka in Sequence II.

2.2.3. Formation of the mound of Mirak 8 and context of archaeological deposits

Based on the available data, it seems that Sequence I at Mirak Mound 8 may have formed as a response to climatic changes during the first half of the Last Glacial (probably during MIS 3), which was more humid than the Upper Pleniglacial (MIS 2 age equivalent). The records of these transitional periods are less well understood in the context of the northern Iranian paleoclimatic and chronostratigraphic framework for the Last Interglacial/Glacial cycle (*i.e.* the Lake Urmia core: Djamali et al., 2008; loess records of North of Iran: Kehl et al., 2005 and Frechen et al., 2009). Human occupations at Mirak were contemporaneous with the aggradation of a covered pediment incised by anastomosed channels. This period was apparently characterized by rapid flooding events (*i.e.* sheet flood or crevasse splay deposits) that buried Paleolithic deposits. If the increase in rainfall events explains the accumulation of sediments deposited during flash floods, we do not exclude the influence of episodic uplift upstream, as pointed out by Kehl (2009). Nevertheless, no stratigraphic evidence of tectonic effect has been observed. Aggradation of the alluvial cover ended with a major aridification marked by an aridisol development, perhaps indicating the end of the Last Glacial period. The scenario of a long-term drying coincided with a sedimentary hiatus, between the units 4 and 3, which separated the Pleistocene desiccated flat from the Holocene sand dune (sequence II). The Holocene history of Mirak is defined by at least two phases of calcareous dust deposits interrupted by the temporary development of a perched water body on the first aeolian mound. The formation of this hydromorphic horizon (Unit 2) in arid environment implies a groundwater flux from the bedrock and its resurgence by a perched spring.

The study of the excavated sediments evidently indicates that, in contrast to the current arid desert situation, the northern part of the Iranian Central Desert, at least for the studied region, had a completely different climate during the end of the Pleistocene. During the first half of the Last Glacial Period (MIS 4/3) the climate of the region was cold and humid. This cold and humid period was characterized by a slow alluvial aggradation interrupted by rapid flooding events. Two of the archaeological layers at Mirak 8 are dated to the chronological interval between 50 ± 3 ka and 28 ± 2 ka, which corresponds to these humid climate conditions. Moreover, the different nature of the sediments of the archaeological layers in comparison to the upper and lower sterile sediments implies that, during each of these occupational events (which might have lasted hundreds of years), the site was situated on dry land, possibly surrounded by streams and marshes. Concerning the Holocene sequence (Sequence 2 in Mirak 8), the current study of Mirak 8 demonstrates that the mounds in Mirak cannot be seen as remnants of a more extensive deposit that has been eroded away, but correspond to Holocene nebkha or shadow dunes. In Mirak 8, it results in at least two phases of calcareous dust deposits interrupted by the temporary development of a perched water body on the first aeolian mound. The two OSL ages derived from the very top of the mound (MK15/1: 0.6 ± 0.1ka) and where the mound meets the flatland area around it (MK15/4: 1.2 ± 0.2 ka) indicate that the formation of the mound of Mirak 8 took approximately 800–1600 years. Therefore, the mounds of the site were formed at a relative rapid pace. As mentioned above, such hydromorphic horizon in arid environment implies a groundwater flux from the bedrock and its resurgence by a perched spring. In that general pattern of dune formation, the vegetation may have played an important role in the formation of the mound by fixing the calcareous sands and consequently the preservation of the underlying Pleistocene sequence, as originally proposed by Vahdati Nasab et al. (2013).

2.3. Lithics and cultural affinities

2.3.1. The lithic assemblage

The lithic assemblage presented here consists of 2313 pieces from the easternmost excavation at Mirak 8. More than 85% of these artifacts are made of varieties of chert (i.e. chert, flint, and jasper). Other raw materials are tuff, sandstone, siltstone, and rarely, microconglomerate. Within this assemblage, 976 pieces are typologically indeterminable fragments or splinters, most of which have very small dimensions; their techno-typological identification is problematic, if not impossible (see Jayez and Vahdati Nasab, 2016) for the morphological characteristics of what is considered “indeterminable”). These pieces have been excluded from our analysis, which leaves 1337 chipped stones to present, including 212 chips (Table 2), which are flakes mostly with dimensions of less than 1 cm (see Shea, 2013: 32).

