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The Quaternary sequence of the Nahr el Kebir, NW Syria: An important repository for evidence of Palaeolithic occupation and landscape evolution in the eastern Mediterranean

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ABSTRACT

The third largest river in Syria, the Nahr el Kebir has a well-preserved record of river-terrace deposits that have produced substantial Palaeolithic artefact assemblages both from within the terrace deposits and from the land surfaces above and around them. At the Mediterranean coastline, the fluvial gravels interdigitate with raised shoreline terrace deposits, providing an insight into the temporal and climatic relations of both of these important geomorphological and morphostratigraphical archives, as well as their relationship with each other. New research is reported here on the Pleistocene geology and geomorphology of the Nahr el Kebir and the associated Palaeolithic archaeology, the latter having been reinterpreted based on reassessment of museum collections arising from earlier detailed work. Field visits revealed an additional, hitherto unrecognized low-level river terrace, whereas one of the previously recognized Palaeolithic levels can be shown to coincide with slope deposits that armour hilltops rather than representing a genuine fluvial formation. The new understanding of these geomorphological and sedimentary archives supports ideas that this corner of the Mediterranean has experienced unusually rapid uplift during the recent Quaternary, as a result of which the local rivers, including the Kebir, have deepened their valleys rapidly. Consequently, only the recent part of the Quaternary is recorded in the Kebir system and the ages envisaged previously for the terrace deposits and the Palaeolithic artefact assemblages were considerable overestimates in many cases, a finding that has significance for their correlation with those from the wider region. Reassessment of the Palaeolithic archaeology suggests a settlement history initially dominated by groups using handaxes, alongside simple core working (0.5–0.3 Ma), followed by a major change with the appearance of Levallois core working alongside handaxes, marking the transition to the early Middle Palaeolithic.

1. Introduction

The third largest river in Syria (length 56 km; catchment area 1104 km^2), the Nahr el Kebir (Fig. 1) is of considerable significance both for the study of Quaternary landscape evolution and for Palaeolithic research. Key to this status is its record of depositional river terraces and the Palaeolithic artefacts that have been recovered from these (Copeland and Hours, 1978, 1979; Sanlaville, 1979), the latter having been the inspiration for much of the research on the former. Of further importance is the interdigitation of these river terraces, in the lowest reach of the Kebir, with raised-shoreline deposits running parallel with the Mediterranean coast (e.g., Devyatkin et al., 1996).

The study of stone artefacts and the river gravels in which they are found has a lengthy pedigree, beginning in earnest with the discoveries of Jacques Boucher de Perthes in the deposits of the River Somme and publicized by his visitors Joseph Prestwich, John Evans and John Lubbock, who took inspiration from these discoveries and established that similar material occurred in English fluvial deposits (Prestwich, 1860;

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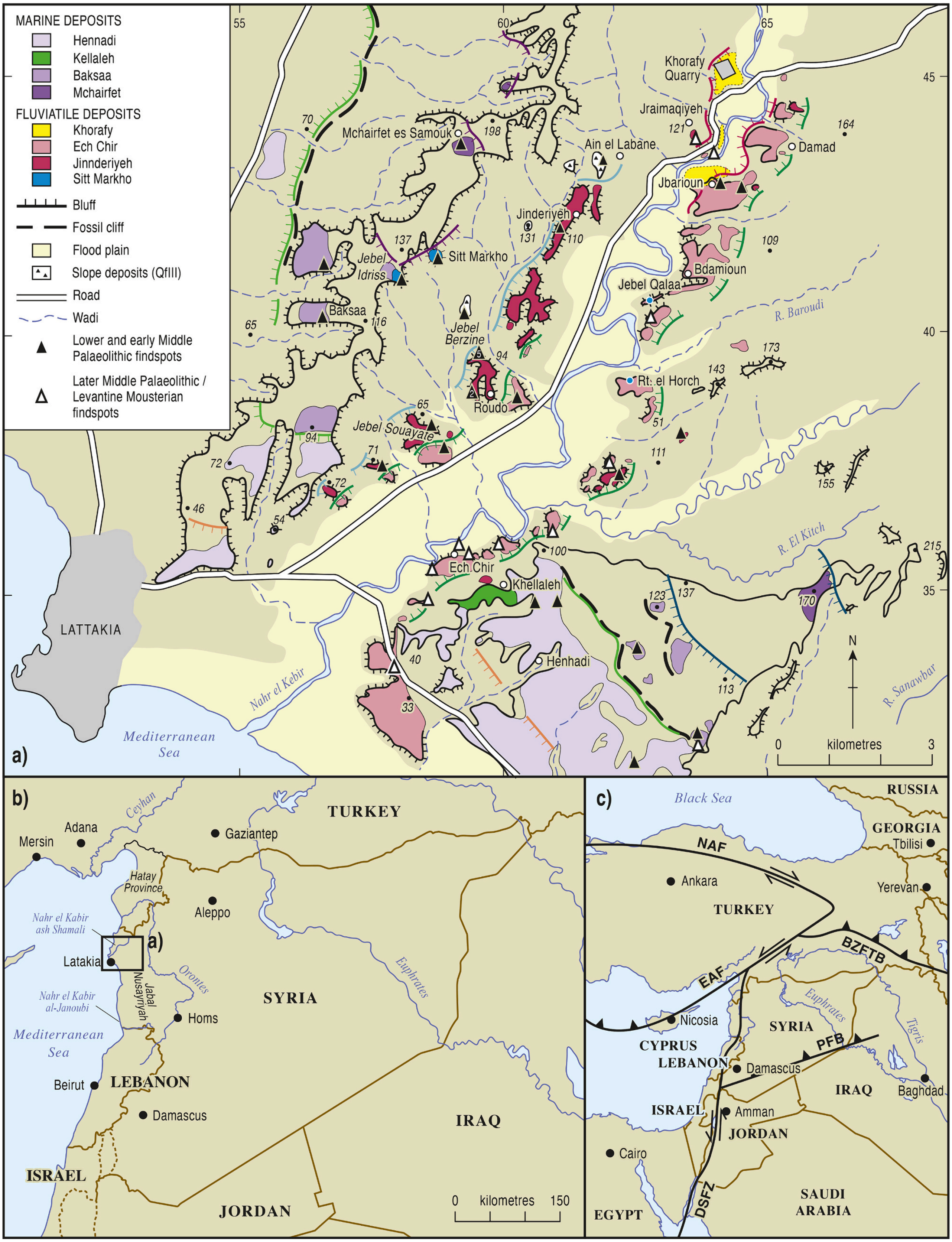

Fig. 1. The location, character and geological context of the Nahr el Kebir. a. Geomorphology of the lower valley of the Nahr el Kebir, showing river and marine terraces, important landscape features and Palaeolithic sites). b. Location within Syria and the Levant, showing the important rivers of the region. c. Location within the wider NE Mediterranean region, showing major fault zones (plate boundaries). Abbreviations: DSFZ - Dead Sea Fault Zone; EAF - East Anatolian Fault; NAF - North Anatolian Fault; BZFTB - Bitlis–Zagros Fold–Thrust Belt; PFB - Palmyrides Fold Belt.

Lubbock, 1862; Evans, 1863). Indeed, this work began before aggradational river terraces were widely recognized and understood (cf. Bridgland, 2014). It led to considerable research on such fluvial archives, as has been documented in recent years (Bridgland et al., 2006; Mishra et al., 2007; Chauhan et al., 2017) in the output of the Fluvial Archives Group, instigator of this present special issue. The Kebir, then, is by no means unusual in attracting attention from archaeologists in advance of its consideration by geomorphologists and Earth scientists, although the mid-20th Century work (e.g., Sanlaville, 1977, 1979; Besançon and Sanlaville, 1981, 1984, 1993) that formed the baseline for this reappraisal was admirably multidisciplinary in nature.

The Levantine Palaeolithic record is, furthermore, of great importance, not just to the spread of hominin populations from Africa to the other parts of the 'Old World', which is likely to have involved migration through the Levant (cf. Goren-Inbar, 1988; Bar-Yosef and Belfer-Cohen, 2001), but also to the understanding of evolutionary changes in Lower and Middle Palaeolithic human behaviours and landscape-use practices, as reflected in stone-tool assemblages (cf. Hauck et al., 2010; Shaw, 2012; Le Tensorer et al., 2015; Barkai and Gopher, 2013; Wojtczak et al., 2014; Meignen and Bar-Yosef, 2020); historically the classification and interpretation of such changes in the archaeological record owe much to localities in, and artefact assemblages from, the Nahr el Kebir (cf. Hours, 1981, 1994; Besançon et al., 1988). The Kebir thus provides valuable insights into the nature and classification of early human (hominin) occupation of the wider region, as well as into geomorphology and, in particular, the contribution from the latter to understanding the record of Quaternary landscape and drainage evolution that can be derived from the morphostratigraphy and lithostratigraphy of terrace deposits.

1.1. Geographical, geomorphological and stratigraphical context

The Nahr el Kebir ash Shamali (this full name distinguishes the northern Kebir from the Nahr el Kebir al-Janoubi, further south, which forms part of the border between Syria and Lebanon) lies entirely seaward of the Orontes (Asi) valley, which extends northwards from Lebanon and into Turkey, largely coinciding with the Dead Sea Fault Zone (Fig. 1b). Nonetheless, the uppermost northern headwaters of the Kebir drain the southern fringe of Hatay Province, Turkey. The upper Kebir catchment generally coincides with the western slopes of the northern Jabal Nusayriyah mountain range, from which the main axis of the valley is aligned NE–SW, with its mouth ~3 km south of Latakia (Fig. 1a). The mountains to the north and east of the Kebir valley are formed from late Mesozoic ophiolites and Mesozoic–Palaeogene limestones, respectively, the latter uplifted to the west of the Dead Sea Fault Zone. The valley largely coincides with a Neogene basin filled with marine and terrestrial sediments, dominantly carbonates and of low resistance to erosion. In common with many other systems in warmer climates, the Kebir terrace deposits are widely calcreted, which results in good-quality exposures of sections revealing fluvially bedded sands and gravels, although it hinders many types of analysis and sampling. This means that calcreted river-terrace deposits, which are commonplace throughout the Mediterranean region (especially on calcareous substrates), are often of greater durability than the bedrock, ensuring their geomorphological prominence in the landscape. Sanlaville's (1979) description of these terraces (in his English abstract) as 'buttes' is thus appropriate.

As with other Syrian systems, as well as those in adjacent parts of Turkey and the wider Levant, much of present understanding of the Pleistocene terrace sequence in the Kebir is based on detailed work in the mid-20th Century by a team comprising Paul Sanlaville, Jacques Besançon, Francis Hours and Lorraine Copeland (Besançon and Hours, 1971; Besançon et al., 1972, 1977, 1978, 1988; Sanlaville, 1977, 1979; Besançon and Sanlaville, 1981, 1984, 1993). In the Kebir, these previous workers recognized a sequence of four Pleistocene fluvial terraces, QfI – QfIV, ranging from ~30 to 110 m above the river (Table 1), above a Holocene 'floodplain terrace' (its age established from pottery fragments), designated Qf0, typically 3–4 m above the river (Copeland and Hours, 1978; Sanlaville, 1979). Terraces QfI – QfIV were attributed to Pleistocene cold stages ranging from early Middle Pleistocene to last glacial (Table 1). They were named as formations by Sanlaville (1979) with reference to type localities at Sitt Markho (QfIV), Jebel Berzine (QfIII), Jinnderiyeh (QfII) and Ech Chir (QfI), although for the last of these a younger colluvial–alluvial subdivision (QfIc), with Upper Palaeolithic archaeology, was also identified and named after Jraimaqiyeh (Table 1; see Fig. 1 for locations of type localities).

Table 1
Fluvial and marine terrace formations of the lower Nahr el Kebir. The notation used in columns 1 and 2 is from the Besançon–Sanlaville team (Sanlaville, 1979), who applied Alpine stage correlations. The Marine Isotope Stage (MIS) equivalents of these now outmoded stages (Šibrava, 1986) are shown in the final column (N.B. - these correlations are with the Alpine stages and do not imply interpreted ages from the present work).

Cold climate deposits	Interglacial deposits	Type locality	Alpine stage	MIS equivalent
QfI		Ech Chir	Würm	4–2
	QmI	Hennadi		5e
QfII		Jinnderiyeh	Riss	6
	QmII	Khellaleh		11–9–7
QfIII		Berzine	Mindel	12
	QmIII	Baksaa		15/13
QfIV		Sitt Markho	Günz	16
	QmIV	Mchairfet		17/older

In contrast to the fluvial formations, the coastal marine terraces were assigned to Middle Pleistocene interglacials, in recognition of their obvious correlation with sea-level highstands. The Upper Pleistocene QmI raised beach, dating from the last interglacial (MIS 5e), was not recognized from this section of the Mediterranean coast until Devyatkin et al. (1996), using biostratigraphy and thermoluminescence dating, showed that beach deposits beneath a well-developed raised shoreline ~40 m above sea level (a.s.l.) SW of Hennadi (Figs. 1 and 2) date from the last interglacial and must therefore represent QmI (Table 1 has been updated accordingly). The original age model (Copeland and Hours, 1978, 1979; Sanlaville, 1979), based on the classic Alpine scheme of four Pleistocene glacials, has also been updated in Table 1 with reference to the marine oxygen isotope stages (MIS) derived from the study of ocean-floor sediments (cf. Bassinot et al., 1994; Lisiecki and Raymo, 2005).

The fluvial and marine terrace classification illustrated in Table 1 was applied throughout the wider area of SW Asia studied by this same group of workers, although the full sequence was not recognized in every region and an additional Pleistocene fluviatile terrace (QfV) was sometimes identified at a higher level than QfIV, such as in the Syrian reach of the Euphrates in the vicinity of Raqqa (Besançon and Sanlaville, 1981; Muhusen, 2002; Besançon and Geyer, 2003); an even older QfVI terrace was also recognized in the Euphrates, at It Dagi (Besançon et al., 1988). In what became an important template for understanding Lower and Middle Palaeolithic archaeology in the wider region, the Kebir was acknowledged as important in furnishing additional evidence from interdigitation with the staircase of interglacial raised beaches (Copeland and Hours, 1978). In their discussion of the evolution of artefact types that they believed to be evident from this system, Copeland and Hours (1978) applied European stage names (Cromerian, Elsterian, Saalian, Eemian) to the assemblages and their contexts.