The three identified levels occurred in distinct stratigraphic units, although some vertical dispersion are observed within each level that may be related to some taphonomic agents (work in progress) (Fig. 5); however, the general state of preservation of the lithics is very good, which testifies to the fact that, if taphonomy has impacted the deposits, the impact has been limited. In that respect, Level 1 appears to occur in a deflated unit; this may explain the wider dispersion and lower density in objects than those observed for levels 2 and 3. In addition, few artefacts were located between these three main archaeological deposits, usually in whole roots or vertical brakes. Apart these very few pieces (around 30 among 2313 artefacts), the artefacts appear to depict three main archaeological deposits.

The L1 lithic assemblage appears to be an industry oriented toward a blade/bladelet production from at least carinated elements. No cores have been found and other tool types are underrepresented. Carinated burins are found exclusively in L1 (Fig. 6: 1–3), which are usually found in the so-called “Zagros Aurignacian” (see: Olszewski and Dibble, 1994, 2002) or “Baradostian” (see: Olszewski, 1993; Solecki, 1958) techno-complexes. The characteristic artifact-types of this assemblage include blades, bladelets, and their associated fragments (Fig. 6:4), although Arjeneh (Font-Yves) points and *lamelles Dufour*

Table 2
Technological structure of the Mirak chipped stone assemblage (L = Layer; Lithic density = total quantity of chipped stones/excavated volume in m^3).
Tableau 2
Structure technologique de l'assemblage de pierres concassées de Mirak (L = couche ; Lithic density = quantité totale de pierres concassées/volume extrait en m^3).

	L1	%	L2	%	L3	%	Sum
Core and frags	0	**0**	12	**1.8**	27	**4.2**	39
Tools	10	**18.2**	121	**18.7**	225	**35.5**	356
Debris	0	**0**	13	**2**	12	**1.9**	25
Debitage	45	**81.8**	502	**77.5**	370	**58.4**	917
Sum	**55**	**100**	**648**	**100**	**634**	**100**	**1337**
+Indeterminable Fragments	13		496		467		976
Lithic density	9.5		101.7		237.8		100.3

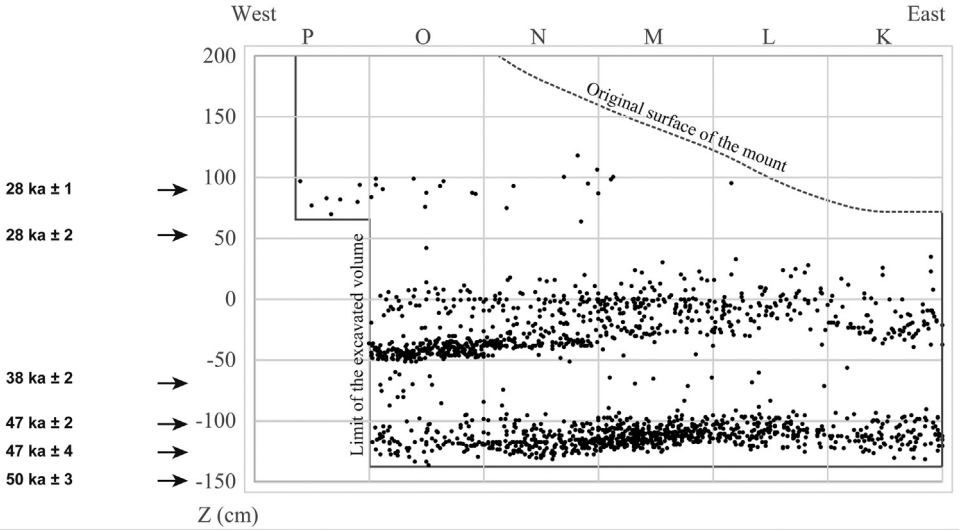


Fig. 5. Mirak 8. Vertical distribution of the archaeological finds, eastern sector; pecks of high density (black arrows). The projection of finds in the east–west vertical plane highlights the three main archaeological concentrations observed during the excavation. They represent a sub-horizontal slope, with a slight dip upwards near the periphery of the mound. The upper assemblage depth (L1) is around 100 ± 20 cm above the reference level. The intermediate assemblage (L2) is the thickest, with a depth around 20 ± 30 cm below the reference level. The basal assemblage (L3) is around 115 ± 12 cm below the reference level.
Fig. 5. Mirak 8. Distribution verticale des objets archéologiques, secteur est ; pics de densité (flèches noires). La projection des objets dans le plan vertical est–ouest met en évidence les trois principales concentrations archéologiques observées lors des fouilles. Subhorizontale, vers l'ouest, elles présentent un léger pendage vers le haut près de la périphérie du monticule. L'assemblage supérieur (L1) est à environ 100 ± 20 cm au-dessus du niveau de référence. L'assemblage intermédiaire (L2) est le plus épais, à une profondeur d'environ 20 ± 30 cm en dessous du niveau de référence, au centre de la butte (lignes O & P). L'assemblage profond (L3) est à environ 115 ± 12 cm sous le niveau de référence.

as major components of both central Zagros and southern Zagros Upper Paleolithic lithic industries (see Conard and Ghasidian, 2011; Ghasidian et al., 2017; Hole, 1970; Hole and Flannery, 1967; Otte et al., 2007) are not observed in the current assemblage of Mirak. Among the platform rejuvenation flakes in this assemblage is one large core tablet (Fig. 6: 5) that indicates the large dimensions of prismatic cores from which the blades were produced. Finally, Levallois–Mousterian tools are completely absent in this layer. As a whole, this layer shows Upper Paleolithic affinities. However, this assessment must be taken with caution; indeed, the density of artifacts is low (see Table 2) and the assemblage was preserved in a deflated horizon and thus may not be fully representative of the original one.

The L2 lithic assemblage is characterized by the mixed presence of Upper Paleolithic industries with characteristics of prismatic blade/bladelet production and Levallois–Mousterian flake-based production, the technological structure of which shows also a moderate percentage of cores and tools (Table 2). Few blades and bladelets are either plain or regularly retouched or notched (Table 4, Fig. 7: 4–5). Semi-parallel arrises (flake scar ridges) are present on the dorsal face of some blades (Fig. 7: 3). The Mousterian industry artifact types are dominated by the Levallois technique (for Mousterian artifact-types see, e.g., Geneste, 1985). They mostly indicate recurrent reduction strategy with radial/centripetal preparation (Fig. 7:6). Levallois flakes with facetted and *chapeau de gendarme* platforms are present as well as the byproducts of Levallois reduction strategy in the form of core preparation elements. Bladelets and some of the blades have been made via the prismatic reduction method. It is worth mentioning that Levallois blade cores are rare in the Mirak assemblage. Regarding the tools (Table 4), among the interesting specimens is one elongated convergent blade with facetted striking platform and inverse