Also important for the interpretation of the morphostratigraphical record of the Kebir is its regional geological context, which is close to a region in the extreme NW of the Mediterranean that has been argued to have experienced unusually rapid late Quaternary uplift (Bridgland and Westaway, 2014). This is based on the interpretation of terrace sequences in rivers to the north, in Turkey: the lowermost Orontes (Bridgland et al., 2012) and the Ceyhan (Seyrek et al., 2008). In the case of the Ceyhan there are datable volcanic rocks interbedded with the Quaternary fluvial sequence that are of considerable value for

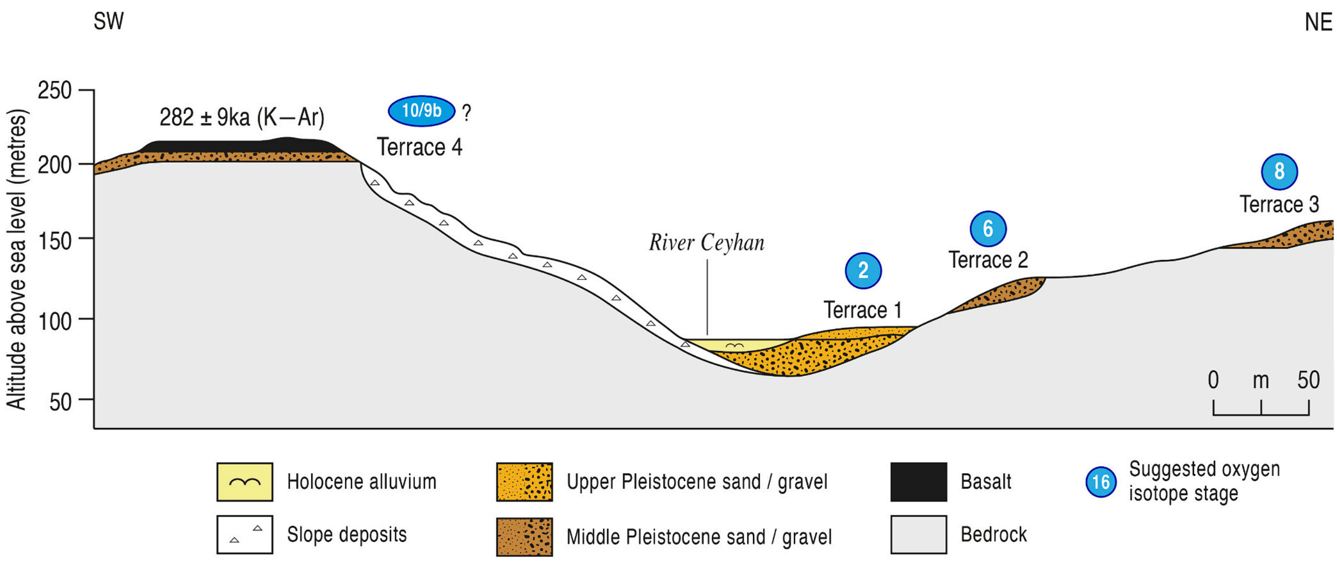

Fig. 2. The lower part of the terrace sequence of the River Ceyhan, southern Turkey, showing age constraint from a dated Middle Pleistocene basaltic lava that was erupted between the formation of terraces 4 and 3. This has provided important evidence for unusually rapid uplift and resultant valley incision in this part of the Mediterranean region (see text). Reproduced from Bridgland and Westaway (2014) with permission of the Geologists' Association.

calibration of terrace ages and, from these, rates of uplift in the valley of that river, which is deeply incised through the Amanos Mountains (Seyrek et al., 2008). Age constraint for the Ceyhan terraces comes from Ar– Ar dating to ~280 ka of basalt capping Terrace 4, thus assigned to MIS 10, with younger terraces inset below this lava (Fig. 2). From this evidence, uplift at up to 0.4 mm a^{-1} is estimated for the Ceyhan system (Seyrek et al., 2008; Bridgland and Westaway, 2014). This rapidly uplifting area coincides with the boundary zone between the Turkish, African and Arabian tectonic plates (cf. Westaway, 2004; Duman and Emre, 2013), with movement on active faults accommodating plate motions implicated in the unusual uplift history (Bridgland and Westaway, 2014). The rapid uplift of this NW corner of Syria is perhaps the reason why earlier workers did not recognize the lowest interglacial raised shoreline here, given its resultant unusually high elevation.

2. New data from the Kebir

2.1. Methods

As part of a long-running programme of geoarchaeological research

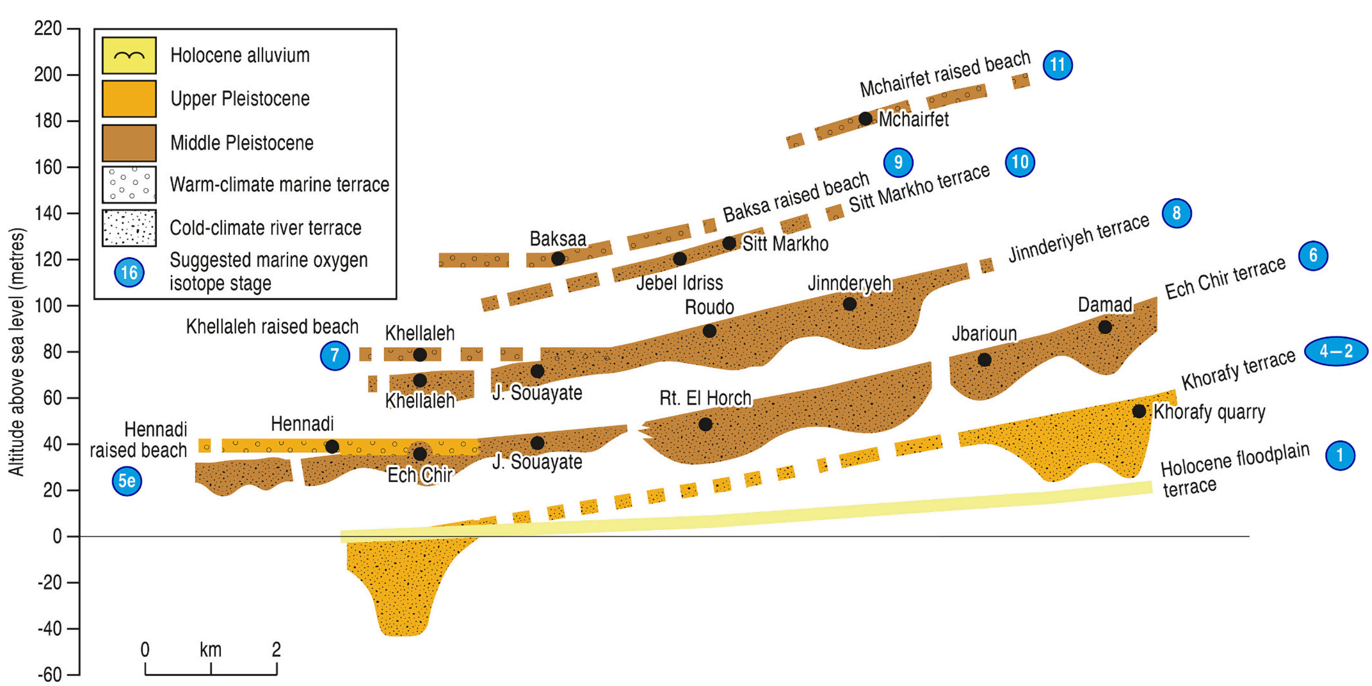

Fig. 3. NE–SW longitudinal profile of the Nahr el Kebir terraces (Modified from Bridgland and Westaway, 2014; original data from Bridgland et al., 2008). Note the combination of deformed coastal terraces, from interglacials, and steeply graded colder-climate gravel terraces that intersect with the much shallower downstream gradient of the modern (Holocene) valley floor. The tilting of marine terraces inland is attributed to an increase in uplift to the north and east (cf. Bridgland et al., 2008). A standard minimal depth of sediments is indicated except where sediment bodies are known to exceed this, in which case the actual thickness is shown. Pecking is used to indicate uncertainty and/or projection. Numbers in blue roundels/ovals signify marine isotope stages. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

on rivers in Syria and Turkey (e.g., Demir et al., 2007, 2012; Bridgland et al., 2008, 2012; Abou Romieh et al., 2009), the Latakia area was visited during 2005, 2007 and 2009, work being undertaken on locating and recording exposures of fluvial and marine terrace deposits in the Middle and Lower Kebir valley, aiming to verify and update the findings of the formative 20th Century studies cited above. This work used differential GPS (dGPS) to determine accurate heights (from terrace surfaces and within/beneath formations) and imagery from Google Earth and shuttle radar topographic mission (SRTM) as a source of base-map data and additional altimetry. The dGPS survey employed Leica System 300 equipment operated in static-survey mode, with reference to temporary base stations on suitable high points and using calibration with known heights such as benchmarks. Universal Transverse Mercator (UTM) co-ordinates are used for locating sites; within this small research area, all coordinates fall within Zone 36S YE. All dGPS-recorded localities were plotted on an enhanced longitudinal profile of the Kebir, allowing the disposition of the various individual terrace remnants to be assessed in the context of the wider data (Bridgland et al., 2008; Fig. 3); this also allowed comparison with the previous scheme. Although their full thickness is rarely seen, the best-preserved terrace formations are up to ~40 m thick, whereas the separation between terraces is around or in excess of 40 m (cf. Fig. 3); thus the sequence is dominated by 'strath terraces' rather than 'fill terraces' (e.g., Merritts et al., 1994), although the vertical extent of bedrock between them is minimal and the distinction therefore somewhat marginal. The sands and gravels forming the terraces are more strongly lithified (calcreted) with greater age. Fig. 3 shows a slight steepening and divergence, tentatively attributed by Bridgland et al. (2008) to a modest increase in uplift rate to the north and east, also presumed to be responsible for deforming the marine terraces where they extend inland.

Samples were collected for clast identification (cf. Bridgland et al., 2012; Demir et al., 2012) and potential dating; a small proportion of the former, in cases where cementation did not preclude this, were processed in the field (Table 3), whereas blocks of cemented gravel and/or sand for luminescence dating of sand grains or uranium-series dating of matrix (cf. Bridgland et al., 2012) were archived at the National Earthquake Center in Damascus. Unfortunately, together with Palaeolithic artefacts encountered during the inspection of geological sections and the mapping of terraces, which were similarly archived, the political situation in Syria has prevented further work on these samples and collections.

Cementation was found not to be universal; sand and gravel extending below the level of the Holocene floodplain were sufficiently unconsolidated to be exploited in a large aggregates quarry at Khorafy, ~15 km upstream from the coast. The exposures in this quarry, not seen by previous workers, demonstrated the existence of a lower-level gravel formation than those previously defined (Bridgland et al., 2008; Fig. 4; Table 2). This was the most significant addition to the pre-existing morpho-stratigraphical scheme, adding a new 'lowest' terrace; moreover, amongst the previously recognized terraces, QfIII (the Berzene

Table 2
Revised interpretation of the Nahr el Kebir river terraces, showing the MIS attribution proposed in this paper (compare with Table 1).

Terrace Formation	Sanlaville, 1979	Height above river	MIS
Khorafy		−10–40 m	4–2
Ech Chir	QfI	35–85 m	6
Jinnderiyeh	QfII	70–105 m	8
Sitt Markho	QfIV	100–135 m	10 (or older)

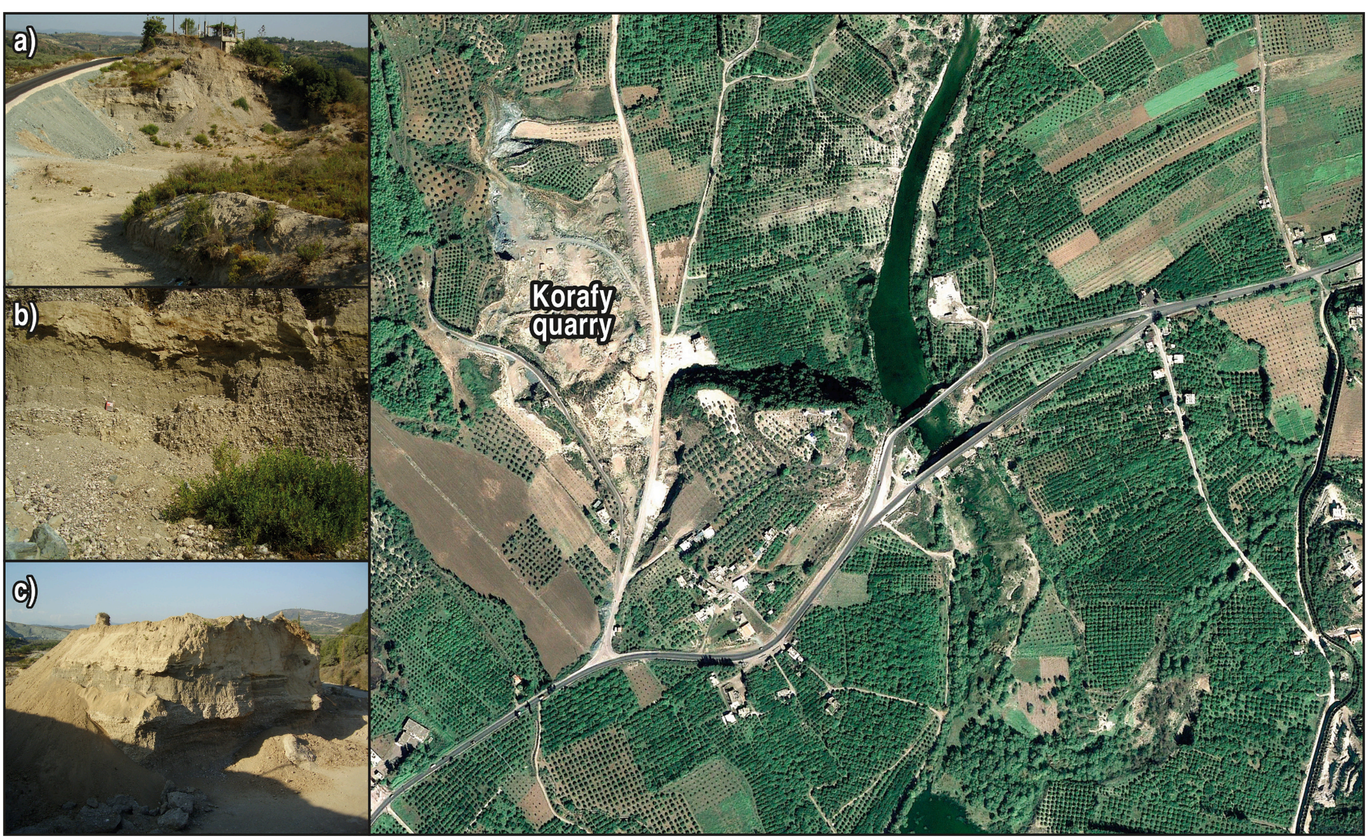

Fig. 4. The newly defined Khorafy Formation at its type locality, Khorafy quarry. The main view is a GoogleEarth image (2009) showing the quarry before it was landscaped. Inset 'a' shows the section to the east of a newly realigned road, in the NW corner of the quarry. Inset 'b' shows a close-up of interbedded unconsolidated sands and gravels, whereas 'c' shows gravels overlain by overbank silts in the central part of quarry. Insets 'b' and 'c' depict sections that were not in existence at the time the GoogleEarth image was recorded.