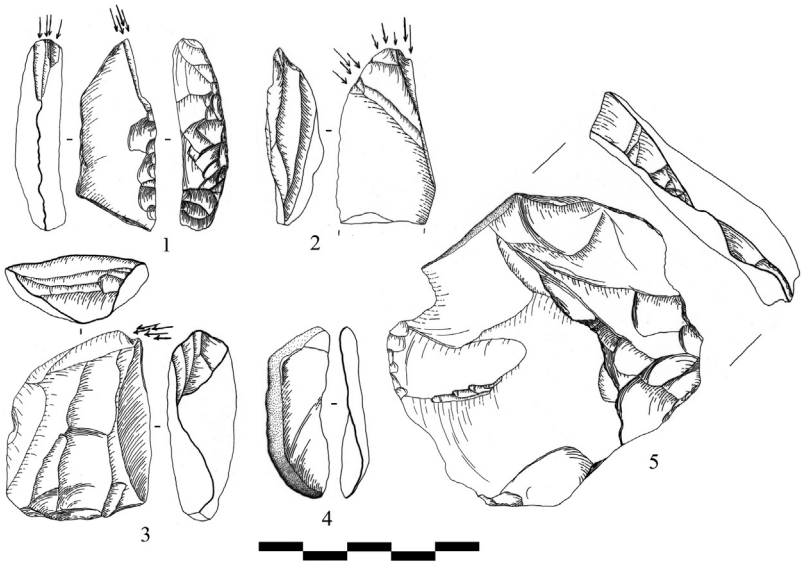


Fig. 6. Lithic artifacts from L1. 1–3. Carinated burin. Twisted blade. 5. Core tablet (drawings by M. Jayez).
Fig. 6. Industrie lithique de L1. 1–3. Burins carénés. 4. Lame torse. 5. Tablette (dessins de M. Jayez).

notching/retouching (Fig. 7: 1). As a whole, Layer 2 appears to present a mix of characteristics usually associated with both Upper and Middle Paleolithic industries.

In L3, cores and tools are well represented (twice as much as in upper layers). Most of the cores are Levallois cores (Fig. 8: 11). If the debitage composition of the layers is considered, L3 lithic assemblage, with less than 5% blade and bladelet products, indicates an industry based on flake production, a number of them being relatively elongated (Table 3). This assemblage includes Mousterian industry artifact types similar to L2 with the dominance of Levallois technique with mostly recurrent reduction strategy with radial/centripetal preparation. Regarding the tools (Table 4), Levallois–Mousterian tools such as various scrapers (Fig. 8: 8, 10) are present in high quantity in L3 as well as some points (Fig. 8: 2, 5–7); they are comparable to those found in the Zagros Mousterian (see Dibble, 1993; Dibble and Holdaway, 1993; Lindly, 1997). Some tools have basal trimming, which might be attributed to the hafting methods (Fig. 8: 1, 8). There are also Levallois points with retouch on both faces and facetted striking platform (Fig. 7: 9). As a whole, L3 has clear Middle Paleolithic affinities.

However, the vertical distribution and field data (such as post-depositional reworking) shows that some pieces cannot be precisely allocated to Layers 2 or 3; among these pieces, one carinated scraper as well as a prismatic core (Fig. 8: 3), here vertical between L2 and L3 respectively, are usually considered as a typical implement of Upper Paleolithic industry of Baradostian/Zagros Aurignacian (see Olszewski and Dibble, 2006; Otte et al., 2007).

2.3.2. *Phases of human occupation*

In contrast to what has been claimed previously about the Middle Paleolithic affinities based on the study of the surface collection of the lithic industries in Mirak (Rezvani and Vahdati Nasab, 2010; Vahdati Nasab et al., 2013), the data derived from the three seasons of excavations at Mirak 8 has clearly identified the presence of vestiges of at least three main archaeological layers.

The upper layer, i.e. L1, has clear Upper Paleolithic affinities, with some resemblance (carinated burins) with the so-called "Zagros Aurignacian" (Olszewski and Dibble, 1994, 2002) or "Baradostian" (Olszewski, 1993; Solecki, 1958) techno-complexes. Yet Arjeneh (Font-Yves) points and *lamelles Dufour* as major components of both central Zagros and southern Zagros Upper Paleolithic lithic industry (see Conard and Ghasidian, 2011; Ghasidian et al., 2017; Hole, 1970; Hole and Flannery, 1967; Otte et al., 2007) are not observed in the current assemblage of Mirak; if confirmed, Mirak would more closely resemble Garm Roud, which dates back to around 33 kya (Berillon et al., 2007, 2016; Chevrier et al., 2006). However, the low density of artifacts in L1 and its evident reworked nature does not allow a precise determination of this upper assemblage and needs caution in its interpretation. The Upper Paleolithic affinities are consistent with the OSL dating, which gives a maximum age of 28 ± 2 kya, and with the presence of a large Upper Paleolithic open-air site, i.e. Delazian, at a very close proximity (2 km northeast of Mirak, see Vahdati Nasab and Clark, 2014).