Formation) could not be verified as a distinctive aggradational river terrace and so does not appear within the updated sequence, as will be described below (Fig. 3; Table 2).

Palaeolithic artefact assemblages recovered from the Nahr el Kebir and studied by previous workers (Copeland and Hours, 1978, 1979) are curated in the National Museum in Damascus. All the extant material from previous studies was analysed as part of PhD research carried out between 2004 and 2008 (Shaw, 2012); although not included in the final thesis (Shaw, 2008), it provides the basis for reassessment of the Palaeolithic archive as presented below. For the methodology applied in this study, see Shaw (2012) and online supplement 1.

2.2. Results: revised terrace stratigraphy

The investigations reported here have led to the erection of a revised terrace stratigraphy for the Pleistocene fluvial and raised coastal deposits of the Nahr el Kebir, as summarized in Figs. 1 and 3 and in Table 2. Sanlaville (1979) had reported that the Kebir terraces diverge upstream, reconstructing them with downstream gradients that increased with age and height above the valley floor. Thus he quoted declivities of 10.0, 5.5 and 3.3 m km^{-1} for terraces QfIII, QfII and QfI, respectively. No very marked divergence is apparent in the new longitudinal plot (Fig. 3), which indicates four approximately parallel fluvial terraces with steep downstream gradients, significantly exceeding that of the modern valley floor, which intersects, in the coastal area, with raised-beach formations that represent the last three interglacials (MIS 9, 7 and 5e). These are not the same four river terraces as were recognized from the 20th Century research, for reasons described above, although the previously established names can be used for three of them: The Sitt Markho, Jinndireyeh and Ech Chir formations (cf. Sanlaville, 1979; Bridgland et al., 2008; Bridgland and Westaway, 2014). As already noted, the existence of a Jebel Berzine Formation (QfIII), disposed between the Sitt Markho (QfIV) and the Jinndireyeh (QfII) terraces and capping a line of small hills to the north and west of outliers of the latter, is not upheld by these new results. Instead, a new lower-level terrace is now recognized, on the basis initially of the gravel exposed in the aggregates quarry at Khorafy but also recognized in the form of deposits underlying the lowest reach of the valley. The names Khorafy Terrace and Khorafy Formation are given to this additional division of the Kebir sequence, which must represent a later phase in valley evolution than any of the terraces recognized in the earlier research (although in part it might coincide with the Jraimaqiyeh subdivision of the Ech Chir Formation; see above). In addition, a certain degree of redefinition of the Jinndireyeh and Ech Chir terraces is required, as will be documented below.

A limited number of gravel analyses were undertaken, because of the difficulty in processing cemented sediments for this purpose, the inaccessibility of samples stored in Damascus, and in part because there was little requirement for recognizing Kebir gravels as distinct from other comparable deposits; all rudaceous sediments encountered showed the combination of limestone, flint, ophiolite (often weathered; when fresh, serpentinite and dolerite components can be detected separately) and subordinate quartzose rocks (quartz/quartzites) that characterize the bedload of the Kebir (Table 3).

Further details of the terrace formations will be provided below, in order of decreasing age.

2.2.1. The Sitt Markho Formation

This formation was defined by Sanlaville (1979) and co-workers on the basis of a type locality (Fig. 1a) at ~110 m above the valley floor, ~10 m below the level of the plateau to the NW. It was suggested to be 'Günz' in age (Sanlaville, 1979), seemingly based on its altitude and the occurrence of weathered clasts as indicators of antiquity. The occurrence of a substantial terrace conglomerate at Sitt Markho was verified by a well exposure, showing ~3 m of cemented gravel above Palaeogene sediments, illustrated by Besançon (1979, his photo 7). Since this previous research took place, the location of this principal outcrop at Sitt

Table 3
Gravel clast lithologies of Kebir gravels.

Lithology	Es Chir Fm, Roudo[a]	Jinndireyehb[b]
Limestone (pinkish)	133 (55.4 %)	104 (60.1 %)
Calcareous gritstone	5 (2.1 %)	
Quartz/quartzite	5 (2.1 %)	
Quartz dolerite	18 (7.5 %)	12 (10.4 %)
Flint, brown (with pale cortex)	19 (7.9 %)	16 (11.0 %)
Flint, white patinated	2 (0.8 %)	3 (1.7 %)
Flint, red (jasper)	1 (0.4 %)	
Chert, fissile/jointed, red (some banded)	10 (4.2 %)	3 (1.7 %)
Mudstone, greenish	2 (0.8 %)	
Serpentinite (ophiolite)	16 (6.7 %)	
Weathered rock (indeterminate ophiolite)	29 (12.1 %)	35 (20.2 %)
Total count	**240**	**173**

[a] Coordinates 60013 39058;
[b] Coordinates 60894 42326; count from calcreted gravel, with most clasts left in situ.

Markho has become built up and it was not possible, during any of the recent visits, to locate any in situ cemented gravel there, although loose blocks of flinty conglomerate were observed amongst surface debris (at 58521 41356), associated with a small sub-horizontal platform below the main plateau level. Although weathered and fragmentary, these calcareously cemented blocks were of similar character to the larger conglomeratic outliers associated with the lower terraces and were considered likely, unless artificially transported to the site, to represent the remnants of a high-terrace deposit. Few artefacts were recorded during this new work (see online supplement 2) but there is no reason to doubt the value of the previously collected assemblage from here as representative of Palaeolithic material from what can be presumed to be an earlier Kebir valley floor, its existence verified by Besançon's published photograph (see above).

A second potential outlier of the Sitt Markho Formation was reported by Sanlaville (1979) at Jebel Idriss (Fig. 1a), associated with what he regarded as a fluvio-marine facies of the Baksaa Formation, QmIII, dating from the temperate episode between the formation of the Sitt Markho and Berzine cold-climate river floodplains. Copeland and Hours (1979) reported abraded artefacts from here, including a single handaxe; as with that from Sitt Markho, this material was attributed to the Early Acheulian. In the present study the presence of artefacts in this general vicinity was confirmed by the discovery (at 57815 40942; 136 m a.s.l.) of a rolled handaxe and two flakes.

2.2.2. The Jebel Berzine Formation

The various small hill-tops upon which outliers of this formation (QfIII) were mapped by earlier workers (e.g., Copeland and Hours, 1978; Sanlaville, 1979; Besançon and Sanlaville, 1984) were visited and verified, in several cases, as coincident with significant accumulations of surface gravel (including cobbles), although no in situ fluvial deposits were observed. Particularly impressive is the type locality at Berzine (59012 40288), where coarse loose gravel within regolith included numerous artefacts and occasional calcreted aggregate blocks. At Ain el Labane (61517 43291), on another supposed QfIII outlier, a survey of field debris yielded two cores and two flakes, all rolled. This location, reaching ~149 m (GoogleEarth), seems higher than the other proposed QfIII outliers and is scarcely lower than the Sitt Markho Formation would be if projected upstream to this area (~5 km upstream from Sitt Markho).

All the mapped occurrences of the Jebel Berzine Formation are small and, with the exception of Ain el Labane, are poorly separated, in terms of altitude, from the highest parts of the more widespread QfII (Jinndireyeh) terrace to the south and east (Fig. 1). The recognition of the Berzine Formation as distinct from Jinndireyeh and, indeed, from Sitt Markho, was strongly reliant on the Middle Acheulian archaeology previously claimed, uniquely amongst the fluvial terraces, from the Berzine Formation (e.g., Copeland and Hours, 1978, 1979). The validity of this archaeological definition will be further discussed below.

2.2.3. The Jinndireyeh Formation

Cemented gravel outliers attributed to the Jinndireyeh Formation (QfII) are highly conspicuous on the NW flank of the Kebir valley (Fig. 1a), where they represent the highest well-preserved terrace within the system. They were recorded at several places, including the type locality, Jinndireyeh (60886 42311), where the channelized base of the formation overlies Pliocene marl bedrock (Fig. 5). At UTM 60924 42314, >5 m of bedded deposits were exposed, consisting of cross-bedded sands with pebbles, passing upwards into horizontally laminated silt, the latter interpreted as floodplain (overbank) deposits. Foreset orientation in the cross-bedded sands was measured in the range 230–240° (WSW), commensurate with deposition by the palaeo-Kebir. Pre-Holocene 'floodloam' is seen preserved much less commonly than coarser sediments within terrace sequences; its preservation here is perhaps attributable to burial by colluvial deposits (see below). Extensive sections from erstwhile quarrying at Roudo revealed a thick sequence of bedded fluvial deposits, with ~4 m of basal sands and fine gravels (unconsolidated) beneath alternating silt and fine sand with middle and upper (cemented) gravels (Fig. 6). A rolled flake was observed within the middle gravel and numerous other abraded artefacts, including

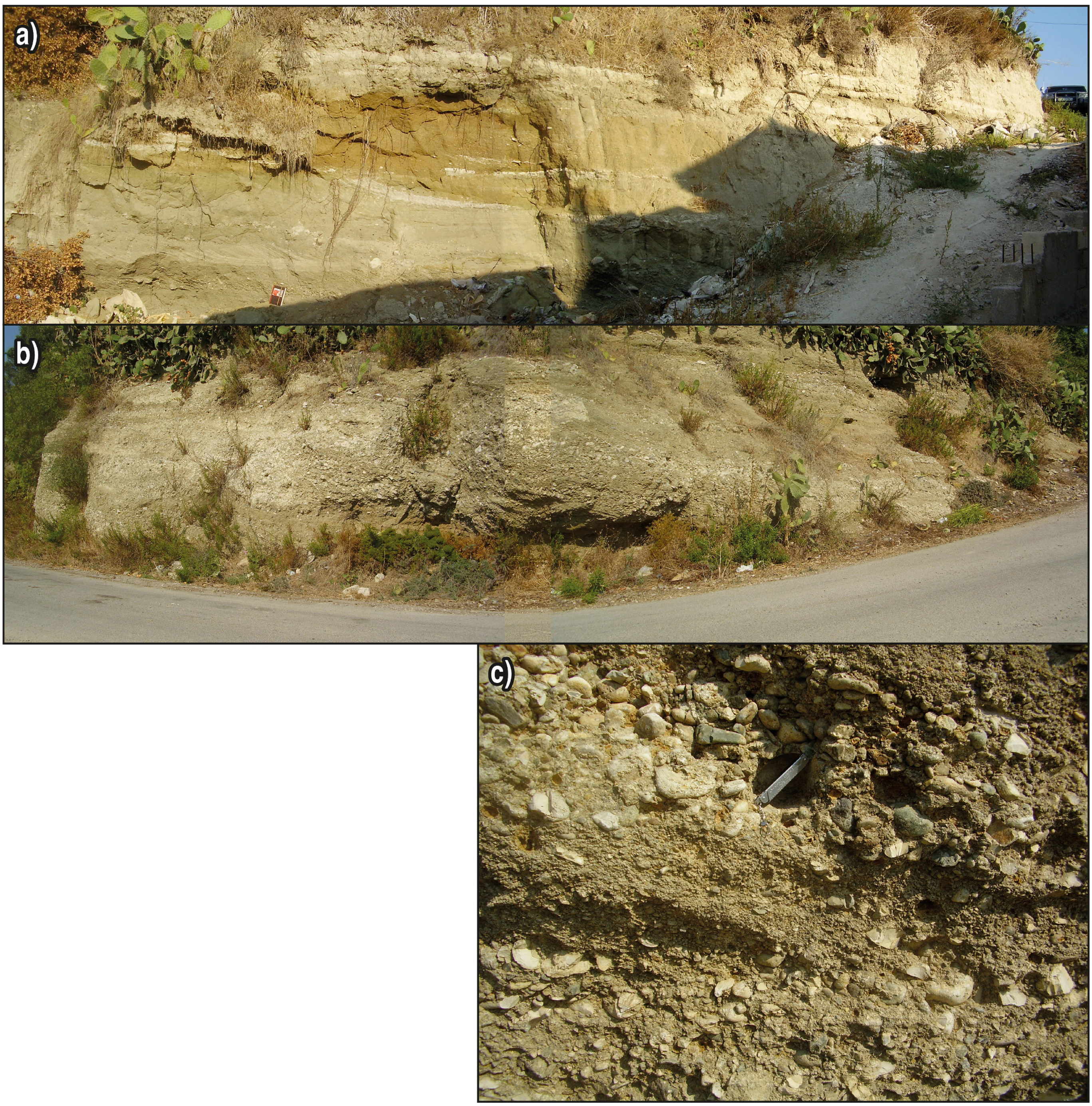

Fig. 5. Sections in the Jinndireyeh Formation at its type locality: 'a'. Section by a track leading to an orchard on the terrace surface (60924 42314), showing the top of the fluvial sequence, with uppermost sands and overbank sediments; 'b'. montaged road-side section NW of the village (60886 42311), showing the base of the Kebir deposits above bedrock marl; 'c'. Close up, showing gravel texture.

Fig. 6. Section in the Jinndireyeh Formation at Roudo 2 (land surface above section: 59520 38567).

handaxes, were found in unstratified situations on or close to the outcrops and were presumably derived from these or earlier fluvial deposits; occasional unstratified and unabraded artefacts might represent later surface archaeology, not originating from within the fluvial deposits.

Over part of their outcrop, the bedded fluvial deposits are overlain by as much as 10 m of unconsolidated gravelly colluvium that was observed, from field debris on plateaux formed on this material, to be a rich source of fluvially abraded artefacts (Bridgland et al., 2008). For example, several handaxes were recovered from loamy, gravelly field debris above the section at Roudo 5 (Fig. 7). Colluvial material of this type was observed in shallow sections above calcreted gravel in the Roudo 5 section and could be seen from below to cap the Jinnderiyeh bluffs (e.g., at 60946 41900) as well as occurring in shallow sections at Jebel Souayate (58154 38088), where four rolled handaxes and numerous flakes were encountered amongst surface material (see online supplement 2). These various exposures revealed loose, dry, unbedded brown loam containing coarse cobble gravel (including artefacts), although caution is required in estimating original thicknesses, given the frequent movement of regolith employed to level terraced field surfaces for agriculture in this region.

Not all the outcrops previously ascribed to QfII are confirmed as representative of the Jinndireyeh Formation, however. On the left side of the valley, around Jbarioun (64000 42630) and Damad (64665 43950 to 65037 44364), deposits assigned by Copeland and Hours (1978) and Sanlaville (1979) to terrace QfII are only ~15–20 m higher than those of the younger Ech Chir Formation in this valley reach and probably represent the (dissected) valley-side feather edge of that lower (QfI) terrace (see below).

At Khellaleh, where Sanlaville (1979) had recorded raised beach deposits overlying fluvial gravel, two distinct deposits were indeed observed: a higher-level cemented gravel with well-rounded flints in a matrix of coarse rounded sand (59878 34833) and, a few metres further south on the same side of the road, a lower-level gravel with clasts of subangular flint and ophiolite, although well-rounded clasts were also present. At 72 m a.s.l., these exposures are within the intersection between the steeply graded, fluvial Jinnderiyeh terrace and the Khellaleh raised beach (see Fig. 3). The fluvial deposits should be the older of the two and so might have been exhumed from beneath the marine gravels (*contra* Sanlaville, 1979); it is unfortunate that no contact between the two was exposed.

2.2.4. The Ech Chir Formation

In the lowest few kilometres of the valley, the Ech Chir Formation crops out on both sides of the river, although, upstream of Roudo, preservation of this terrace is restricted to the left (south) side of the Kebir (Fig. 1a). Sections were recorded at several localities, such as a quarry at Damad (64665 43950), where a body of calcreted gravel and interbedded sand was observed, within which a Palaeolithic flake, in rolled condition, was recorded. Shallow cuttings 500 m to the NE (65037 44364) revealed deposits that were classified as QfII by Sanlaville (1979) but are interpreted here as the valley-side feather-edge of the Ech Chir Formation. They consist of cemented sand and gravel with well-developed trough cross stratification, the foreset orientation indicative of palaeo-flow to the SW. East of Jbarioun (64000 42630), sections revealed upper and lower calcreted gravels separated by fluvially bedded fine sand and silt, a further rare occurrence of fine-grained overbank sediment. These two gravels might represent the lower (QIa) and upper (QIb) divisions of the main fluviatile Ech Chir formation identified by Sanlaville (1979). Another section to the NW of this village showed poorly sorted cobble-gravel, strongly imbricated by flow to the SW and containing mainly limestone and ophiolite clasts (63647 42787). Additional sections were recorded working downstream on the left side of the river, at Bdamyoun (63360 41526) and Jebel Qalaa (62567 39938), showing both cemented and unconsolidated gravel of the Ech Chir Formation. At Bdamyoun, the top of cemented gravel was revealed in a step between fields (Fig. 8), matching the river-ward edge of the Ech Chir terrace as indicated in the Sanlaville (1979) mapping. A core and a flake, both rolled and unstratified, were found at Bdamyoun, their condition suggesting that they have come from the sediment body there, whereas the Jbarioun section yielded a flake from within the deposits.

At Roudo, the most northerly right-bank outlier of the Ech Chir Formation underlies the lower (SE) fringe of the village. Below the road, an exposure (at 60079 38969) revealed <1 m of well-bedded fine gravel, sand and poorly sorted medium-grained gravel. On the opposite side of the river ~2 km to the east, in an exposure (62086 38991) near the locality labelled Route el Horch on the Sanlaville (1979) map, the channelized base of the Ech Chir Formation was observed in section, overlying soft marl bedrock. The fluvial deposits comprised coarse, poorly sorted (lag) gravel beneath more sandy and cross-stratified beds; again, artefacts were observed within these deposits, in the form of two flakes, lying in close proximity ~2 m above the base of the sequence (Fig. 9). Roughly 2 km to the south, at Cheikh Youssef (61436 37072), calcreted gravel, variably fine- and coarse-grained, was again seen channelled into bedrock marl. At Ech Chir itself, a temporary section (58956 35410) exposed ~3 m of cemented gravel, although the cementation was much weaker in the lower half. Four artefacts, including a rolled handaxe, were recovered from the deposits, all within a zone 1–1.5 m below the top of the section. The land surface in this built-up area is ~35 m a.s.l.

2.2.5. The Khorafy Formation

This newly defined formation was well exposed in the quarry that represents the type locality, from which large volumes of what is generally unconsolidated aggregate have been removed. At the northern margin of the quarry (63808 45068), a valley-side feather-edge of this terrace formation was recorded above weathered ophiolitic bedrock, the gravel here being rich in weathered clasts of this same material (the domination by local material made this an unsuitable location for gravel clast analysis). The deposits were seen to thicken rapidly into the quarried and worked-out area, suggesting that the limits of extraction

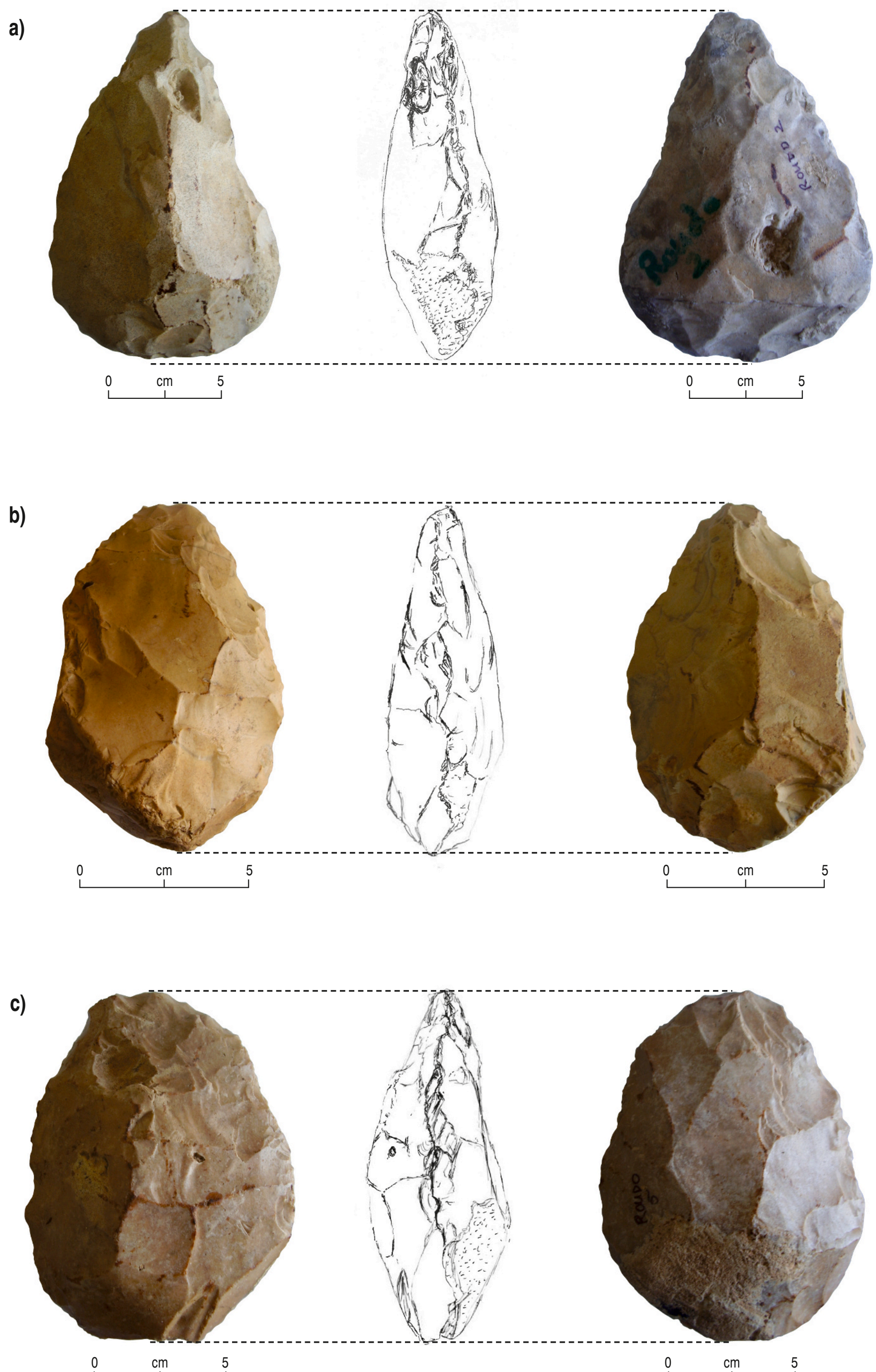

Fig. 7. Artefacts from Roudo, as an example of finds from the project fieldwork. For a larger sample, see online supplement 2. Photographs and drawings (by DRB) were made during the fieldwork programme prior to archiving the material in Syria. Handaxes showing various degrees of abrasion from fluvial transport: a - Roudo 2 (59520 38567), unstratified; b–e - Roudo 5 (59525 39279), in loamy regolith on the land surface above terrace sections (~ 82 m a.s.l.); drawings (f) and photographs (g) of a core from the same Roudo 5 location (edge drawing and photograph are from different sides).

here closely approximate to the extent of the formation (Fig. 4). Exposures of the thicker sequence further south (63966 45025) showed very coarse gravel beds at various points within the sequence, with boulder-sized clasts (longest axis ~1.25 m) of limestone and Pliocene marl. These were interbedded with finer gravel and sand.

A new road cutting and quarry sections at Jraimaqiyeh (e.g., at 63926 43817) again showed very coarse gravel representative of this terrace, with boulders (up to 0.65 m longest axis), especially towards the base of the section (bedrock not seen). Sedimentary characteristics suggest slumping of limestone debris into the river before entrainment of much of the material into the fluvial bedload (Fig. 10). Nearby (63891 43807) the gravel was much finer, with coarse sand and granule sizes common. In a quarry section here, at 63760 43811, a small flake was observed within the sediments. At Mazar Chekh Taha (64282 44927), a bedrock 'island' protrudes through these youngest fluvial terrace deposits to crop out in the valley floor. The furthest downstream that this

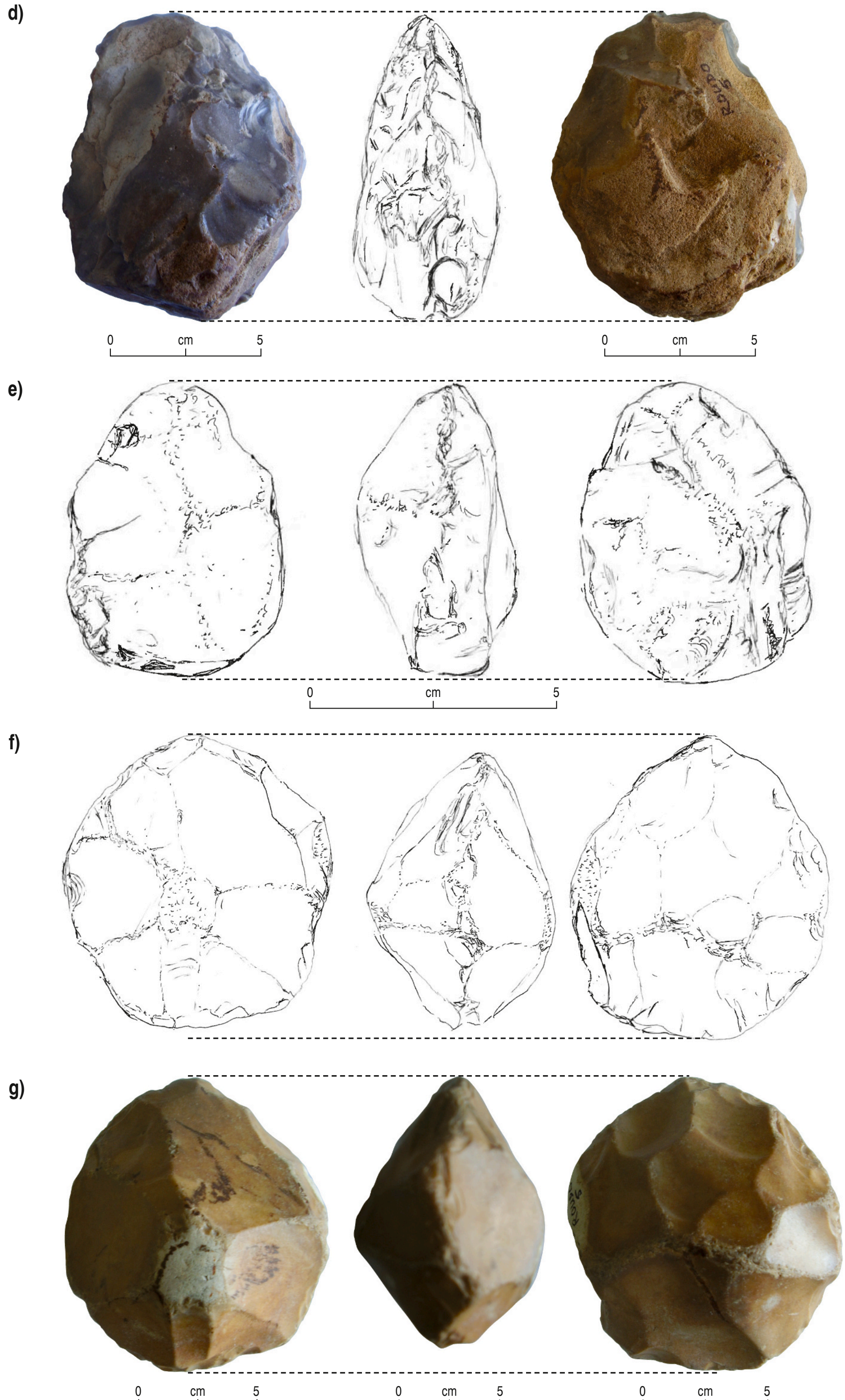

Fig. 7. (*continued*).

lowest terrace formation was observed in outcrop was NW of Jbarioun, where an extensive quarry exposure just to the east of the river revealed a remnant, somewhat isolated by the quarrying, of dominantly overbank, silty sediments with interbedded sand seams and fine gravel lenses, >5 m thick.