The lower layer, i.e. L3, has clear Middle Paleolithic affinities; with regards to Levallois–Mousterian tools (various scrapers and points); the assemblage is comparable to those of classical Zagros Mousterian sites (see Dibble, 1993; Dibble and Holdaway, 1993; Lindly, 1997). Interestingly, this assemblage dates between 47 ± 2 kya and 47 ± 4 kya, which, although compatible with the general chronological framework of Middle Paleolithic assemblages in the Middle East, appears very recent compared to the Middle Paleolithic known in the Zagros, and earlier than the early Upper Paleolithic assemblages of the Zagros (Becerra-Valdivia et al., 2017).

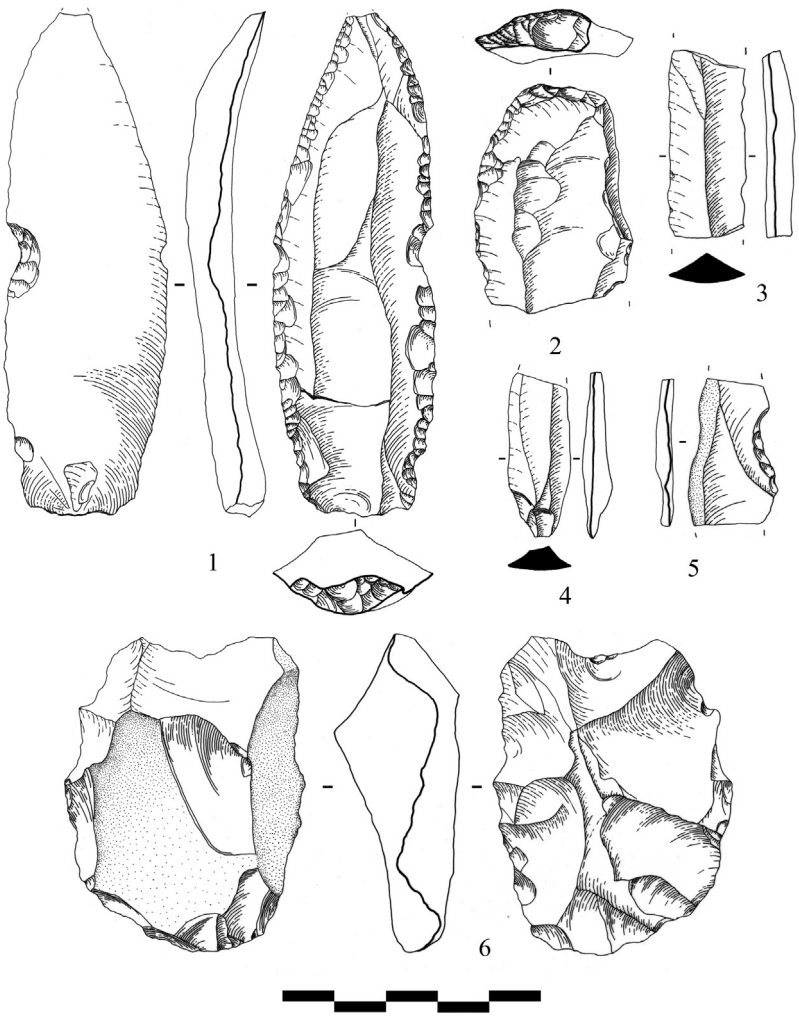


Fig. 7. Lithic artifacts from L2. 1. Mousterian point on a blade. 2. End scraper. 3–4. Bladelet fragments. 5. Notched blade fragment. 6. Recurrent centripetal flake core (drawings by M. Jayez).
Fig. 7. Industrie lithique de L2. 1. Pointe moustérienne sur lame. 2. Grattoir terminal. 3–4. Fragments de lamelle. 5. Fragment de lame avec encoche. 6. Nucléus récurrent, centripète à éclats (dessins de M. Jayez).