2.3. *Overview: revised terrace sequence and status of the Berzine Formation*

The revised sequence of Kebir terraces has already been illustrated in Fig. 3, which shows, in longitudinal profile, four gravel terraces with steep downstream gradients. It also shows their relation to raised shoreline deposits in the lower (coastal) part of the system as well as to the Holocene valley-floor alluvium. The fact that the fluvial and coastal

Fig. 8. Section north of Bdamyoun (63360 41526) revealing calcreted gravel (above uncemented gravel) at the edge of the Ech Chir terrace (looking SW).

terraces intersect rather than coalesce suggests that the former represent the cold-climate parts of the Pleistocene glacial–interglacial cycles, their steep gradients being in keeping with this, as they would potentially have been graded to low Mediterranean sea levels. Three of the fluvial formations established by the Sanlaville (1979) team are represented here: their QfIV, QfII and QfI. A new lower terrace formation is added in the form of the Khorafy Formation and the Berzine Formation (QfIII) of Sanlaville is omitted. In the absence of in situ fluvial deposits capping the QfIII outliers, it is considered likely that these small hill-top concentrations of surface gravel are instead topped by remnants of slope deposits that have formed on the NW flank of the Kebir valley. Indeed, slope material of a similar type, and with comparable artefact content, caps the flat tops of the best-preserved remnants of QfII, the Jinnderiyeh Formation, as noted above. This suggestion is illustrated in Fig. 11. The Khorafy Formation was not documented in the earlier studies but, as Bridgland et al. (2008) noted, its top probably coincides with a lower flat surface included within the Ech Chir terrace north of Jbarioun, identified by Copeland and Hours (1978) and by Sanlaville (1979, p. 24: his "troisième replat d' érosion"). It might also be represented by Sanlaville's Jraimaqiyeh (QfIc) subdivision of the Ech Chir Formation (see above).

2.4. Likely ages of the Kebir terraces

Estimated ages for the different elements of the Nahr el Kebir terrace staircase as it is now envisaged (cf. Table 2; Figs. 3 and 11) can be obtained with reference to the reconstructed unusually rapid uplift history in this part of the NW Mediterranean area (Seyrek et al., 2008; Bridgland et al., 2012; Bridgland and Westaway, 2014; see above). The implication is relatively young ages for terrace deposits in this region, relative to height above valley floor, the rivers having deepened their valleys rapidly in response to this uplift. If the calculated uplift rate for the Ceyhan (see above, Fig. 2) is adopted, with caution, for suggesting ages for the Kebir terrace formations, matching to the nearest Milankovitch cold-climatic event, the MIS correlations suggested in Table 2 are obtained.

In common with comparable archives worldwide, it can be supposed that the formation of the Kebir terrace system, as well as being a response to regional uplift and enhanced by the above-mentioned tectonic effect, will have been triggered by interglacial–glacial climatic fluctuation during the Quaternary (e.g., Antoine, 1994; Bridgland, 2000; Bridgland et al., 2004; Bridgland and Westaway, 2008), providing a climatic driver that is the justification for the above matching of terraces to odd-numbered MIS. Oscillation of Quaternary climate is inferred to have driven the differing fluvial activities, from erosion into the valley floor to aggradation of different types of sediment, the sedimentary style being a further reflection of climate. There has been considerable debate about the mechanisms whereby climate changes translate into differing fluvial regimes, with apparent differences between river systems even when in the same general region (cf. Vandenberghe, 1995, 2002, 2003, 2007; Antoine, 1994; Maddy et al., 2000, 2001; Starkel, 2003; Cordier et al., 2006; Bridgland and Westaway, 2008, 2012, 2014). It is generally

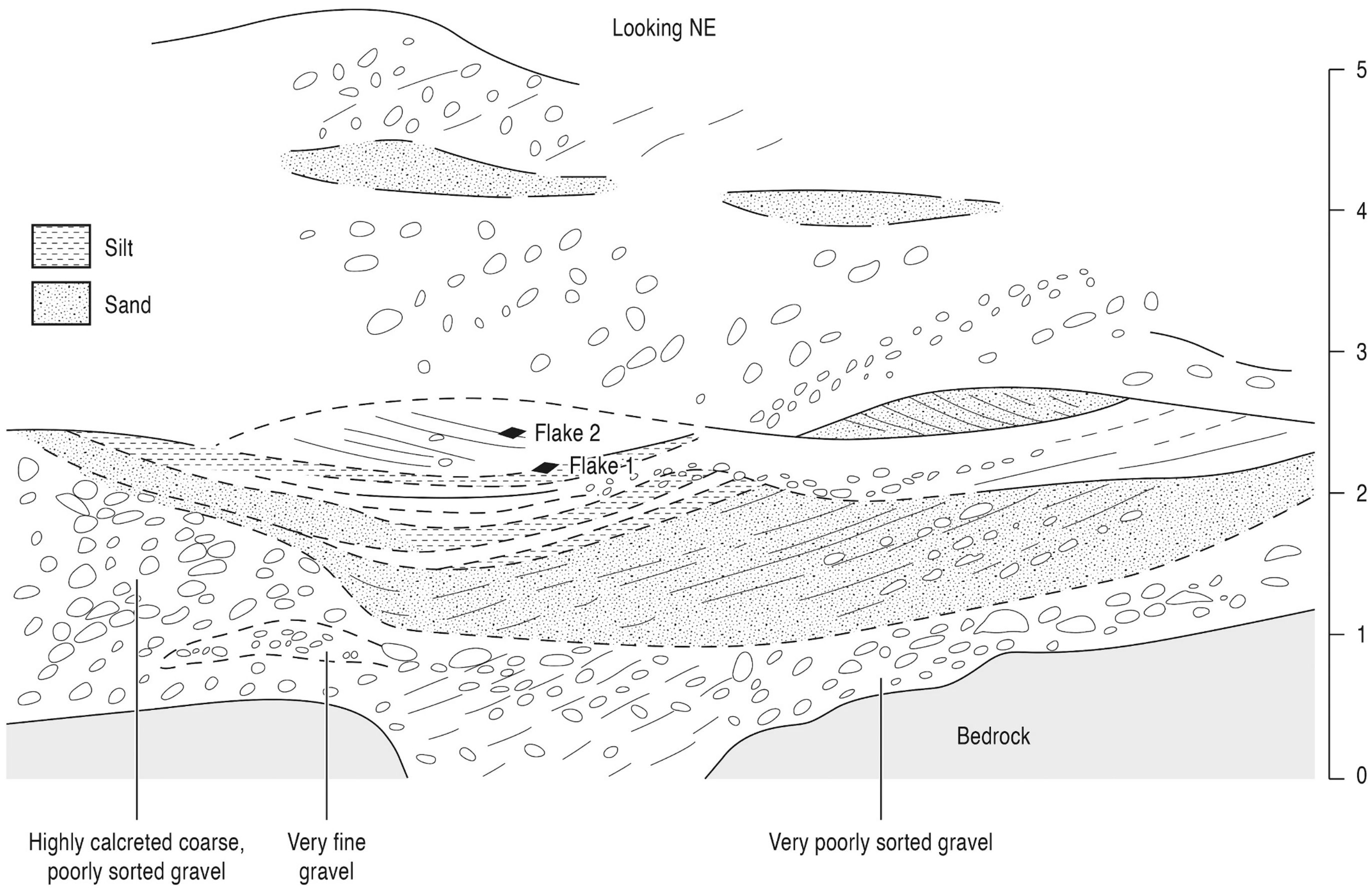

Fig. 9. Section in the Ech Chir Formation at Rt. El Horch, showing partly calcreted gravel and sand above bedrock marl. Note the two Palaeolithic flakes. Scale in metres (no vertical exaggeration). From a field sketch by DRB in Rob Westaway's notebook.

supposed that the coarse gravel deposits that characterize terraces in many areas were formed during periods of landscape instability, leading to ample sediment supply, probably corresponding to the colder parts of glacial–interglacial climate cycles. Even in the Mediterranean region, where the considerable distance from areas that were glaciated raises the possibility of a prevailing humidity cycle (pluvials and interpluvials), the balance of evidence favours temperature variation as the key driver of fluvial activity (cf. Macklin et al., 2002).

It is thus suggested that the four confirmed Kebir terraces represent the last four 100 ka (Milankovitch) climate cycles and result from cold-climate gravel aggradation during MIS 10, 8, 6 and 4–2 (the last cold cycle encompasses MIS 5d–1 inclusive). Figs. 3 and 11 reveal an approximate vertical interval of 40 m between these four successive Kebir terraces, conforming exactly with the uplift rate of ~40 m per 100 ka or ~ 0.4 mm a^{-1} calculated by Seyrek et al. (2008) from the terraces of the River Ceyhan (see above). Indeed, the rapidity of the uplift hereabouts, an effect that appears to be restricted to the region around the İskenderun Gulf, means that the Kebir terraces are much younger than seemingly similar features in other parts of the Levant, if height above valley floor is taken as the point of comparison. Thus the Sanlaville (1979) scheme (Table 1), which was based on those for comparable terrace sequences applied by the Sanlaville–Besançon team throughout the region, greatly overestimated the ages of the Kebir terraces.

2.5. Palaeolithic assemblages

The Lower and Middle Palaeolithic archaeology from the river terraces of the Nahr el Kebir formed the basis for a model of typo-technological artefact change over time (Copeland and Hours, 1978, 1979), a scheme that was subsequently expanded and applied across the northern Levant to reflect regional scale patterns of earlier Palaeolithic settlement history (Copeland and Hours, 1993; Copeland, 2004). Although some artefacts were recovered from the deposits of the younger terraces, the lithic artefacts used to define this sequence in the Kebir were mostly recovered from field surfaces in proximity to what were identified as Pleistocene fluvial and marine cemented-sediment outcrops; widespread calcreting of sediment bodies largely prevented artefact discovery from within these, with only the Ech Chir Formation, parts of which remain uncemented, yielding significant amounts of material. In many instances, artefacts in two condition states and from two sources were recovered:

1. Rolled, edge-damaged, patinated and stained examples. In some instances, these were recovered directly from exposures of fluvial deposits, but most were from field surfaces in areas where sections through fluvial exposures occurred, or where disaggregated and eroded terrace deposits were identified. The fluvially abraded condition of such surface finds demonstrated that that this material originated from within the deposits of these terraces and wasat least as old as those deposits.
2. Patinated, stained, but unabraded and significantly less edge-damaged pieces that were unstratified and recovered from locations where Pleistocene fluvial terraces and raised beaches were identified. These were thought to be discards from occupation of the surfaces of fluvial and marine deposits and/or from colluvium overlying these surfaces. Thus they have not been transported in river bedload or moved on a beach, which explains their unabraded condition.

This association between the abraded material and chronologically

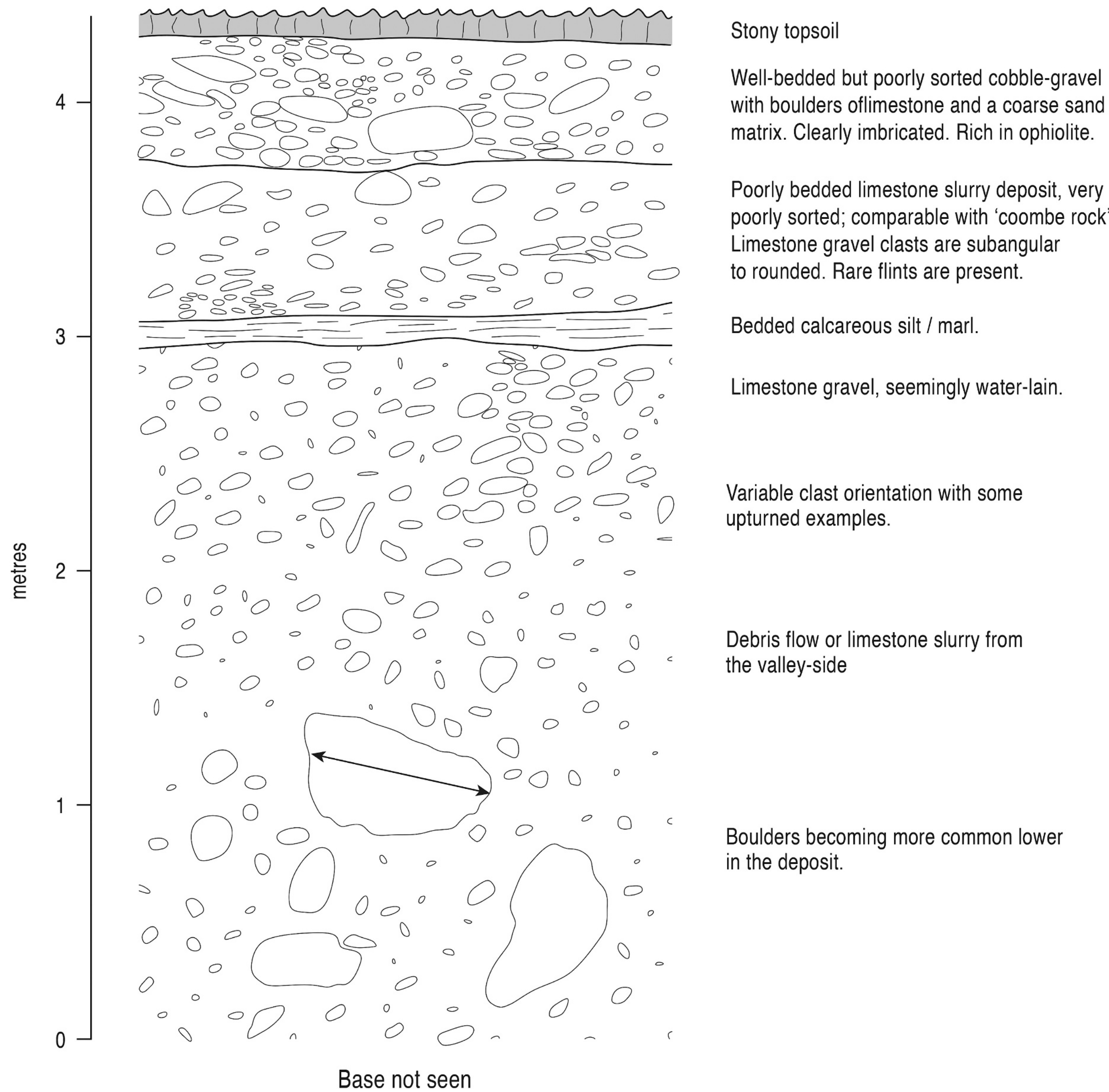

Fig. 10. Section in a new road cutting (2007) at Jraimaqiyeh. From a field sketch by DRB in Rob Westaway's notebook. The evidence for incorporation of slope deposits provides a convincing link to the description by Sanlaville (1979) of his 'late Würm' QIc Jraimaqiyeh division, envisaged by him as a poorly represented lower terrace and thus seen as a potential early record of the Khorafy Formation.

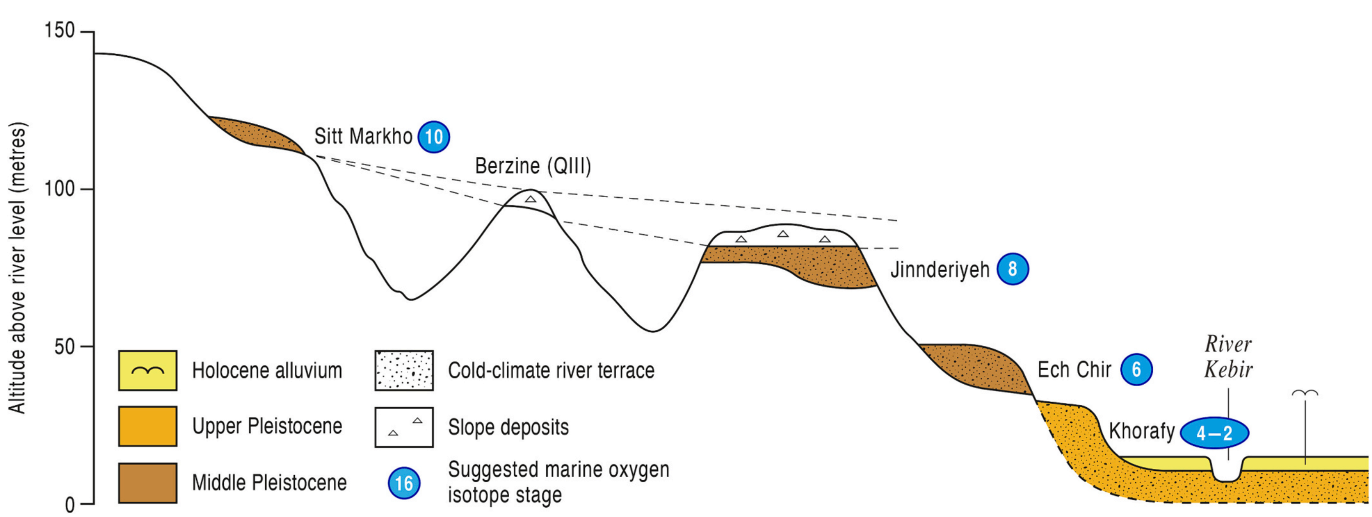

Fig. 11. Idealized transverse profile through the Kebir sequence, largely based on the NW side of the valley and showing the revised interpretation of Jebel Berzine and equivalent outliers.

Table 4
Palaeolithic artefact assemblages from the Nahr El Kebir, from Copeland and Hours (1979) and reassessed extant material.

Site	Associated Pleistocene deposits (Sanlaville, 1979)	Revised associated Pleistocene deposits	Age of Pleistocene deposits (Sanlaville, 1979)	Revised age of Pleistocene deposit	Typology of abraded artefacts (Copeland and Hours, 1979)	Typology of fresh artefacts (Copeland and Hours, 1979)	Number of abraded artefacts (Copeland and Hours, 1979)	Number of unabraded artefacts (Copeland and Hours, 1979)	Number of extant abraded artefacts	Number of extant unabraded artefacts
Mchairfet es Smouk	QmIV	Mchairfet Raised Beach	MIS 17	MIS 11	?	Final Acheulian	0	186	48	18
Sitt Markho	QfIV	Sitt Markho Terrace	MIS 16	MIS 10	Early Acheulian	None	90	0	53	0
Fidio	QmIII	Baksa Raised Beach	MIS 15/14	MIS 9	Early Acheulian	Final Acheulian	20	329	18	158
Jebal Idris	QmIII	Baksa Raised Beach	MIS 15/14	MIS 9	Early Acheulian	Final Acheulian	33	64	7	19
Cheikh Mohammed 8	QmIII	Baksa Raised Beach	MIS 15/13	MIS 9	Early Acheulian	Levallois Mousterian	34	8	8	
Jinnata	QmIII	Baksa Raised Beach	MIS 15/13	MIS 9	None	?Late Acheulian	0	8	0	0
Sqoubine	QmIII	Baksa Raised Beach	MIS 15/13	MIS 9	Early Acheulian	None	19	0	0	0
Berzine	QfIII		MIS 12	?	Middle Acheulian	None	243	0	63	0
Ain El Labane	QfIII		MIS 12	?	?Acheulian	None	16	0	0	0
Dahr el Ayani	QfII	Jinnderiyeh terrace	MIS 6	MIS 8	Late Acheulian	None	81	0	20	2
Roudo Upper	QfII	Jinnderiyeh terrace	MIS 6	MIS 8	Late Acheulian	None	413	0	94	23
Jinnderiyeh	QfII	Jinnderiyeh terrace	MIS 6	MIS 8	?Acheulian	None	70	0	0	0
Souyate Upper	QfII	Jinnderiyeh terrace	MIS 6	MIS 8	Late Acheulian	None	66	0	?	?
Jebal Jibta	QmII	Khellaleh Raised Beach	MIS 11-9-7	MIS 7	Middle Acheulian	None	292	0	70	19
Khellale 4	QmII	Khellaleh Raised Beach	MIS 11-9-7	MIS 7	Middle Acheulian	?Final Acheulian	270	<13	49	11
Khellale 5	QmII	Khellaleh Raised Beach	MIS 11-9-7	MIS 7	Middle Acheulian	?Final Acheulian	65	<13	17	4
Nahr el Arab	QmII	Khellaleh Raised Beach	MIS 11-9-7	MIS 7	Acheulian	Final Acheulian	8	354	7	112
El Hakime	QmII	?Khellaleh Raised Beach	MIS 11-9-7	?MIS 7	None	Final Acheulian	0	6	0	0
Dahr Quadi Hasane	QfII	Ech Chir Terrace	MIS 6	MIS 6	Late Acheulian	None	45	0	0	0
Roudo Lower	QfI	Ech Chir Terrace	MIS 4-2	MIS 6	Final Acheulian	None	117	0	23	6
Souyate Lower	QfI	Ech Chir Terrace	MIS 4-2	MIS 6	Final Acheulian	None	103	0	?	?
Jbaryoun	QfI	Ech Chir Terrace	MIS 4-2	MIS 6	?Acheulian	None	54	0	0	0

distinct deposits was exploited to erect an evolutionary model for the Lower and Middle Palaeolithic of the Kebir and, subsequently, the northern Levant (Table 4). This was considered to demonstrate Lower Palaeolithic 'cultural' evolution through various divisions of the Acheulian (handaxe industry), from Early Acheulian (Acheuléen ancien) though Middle Acheulian (Acheuléen moyen) and Late Acheulian (Acheuléen récent). Additionally, the unabraded artefacts from the surfaces of terraces included a single group of technologically consistent collections of artefact assemblages containing handaxes and evidence of Middle Palaeolithic Levallois core working, grouped under the term Final Acheulian (Acheuléen final). These were from the surfaces of terraces of multiple ages and considered to be from later occupation of the landscape rather than components of, and therefore potentially coeval with, the sediment bodies on which they were found (Copeland and Hours, 1978, 1979). These Acheulian assemblages were post-dated by Middle Palaeolithic 'Mousterian' material lacking handaxes and dominated by Levallois technology.

In the Copeland and Hours (1978, 1979) scheme, assemblages containing small numbers of handaxes or 'proto-handaxes', a preponderance of 'chopper' cores and an absence of evidence for Levallois flaking were taken to characterize the Early Acheulian. This was defined from small collections (total of 156 pieces) from three Kebir localities (Sitt Markho, Jebel Idris and Sheikh Mohammed). These were seen as distinct from those of the Middle Acheulian and the Late Acheulian, the latter associated with the first evidence of Levallois flaking and handaxes in greater numbers. The division between the Middle and Late Acheulian was based on subtle changes in the composition of the handaxe assemblages (a proportional increase in pointed and amygdaloidal forms) and an increase in Levallois flaking (Copeland and Hours, 1979). The Final Acheulian (or the 'Samoukian') was considered to be characterized by a reduction in the number and size of bifacial tools (handaxes), an increased emphasis on Levallois flaking and the presence of small 'chopping tools', leading to Middle Palaeolithic Levantine Mousterian assemblages without handaxes and dominated by Levallois core-working.

This overall framework was subsequently applied to other areas of Syria and Lebanon, most notably the valleys of the Orontes (Copeland and Hours, 1993) and the Euphrates (Copeland, 2004); the Kebir sequence, however, was regarded as the most complete expression, containing most of the identified cultural facies (Copeland and Hours, 1978).

The new, revised geological sequence for the Pleistocene fluvial deposits of the Kebir requires the associated Palaeolithic archaeological record to be reconsidered and implications for the Palaeolithic settlement history of the region to be assessed. Utilizing this new understanding of the deposits, the extant historical collections stored in the National Museum in Damascus have been analysed using updated methodology (Shaw, 2012 and online supplement 1) and related to the small number of artefacts recovered during the present study (these could not be studied in detail but available information is provided in online supplement 2).

2.5.1. *Mchairfet Raised Beach (MIS 11), Sitt Markho Terrace (MIS 10) and Baksaa Raised Beach (MIS 9)*

Previously regarded as significantly older (MIS 17 – MIS 15/13), these deposits are associated with small collections of artefacts that have clearly been abraded and presumably reworked by fluvial/marine processes. The earliest of these are from Mchairfet Es Samouk; all the artefacts from here were previously regarded as post-dating the raised-beach deposits (see Copeland and Hours, 1978, 1979). However, the extant collection contains a small number of pieces that are heavily abraded and thus seem likely to originate from these high-energy deposits, now attributed, on the basis of the rapid local uplift, to MIS 11 (Fig. 3). This collection, along with those associated with the later (fluvial) Sitt Markho Terrace and with the Baksaa Raised Beach, contains small numbers of handaxes alongside simple migrating-platform and discoidal cores. Notably, all lack any evidence for Levallois reduction (Table 5).

Following the previous terrace framework, Copeland and Hours (1978, 1979) interpreted the material from these sites as 'Early Acheulian' and similar in age to Early Pleistocene sites in the Orontes and Euphrates, currently thought to date to between MIS 36 and MIS 16 (see Bridgland et al., 2012; Shaw, 2012). The reappraisal in this report demonstrates that this is not the case, and that no Palaeolithic archaeology or deposits are known from the Kebir that date from this early period. Instead, the archaeology from these sites sits alongside other Lower Palaeolithic assemblages dated to between MIS 13 and MIS 9 that are associated with similar handaxe manufacture and simple core working, but lack evidence of Levallois technology (Shaw, 2012).

2.5.2. *Berzine*

Field surfaces at Berzine have produced heavily abraded artefacts, including handaxes ($n \geq 75$). Originally thought to derive directly from a Pleistocene river terrace, the current study suggests that these originate from slope deposits that have reworked material from earlier, higher-level terrace sediments. As the in situ fluvial and marine gravels are usually cemented, this new interpretation can account for the high concentration of reworked handaxes recovered from these unconsolidated colluvial deposits, such as were observed in section at Jinndireyeh and forming surface regolith at Roudo (Fig. 7; see above). It may also account (in contrast with all other pre-MIS 6 fluvial and marine formations) for the lack of later unabraded material interpreted as post-dating the terrace (see below).

This new understanding of the Berzine deposits is highly significant, as the assemblage from this level was used to define the 'Middle Acheulian' of the Kebir, as distinct from the 'Early Acheulian' of sites such as Sitt Markho (Copeland and Hours, 1978, 1979). Although much larger, the Berzine collection is technologically analogous with that from the Mchairfet Raised Beach and the Sitt Markho Terrace, from which it may well have been largely derived, according to the new interpretation. The extant material is dominated by large, thick, elongated ovate handaxes, often produced with the aid of a soft hammer, whereas both this and the larger core assemblage studied by Copeland and Hours (1979) are dominated by simple migrating-platform cores and lack evidence for Levallois flaking.

Table 5
Palaeolithic artefacts from the Mchairfet Raised Beach, Sitt Markho Terrace and Baksaa Raised Beach.