Table 3
Debitage composition of the Mirak chipped stone assemblage (L = Layer).
Tableau 3
Composition de débitage de l'assemblage de pierre écaillée de Mirak (L = couche).

Debitage	L1	%	L2	%	L3	%	Sum
Bladelets and fragments	4	8.9	21	4.2	4	1.1	29
Blades and fragments	3	6.7	41	8.2	15	4.1	59
Flakes and fragments	33	73.3	326	64.9	258	69.7	617
Chips	5	11.1	114	22.7	93	25.1	212
Sum	**45**	**100**	**502**	**100**	**370**	**100**	**917**

The intermediate layer, i.e. L2, might be the most controversial one, representing a mixture of industries with both Middle and Upper Paleolithic affinities, in a chronological framework that dates it to between 28 ± 2 and 38 ± 2 kya. Based on this preliminary chronological framework, L2 appears possibly contemporary of the early Upper Paleolithic of the Zagros (Becerra-Valdivia et al., 2017), where facetted platforms or sidescrapers have been identified (e.g., Tsanova, 2013). However, more studies are ongoing, including the technotypology of the intermediate layer, as well as a refined chronology based on recent OSL samples that should allow us refining our understanding of the nature, the chronology and the context of this intermediate human occupations at Mirak. However, to our knowledge, despite some potential resemblances with the early Upper Paleolithic of the Zagros, such mixture of industries has no