Site	Associated Pleistocene deposits (Sanlaville, 1979)	Revised associated Pleistocene deposits	Revised age of Pleistocene Deposit	Non-Levallois Flakes	Non-Levallois Cores	Levallois Flakes	Levallois Cores	Handaxes
Mchairfet es Smouk	QmIV	Mchairfet Raised Beach	MIS 11	9	36	0	0	3
Sitt Markho	QfIV	Sitt Markho Terrace	MIS 10	37	14	0	0	2
Fidio	QmIII	Baksa Raised Beach	MIS 9	17	0	0	0	1
Jebal Idris	QmIII	Baksa Raised Beach	MIS 9	0	3	0	0	4
Cheikh Mohammed	QmIII	Baksa Raised Beach	MIS 9	5	1	0	0	2
Totals				**68**	**54**	**0**	**0**	**12**

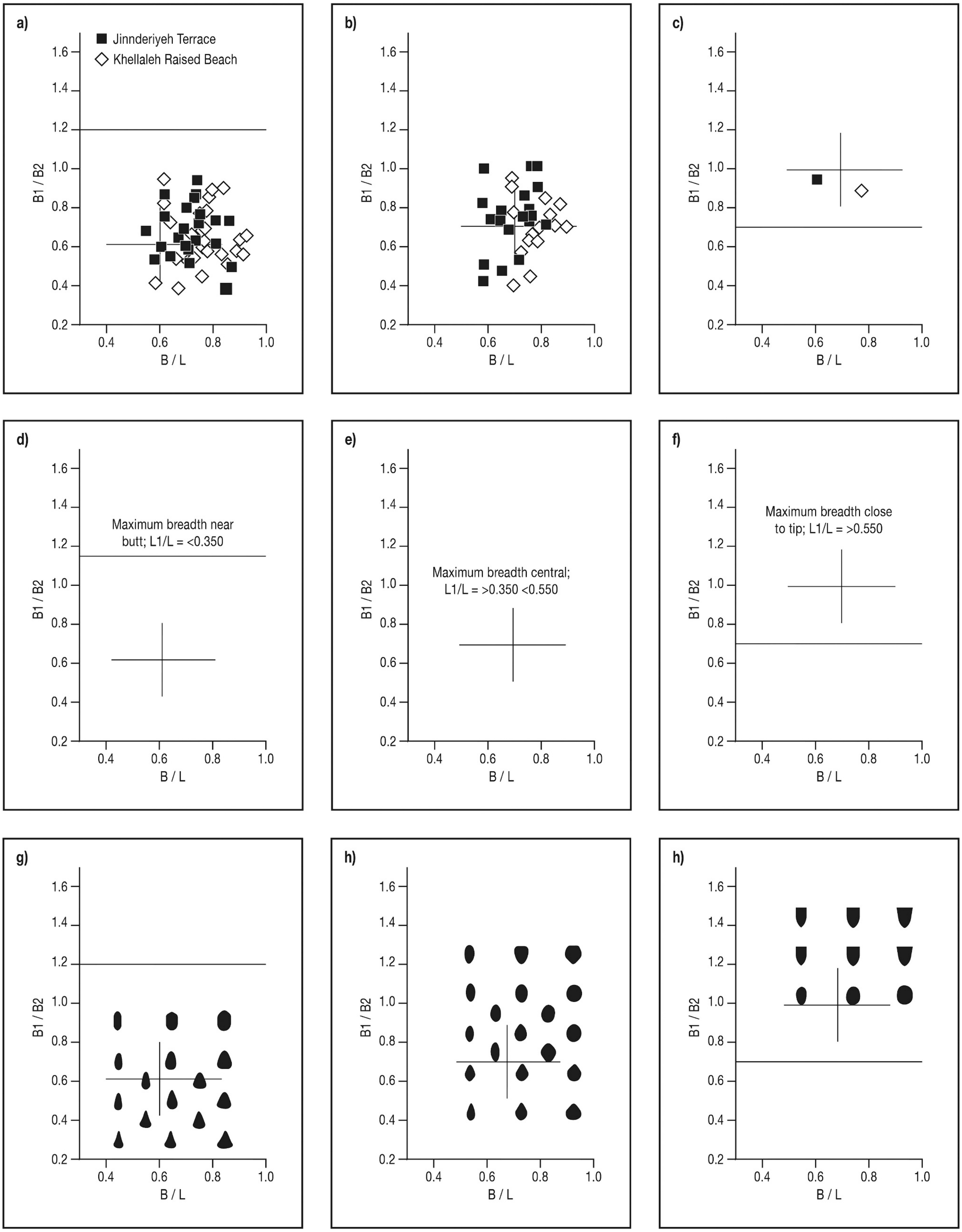

Fig. 12. Planform of reworked (abraded) handaxes associated with the Jinnderiyeh Terrace (solid squares) and Khellaleh Raised Beach (open diamonds); see online supplement 1 for further details.

Table 6
Dimensions and scar counts for handaxes from Berzine, Jinnderiyeh Terrace, Khellale Raised Beach and Final Acheulian sites.

Assemblages	Average length	average butt thickness	average tip thickness	average scar counts
Berzine (n = 41)	117.4	48.1	28	16.9
Jinnderiyeh Terrace (*n* = 47)	111.5	40.6	26.7	18.7
Khellaleh Raised Beach (n = 53)	107.4	39.1	26.3	19.5
Final Achuelian sites (*n* = 20)	94.4	31.5	20.3	19.9

Table 7
Extent of butt working and hammer mode for handaxes from Berzine, Jinnderiyeh Terrace, Khellale Raised Beach and Final Achuelian sites.

Assemblages	Extent of flaking of handaxe butt			Hammer mode		
	None	Partial	Full	Hard	Soft	Mixed
Berzine (*n* = 41)	34.1 %	31.7 %	34.1 %	65.5 %	24.1 %	10.3 %
Jinnderiyeh terrace (n = 47)	14.9 %	55.3 %	29.8 %	79.5 %	10.3 %	10.3 %
Khellale Raised Beach (*n* = 53)	30.2 %	45.3 %	24.5 %	85.3 %	8.8 %	5.9 %
Final Achuelian sites (n = 20)	30.0 %	40.0 %	30.0 %	57.7 %	23.1 %	19.2 %

2.5.3. Jinnderiyeh Terrace (MIS 8) and Khellaleh Raised Beach (MIS 7)

The fluvial and marine deposits of the Jinnderiyeh Terrace and the Khellaleh Raised Beach are associated with large collections of reworked artefacts, particularly handaxes. Under the original lithostratigraphical scheme of Sanlaville (1979), the Khellaleh Raised Beach was regarded as pre-dating the Jinnderiyeh Terrace, whereas the present study indicates that the opposite is the case. This is significant as it undermines the suggested typo-technological transition from the 'Middle Acheulian' of the Khellaleh Raised Beach to the 'Late Acheulian' of the Jinnderiyeh Formation. The key elements in this distinction are a subtle change in handaxe form (an increase in pointed handaxes) and elevated levels of Levallois reduction. Reanalysis of the extant collections finds both suggestions to be questionable. Fig. 12 uses Roe's (1964, 1968) morphometric criteria to illustrate the handaxe forms present. This demonstrates that those from both formations are morphologically analogous and concentrated around elongated ovate handaxes. The core and flake assemblages, although biased towards what were considered typo-technologically significant elements, are also similar, being heavily dominated by simple migrating-platform cores. Despite this selection for diagnostic elements only, a single fluvially abraded Levallois core could be identified; this is from Roudo 'Superieur' and thus likely to derive from the Jinnderiyeh Terrace, implying that the artefact assemblages from the Jinnderiyeh and Khellaleh deposits are typo-technologically analogous, with evidence that the first local appearance of Levallois flaking is associated with the Jinnderiyeh Terrace.

The assemblages from the Jinnderiyeh Terrace and Khellaleh Raise Beach are particularly significant, then, as they provide support the presence of Levallois in Palaeolithic assemblages from MIS 8–7 onwards, initially alongside handaxes (Shaw, 2008). Most other collections containing Levallois material and handaxes in the northern Levant are surface finds lacking chronology. However, assemblages with Levallois from Tahoun Semaan 1 and 2/3 in the Orontes are associated with terrace deposits potentially of MIS 7 age (Shaw, 2012).

2.5.4. Ech Chir Terrace (MIS 6)

Sanlaville (1979) recognized separate lower gravel with overlying sand (QIa) and upper gravel (QIb) divisions within the Ech Chir Formation (the 'f' for fluvial was omitted in that description; both pre-date the 'late Würm' Jraimaqiyeh (QIc) division; see above). Copeland and Hours (1979) identified two groups of assemblages, 'Final Acheulian' with handaxes and evidence of Levallois core working from Q1a, and poorly characterized Middle Palaeolithic/Levantine Mousterian from Q1b. The main archaeological assemblages associated with the Ech Chir Terrace (QIa) were small samples from Roudo 'Inferieur', Souayate 'Inferieur', Jbarioun and Dahr Wadi Hassane. Unfortunately, no material from the latter two survives, whereas the majority of pieces from Souayate 'Inferieur' have been amalgamated with those from Souayate 'Superieur' (part of the Jinnderiyeh Terrace and possibly the slope deposits identified above). The collection from Roudo 'Inferieur' includes abraded pointed ovate handaxes that are technologically and metrically analogous with those from earlier deposits (see above). It also contains clear evidence for Levallois flaking, in the form of four abraded cores. This material could be broadly contemporaneous with the Ech Chir terrace deposits, reworked from older fluvial or marine deposits and/or derived from earlier sediments; it clearly demonstrates the presence of Levallois core working by MIS 6. Very little archaeology attributed to

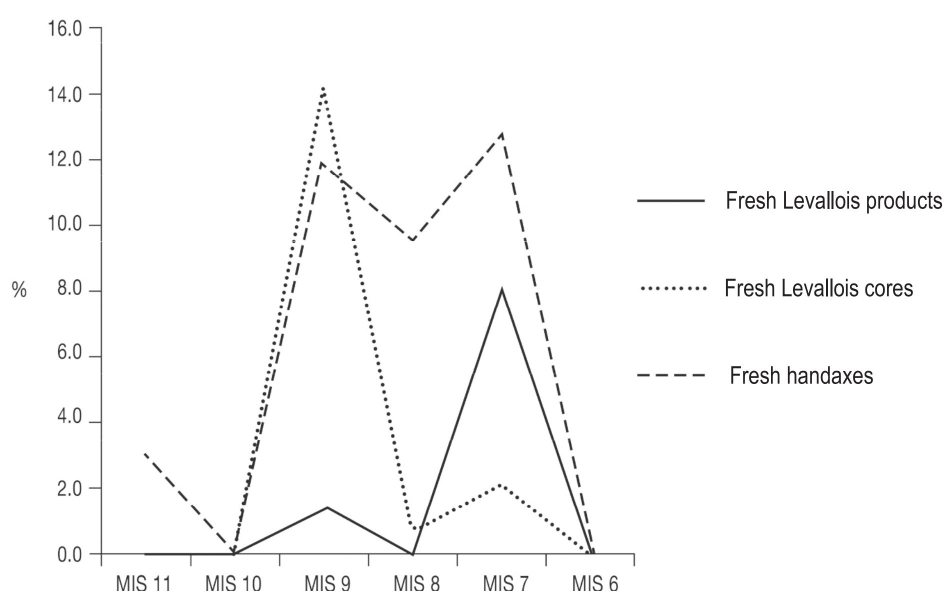

Fig. 13. Fresh Palaeolithic artefacts recovered from terrace surfaces and suggested age of terraces.

Table 8
Lower and Middle Palaeolithic sites from the Euphrates, Orontes and Nahr el Kebir, Syria (data from Shaw, 2012 and current study).

Site	River System	MIS	Simple Core and Flake	Hand-axes	Levallois	Comments
Maadan I	Euphrates	>36	x			
Maadan 5	Euphrates	>36	x			
Ain Abu Jemaa	Euphrates	≤36–≥20	x	x		
Ain Tabous	Euphrates	≤36–≥20	x	x		
Hamadine	Euphrates	≤36–≥20	x	x		
Hammam Kebir II	Euphrates	≤36–≥10	x	x		
Halouandji IV	Sajour	≤36–≥10	x	x		
Rastan	Orontes	≤16–≥10	x	x		
Latamne 'Living Floor'	Orontes	>12	x	x		
Gharmachi 1	Orontes	≤12–≥10	x	x		
Mchairfet es Smouk (Abraded)	Kebir	≥11	x	x		
Sitt Markho	Kebir	≥10	x	x		
Fidio (Abraded)	Kebir	≥9	x	x		
Jebal Idris (Abraded)	Kebir	≥9	x	x		
Cheikh Mohammed (Abraded)	Kebir	≥9	x	x		
Jrabiyat 2	Orontes	≤9–≥7	x	x		
Jrabiyat 3	Orontes	≤9–≥7	x	x		
Jrabiyat 4	Orontes	≤9–≥7	x	x		
Dahr el Ayani (Abraded)	Kebir	≤8	x	x		
Khellale 4 (Abraded)	Kebir	≥7	x	x		
Khellale 5 (Abraded)	Kebir	≥7	Xx	x		
Fidio (Fresh)	Kebir	≤9	x	x	x	
Cheikh Mohammed (Fresh)	Kebir	<9	x	x	x	
Roudo Upper (Abraded)	Kebir	≥8	x	x	x	
Nahr el Arab (Fresh)	Kebir	≤7	x	x	x	
Tahoun Semaan 2 and 3	Orontes	?7	x	x	x	
Roudo Lower (Abraded)	Kebir	≥6	x	x	x	
Tulul Defai	Orontes		Xx	x	x	
Chnine West 1	Euphrates		x	x	x	
Qara Yaaqoub	Sajour		x	x	x	
Chnine East 1	Euphrates		x	x	x	Handaxes represented by thinning flakes
Tahoun Semaan 1	Orontes	?7	x	x	x	1 handaxe and thinning flakes
Rhayat 2	Balikh	?6–4	x	x	x	1 handaxe
Latamne — Red Colluvium	Orontes	<12	x		x	

sub-unit QIb survives but, based on the revised terrace stratigraphy for the Kebir, this material might indicate later Middle Palaeolithic/ Levantine Mousterian from MIS 6 and later.

Palaeolithic artefacts were recovered during the present study in association with deposits of the Ech Chir Terrace (see online supplement 2). These include undiagnostic flakes identified within the fluvial deposits and fluvially abraded handaxes from field surfaces. The handaxes are similar to those recovered from this terrace by Copeland and Hours. Although the lower (a) and upper (b) divisions of the formation were potentially recognized in the section East of Jbarioun (see above), no distinction could otherwise be made.

2.5.5. *Surface sites*

The collections made by Copeland and Hours (1978, 1979) from the Nahr el Kebir include 'Final Acheulian' assemblages originating from terrace surfaces ascribed to all pre-MIS 6 terraces, except for localities attributed by Sanlaville (1979) to the Berzine formation. The material in these collections is in a consistent condition, being heavily patinated, lightly to heavy stained, but unabraded and only lightly edge-damaged. This condition would support an association with the surfaces of the marine and fluvial deposits and/or the extensive colluvial deposits that overlie them. Copeland and Hours (1979) recovered fresh, unabraded artefacts identified as 'Final Acheulian' from terrace surfaces at least five locations (Mchairfet es Smouk, Fidio, Jebel Idris, Nahr el-Arab and El Hakime: see Table 4). The extant collections from these sites contain unabraded handaxes and Levallois cores/products, along with discoidal cores and examples flaked from single/opposed unprepared platforms. All are in the same fresh condition and have been produced on flint cobbles. This exploitation of cobbles from secondary sources (from the beaches and fluvial deposits with which they are associated) through discoidal flaking and reduction from single/opposed platforms accounts for what were previously identified as 'small chopping tools' (Copeland and Hours, 1979). The handaxes from these assemblages are largely analogous in planform and technological characteristics to the reworked examples from the region (Tables 6 and 7), although they tend to be marginally smaller. Currently it is not possible to assign specific age attributions to these assemblages, although the distribution of unabraded handaxes and Levallois material in the Kebir valley is potentially informative, as it demonstrates that these are only associated with the surface of deposits thought to pre-date MIS 6 (Fig. 13). This indicates a *terminus ante quem*.