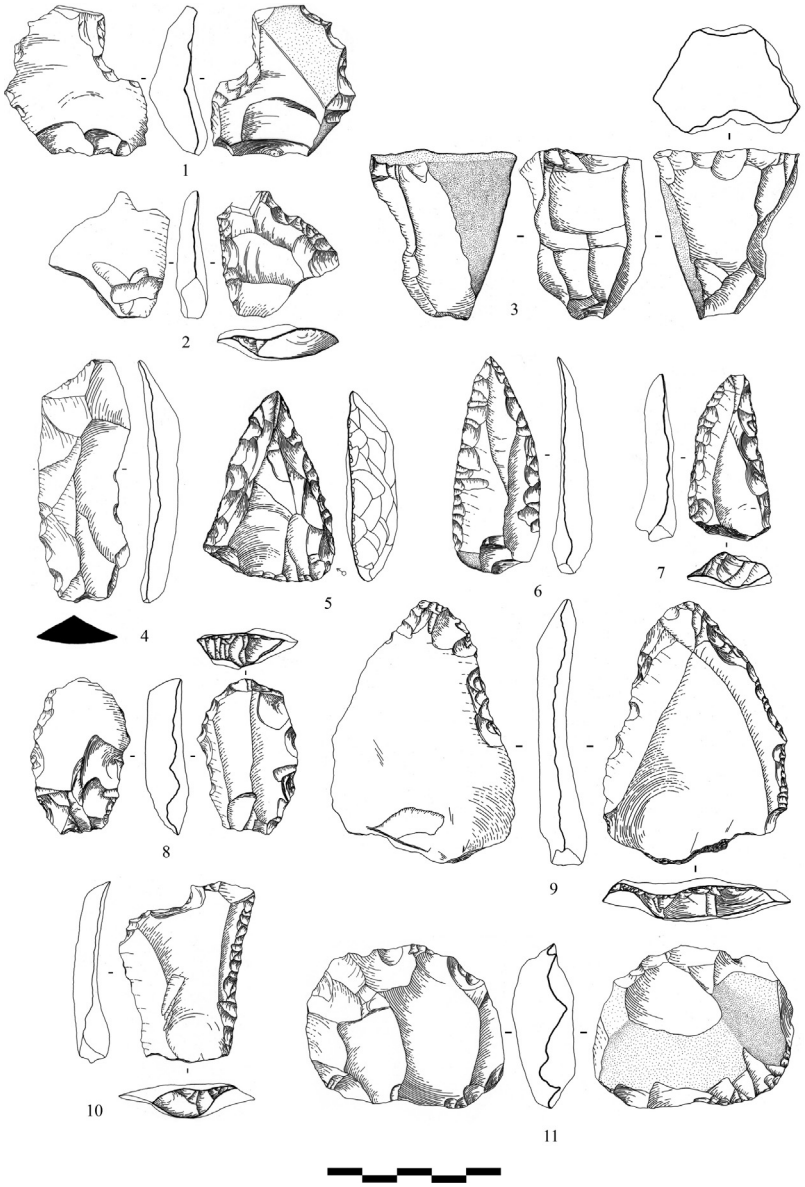


Fig. 8. Lithic artifacts from L3. 1. Notch-denticulated. 2. Convergent point/scraper? 3. Prismatic core (L2–L3). 4. Levallois blade. 5. Déjeté point. 6–7. Mousterian point on elongated flake. 8. End scraper with basal trimming on the ventral face. 9. Levallois point. 10. Side scraper and notched. 11. Levallois flake core (drawings by M. Jayez).
Fig. 8. Industrie lithique de L3. 1. Denticulé. 2. Pointe/grattoir ? convergent 3. Nucléus prismatique (L2–L3). 4. Lame Levallois. 5. Pointe déjetée. 6–7. Pointes moustériennes sur éclat allongé. 8. Grattoir terminal avec retouche basale sur la face ventrale. 9. Pointe Levallois. 10. Grattoir latéral et à encoche. 11. Nucléus Levallois à éclat (dessins de M. Jayez).

equivalent to date within the regional context of the Iranian Central Plateau, and together with its chronological framework points the complexity of the cultural evolution in a wide area between Zagros and Central Asia.

Finally, beside this general pattern, a carinated scraper and a prismatic core, which are typical of the Baradostian/Zagros Aurignacian (see Olszewski and Dibble, 2006; Otte et al., 2007), have been collected between the lowest layers (L2 and L3) and could not be allocated precisely to one of these levels. Although, as mentioned above, this may be related to some post-depositional reworking based on field data and vertical distribution, this points to the originality of the lithic industries of Mirak, and one cannot exclude some potential affinities of the Mirak's lower lithic assemblages with early Upper Paleolithic or late Middle Paleolithic cultures of the Zagros. Further analysis of the lithic assemblage will address these potential affinities.

3. Conclusion

In summary, Mirak provides unique data in the area between the Zagros and Central Asia, depicting successive

Table 4
Tools composition of the Mirak chipped stone assemblage (L = layer).
Tableau 4
Composition des outils de l'assemblage en pierre taillée de Mirak (L = couche).

Tool type	L1	%	L2	%	L3	%	Sum	%
Flake tools								
Multiple tools	**1**	**10**	**5**	**4.1**	**13**	**5.8**	**19**	**5.3**
Scraper and notched	0		5		12		17	
Scraper and burin	0		0		1		1	
Scraper and carinated burin	1		0		0		1	
Retouched	**3**	**30**	**30**	**24.8**	**56**	**24.9**	**89**	**25.0**
Burin	**2**	**20**	**1**	**0.8**	**3**	**1.3**	**6**	**1.7**
Simple	0		0		3		3	
Transverse	0		1		0		1	
Carinated	2		0		0		2	
Notch-Denticulated	**2**	**20**	**17**	**14**	**37**	**16.4**	**56**	**15.7**
Scraper	**2**	**20**	**37**	**30.6**	**89**	**39.6**	**128**	**36.0**
Double	1		3		13		17	
Side	1		19		50		70	
End	0		9		6		15	
Convergent	0		6		11		17	
Déjeté	0		0		5		5	
Round	0		0		2		2	
Carinated	0		0		1		1	
Transverse	0		0		1		1	
Point	**0**	**0**	**9**	**7.5**	**6**	**2.7**	**15**	**4.2**
Levallois	0		3		2		5	
Mousterian	0		6		3		9	
Déjeté	0		0		1		1	
Blade Tools	**0**	**0**	**16**	**13.2**	**17**	**7.5**	**33**	**9.3**
Notched/denticulate blade	0		5		3		8	2.2
Point on blade	0		0		2		2	0.6
Retouched blade	0		8		7		15	4.2
Scraper on blade	0		2		4		6	1.7
Naturally backed knife	0		1		1		2	0.6
Other tools	**0**	**0**	**6**	**5**	**4**	**1.8**	**10**	**2.8**
Sum	**10**	**100**	**121**	**100**	**225**	**100**	**356**	**100**

phases of human occupation in the Iranian Central Plateau during the late Pleistocene, anchored in a precise geological and chronological framework, in contrast to previous studies, which had relied solely on surface finds. Although caution is needed, from the lithics analysis and the distribution of the finds, at least three main archaeological layers can be identified in Mirak 8. These layers appear to be culturally and chronologically distinct, corresponding to at least three main phases of human occupation. The upper layer (L1) with a maximum age of 28 kya, shows some Upper Paleolithic affinities, although poorly preserved. The intermediate layer (L2) indicates characteristics similar to both Upper and Middle Paleolithic industries that can be seen as an intermediate Paleolithic and dates between 28 ± 2 and 38 ± 2 kya; it appears very original in the context of the Iranian Central Plateau. The lower layer (L3) has clear Middle Paleolithic affinities and dates back to around 47 kya; it would represent a very recent Middle Paleolithic industry compared to what is known in the area. Although further investigations are needed and in progress, Mirak industries point to the complexity of the cultural evolution in a wide area between Zagros and Central Asia.

Acknowledgments

We would like to thank the Research Center for Cultural Heritage and Tourism of Iran (RICHT) and the Iranian Center for Archaeological Research (ICAR) for granting us the permission to conduct the fieldworks at the site. We also would like to express our great gratitude to Mr. Jalil Golshan at the RICHT for his tremendous support during the three seasons of the field missions. We thank the Office of International Affairs at the RICHT for facilitating the process of visa for the non-Iranian partners of the project. We are greatly indebted to Mr. Khajeh Beidokhti, the director of the Iranian Cultural Heritage Organization (ICHO) office in Semnan Province and his colleagues for providing such ideal conditions to conduct the fieldwork. The fieldwork and geological analyses have been cofounded by the office of governor of Semnan (Dr. Khabbaz and his deputy Mr. Zandieh Vakil), the French Ministry of Europe and Foreign Affair (MEAE) and the UMR 7194 CNRS–MNHN–UPVD (Paris); we are very grateful to them. The luminescence dating study was conducted thanks to financial support from the French National Research Agency via the LaScArBx Labex (Project number ANR-10-LABX-52). We would also like to thank Patrick August for his help in identification of the fauna remains. Mr. Hassan Rezvani, the discoverer of Mirak, generously allowed us to conduct field research there. We are grateful to Mr. Soroush Hashemi, and Kamran Shojaee at the ICHO office in Semnan for their magnificent logistical support. Dr. Kourosh Mohammadkhani assisted us in geomagnetic fieldwork. Dr. Razieh Lak, Research Deputy at the Geological Survey of Iran and Mr. Habib Poorfaraj, who was in charge of the raw material sourcing, we thank all of them. We are grateful to Mr. Iraj

Beheshti at the Iranian Centre for Preservation and Restoration, for his help in identifying the raw material types. We would like to thank Kyle G. Olson for his help in editing the final manuscript. Contributions of co-authors: responsibilities (HVN, GB, AAK), lithics analysis (MiH, MJ, SB), fauna (NS, ZA), geology (GJ, MAK), chronology (GG, MaH), spatial distribution (GB and MiH), design (HVN, GB), and writing of the manuscript (all).

Special thanks go to the field crew in alphabetical order: Alieh Abdollahi, Mahkameh Abolfathi, Laya Alinia, Benoit Chevrier, Nasim Feizi, Mahyar Khademi, Ashghar Nateghi, Mona Oryat, Soroush Razi, Robabeh Sadeghinejad, Yashar Sadeghi, Sanaz Shirvani, Mohammad Javad Shoaee, and Marzieh Zareh Khalili.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.crpv.2019.02.005.

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