Although the presence of material of multiple ages cannot be excluded, the evidence would suggest broad contemporaneity between these surface assemblages and deposits of the Jinnderiyeh Terrace (MIS 8) and/or Khellaleh Raised Beach (MIS 7), and that they pre-date the Ech Chir Terrace (MIS 6). An early Middle Palaeolithic (MIS 9–7) date for these surface collections is therefore likely, and would be consistent with similar surface assemblages, some with indications of a comparable age, containing handaxes and Levallois artefacts in the Orontes and Euphrates valleys (Shaw, 2012).

3. Discussion

3.1. *Reinterpretation of the terrace sequence*

It has already been noted, with reference to Fig. 3, that the Sanlaville (1979) interpretation of the Kebir terraces as markedly divergent upstream cannot be corroborated. Instead, the new survey suggests a suite of broadly parallel terraces, all with steep gradients, considerably in excess of that shown by the modern floodplain. Equally fundamental is that the Berzine Terrace cannot be verified as a genuine fluvial formation; on the contrary, it is considered likely that the small hill-top outliers assigned to this formation previously are instead capped by remnants of slope deposits, perhaps once forming a 'glacis' that mantled the NW flank of the valley (see above). Fluvially-abraded artefacts and fragments of calcreted gravel observed amongst the surface debris that coincides with these outliers have probably been derived from higher terrace deposits that have been largely or totally destroyed by erosion. These finds were comparable with material, including numerous heavily abraded handaxes, recovered from the surface of colluvial overburden capping the Jinndireyeh Formation to the SE of the string of Berzine terrace outliers, as has been borne out by the archaeological analysis (see above). This overburden can be presumed to be a thicker downslope representation of the same colluvial 'glacis' material (Fig. 11). Given that fragments of calcreted gravel and artefacts in comparable condition to those from Berzine have also been observed in association with the Sitt Markho outlier (Copeland and Hours, 1979), representative of the highest terrace within the Kebir record, that highest terrace might well be the source of a large proportion of these materials. Although no in situ fluvial sediments were observed at Sitt Markho during the research reported here, it is clear that the artefacts and conglomerate fragments at Berzine and capping the Jinndireyeh Formation must have had a Pleistocene fluvial and/or marine source from upslope. The mismatch between the previously interpreted Palaeolithic assemblages at Sitt Markho and Jebel Berzine would appear to be the chief obstacle to this revised interpretation; this is seemingly eradicated by the more parsimonious interpretation of the archaeology proposed above.

Notwithstanding any archaeological objections, the suggestion, implicit from this reinterpretation, that much of the Lower Palaeolithic record from Berzine and associated sites is derived from older Pleistocene terraces that have been almost entirely lost to erosion, is readily reconciled with new thinking about the mechanics of terrace formation and the dating of the sequence. Despite the addition of a lower, younger terrace overlooked by previous workers, the sequence as a whole is very much younger than envisaged in the earlier interpretations. Thus the Sitt Markho Formation is now attributed to MIS 10 (Fig. 3), which, in terms of the Alpine classification used by Sanlaville (1979) and co-workers, is post-Mindel, in marked contrast to the Günz (=MIS 16) age they assigned to this highest terrace (cf. Table 1). This goes some way to explain the inconsistencies between Palaeolithic records discussed at length, e.g., by Copeland and Hours (1979), who believed the Sitt Markho deposits to be comparable in age with the site at Ubeidiya, Israel, whereas in fact the latter is much older, now dated to 1.4 Ma (Tchernov, 1987, 1999). Similarly, even though they attributed the Berzine assemblage to a river flowing at the level of the small outliers along the NW side of the Kebir valley (whereas in fact these artefacts are now considered to have been reworked from older, higher-level deposits), the age of the Berzine assemblage was probably over-estimated by Copeland and Hours (1979); these artefacts may well be younger than the MIS 12 age implied by the scheme of Sanlaville (1979, cf. Table 1).

3.2. Revised interpretation of the Palaeolithic sequence

The revised terrace stratigraphy for the Kebir and new analysis of the associated Lower and Middle Palaeolithic archaeological records enables the archaeology to be related more convincingly with that from the Orontes and Euphrates valleys. The Lower and Middle Palaeolithic archaeology from those valleys has been reassessed by Shaw (2012) and the combined datasets are summarized and correlated in Table 8.

The earliest Lower Palaeolithic archaeology from the Kebir terraces is unlikely significantly to pre-date MIS 11. The earliest artefact assemblages are those from the Mchairfet Raised Beach, Sitt Markho Terrace and Baksaa Raised Beach (MIS 11–9), which contain fluvially abraded handaxes and migrating-platform cores, without evidence of Levallois core working. These sit alongside handaxe and simple core assemblages that occur extensively in the northern Levant in deposits dated from MIS 13 to MIS 9 (Table 8).

The handaxes in collections from the Kebir are remarkably uniform, both in terms of technological characteristics and form (elongated ovates with pointed tips), and do not exhibit any noticeable differences such as were previously thought to indicate a transition between Early, Middle and Late Acheulian divisions. This similarity in form may reflect their being produced by means of broadly analogous reduction strategies applied to medium-sized cobbles, this being the only available flint source in the Kebir valley (Dubertret, 1966).

As previously observed by Copeland and Hours (1978, 1979), the artefacts from the Kebir do not include 'trihedral handaxes', a form that occurs elsewhere in Syria and has been associated with the 'Middle Acheulian'. The absence of trihedrals from the 'Middle Acheulian' at Berzine was previously taken as indicative of different regional facies (Copeland and Hours, 1979). In this regard, the new age estimates for the Kebir deposits may be significant, as they suggest that all the identified deposits in the Kebir can be assigned to MIS 11 and later, whereas dated assemblages from Syria with trihedrals are assigned to MIS 12 or earlier. Examples include Latamneh, in the Orontes Valley, which can be dated to ~0.5 Ma (MIS 12) or perhaps ~1 Ma (Bridgland et al., 2003, 2012; Bar-Yosef and Belmaker, 2010; Shaw, 2012), and El Meirah, in the el Kowm Basin, which is attributed to MIS 16 (Boëda et al., 2004). However, other factors could also be influencing this absence; for example, it has been suggested that the prevalence of trihedrals at Latamneh is due to exploitation of tabular bedrock-flint blanks using focused hard-hammer reduction (Shaw, 2012). In contrast, production in the Kebir of large cutting tools has relied exclusively on flint cobbles (tabular bedrock blanks not being available) and often involved soft-hammer thinning. Regardless of the implications of the lack of trihedrals, it is clear is that neither the geological framework for the Kebir valley nor the handaxe assemblages support previous claims for 'cultural' evolution here through various divisions of the Acheulian.

The appearance of Levallois flaking is often cited as an important marker in regional Palaeolithic sequences, either as having chronological significance (e.g., Copeland and Hours, 1979) and/or because it is often associated with evidence for more logistical use of landscape by early humans (e.g., Scott, 2011; Shaw, 2012). The evidence from the Kebir is particularly significant, indicating a regional appearance of Levallois during or after MIS 9, which compliments observations made for the Orontes and Euphrates Valleys (Shaw, 2012). The revised terrace stratigraphy for the Kebir additionally indicates that later Middle Palaeolithic/Levantine Mousterian may date to MIS 6 and later. Traditionally the Palaeolithic record of the Levant was divided between the Lower Palaeolithic, with handaxes but little evidence of Levallois flaking, and the Middle Palaeolithic, with abundant evidence of Levallois flaking (alongside other core-working techniques) but lacking handaxes. Over recent decades it has become apparent that the situation is much more complex, with the transition between the Lower and Middle Palaeolithic seeing the appearance of diverse and complex lithic assemblages with both Levallois and laminar core reduction strategies and a general decline in the handaxe as part of the Acheulo-Yabrudian and Hummalian techno-complexes (Jelinek, 1990; Copeland, 2000; Barkai et al., 2009; Barkai and Gopher, 2013; Wojtczak et al., 2014; Shaw, 2017). This transition is also marked by more logistical use of resources and landscapes (e.g., Stiner et al., 2009, 2011), the first repeated occupation of cave sites and rock shelters with more structured use of space (Shahack-Gross et al., 2014) and enhanced technological diversity (Jelinek, 1990; Copeland, 2000; Barkai et al., 2009).

The evidence from the Kebir, alongside that from the Orontes and Euphrates, is indicative of this greater complexity from MIS 9 onwards, with the presence of early Middle Palaeolithic assemblages containing handaxes and Levallois artefacts, which reflect this more logistical and complex use of landscapes by hominins (Shaw, 2012). Notably, however, these collections differ from Acheulo-Yabrudian and Hummalian assemblages, with a greater focus on of handaxes and Levallois reduction, and a lack of the laminar technologies present in those techno complexes. Possible explanations for these differences could be chronological, the presence of a different but broadly contemporary techno-complexes (particularly within the Nahr El Kebir and Orontes, where most collections have been identified) or the selective nature of artefacts recovered as part of brief surveys that lack of excavated assemblages.

4. Conclusions

New research on the Pleistocene and Palaeolithic sequences of the Nahr el Kebir has enabled updated interpretations, accommodating modern knowledge of the complexity of the Quaternary record of climatic fluctuation and a new understanding of crustal processes. The last is key in pointing to this corner of the Mediterranean as having experienced unusually rapid uplift during the recent Quaternary, as a result of which the local rivers, including the Kebir, have deepened their valleys over a much shorter period than rivers in the wider region. Thus the Kebir terraces are quite widely spaced and younger than terraces at comparable heights (above river) in valleys elsewhere: an important nuance for the understanding of landscape evolution over the last 0.5 Ma. As a result, the Kebir terrace sequence represents only the recent part of the Quaternary, approximately coincident with the last four Milankovitch cycles.

This reinterpretation means that ages envisaged previously for the artefact assemblages from the Kebir terraces have been considerably overestimated in some cases, with significant repercussions for understanding of the Lower and Middle Palaeolithic record from the Levant, given the role of the Kebir archive as a template for the wider region. In addition, the revised Pleistocene lithostratigraphical framework and reassessment of the associated Palaeolithic archaeology add to and enhance interpretations of the Lower and early Middle Palaeolithic settlement history of the northern Levant, in particular within the Orontes and Euphrates Valleys. These results demonstrate Lower Palaeolithic technologies dominated by handaxes and simple core working constitute the archaeological record representing MIS 13 to 9 in the Kebir, Orontes and Euphrates valleys, with the appearance of Levallois technique alongside handaxes from approximately MIS 9. The appearance of early Middle Palaeolithic archaeology in the Kebir, Orontes and Euphrates valleys is a probable reflection of wider cross-regional modification of technology and behaviour, which in the southern Levant is related to archaeological assemblages subsumed under the term Acheulo-Yabrudian techno-complex.

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CRediT authorship contribution statement

David R. Bridgland: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Andrew D. Shaw:** Investigation, Methodology, Writing – review & editing. **Rob Westaway:** Formal analysis, Investigation, Methodology, Software. **Mohamad Daoud** Conceptualization. **Mohamad Abou Romieh** Conceptualization, Investigation.

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Data availability

Data will be made available on request.

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References

Abou Romieh, M., Westaway, R., Daoud, M., Radwan, Y., Yassminh, R., Khalil, A., Al-Ashkar, A., Loughlin, S., Arrell, K., Bridgland, D., 2009. Active crustal shortening in NE Syria revealed by deformed terraces of the River Euphrates. Terra Nova 21, 427–437.
Antoine, P., 1994. The Somme valley terrace system (northern France): a model of river response to Quaternary climatic variations since 800,000 bp. Terra Nova 6, 453–464.
Barkai, R., Gopher, A., 2013. Cultural and biological transformations in the Middle Pleistocene Levant: a view from Qesem Cave, Israel. In: Akazawa, T., Nishiaki, Y., Aoki, K. (Eds.), Dynamics of Learning in Neanderthals and Modern Humans. Springer Japan, Tokyo, pp. 115–137.
Barkai, R., Lemorini, C., Shimelmitz, R., Lev, Z., Stiner, M.C., Gopher, A., 2009. A blade for all seasons? Making and using Amudian blades at Qesem Cave, Israel. Hum. Evol. 24, 57–75.
Bar-Yosef, O., Belfer-Cohen, A., 2001. From Africa to Eurasia - early dispersals. Quat. Int. 75, 19–28.
Bar-Yosef, O., Belmaker, M., 2010. Early and Middle Pleistocene Faunal and hominin dispersals through Southwestern Asia. Quaternary Sci. Rev. 30, 1318–1337.
Bassinot, F.C., Labeyrie, L.D., Vincent, E., Quidelleur, X., Shackleton, N.J., Lancelot, Y., 1994. The astronomical theory of climate and the age of the Brunhes–Matuyama magnetic reversal. Earth Planet. Sci. Lett. 126, 91–108.
Besançon, J., 1979. Préhistoire et géomorphologie. In: Sanlaville, P. (Ed.), Quaternaire et préhistoire du Nahr el Kébir septentrional. Les débuts de l'occupation humaine dans la Syrie du nord et au Levant. Collection de la Maison de l'Orient Méditerranéan no, 9, Série Géographique et Préhistorique no, 1. CNRS, Paris, pp. 121–135.
Besançon, J., Geyer, B., 2003. La géomorphologie de la basse vallée de l'Euphrate Syrien: Contribution à l'étude des changements de l'environnement géographique au Quaternaire. In: Geyer, B., Montchambert, J.-Y. (Eds.), La Basse Vallée de l'Euphrate Syrien du Néolithique a l'avenement de l'Islam. Vol. 1: text, Mission Archéologique de Mari, vol, 6. Institut Francais du Proche Orient, Beirut, Lebanon, pp. 7–59.
Besançon, J., Hours, F., 1971. Préhistoire et géomorphologie: les forms du relief et les dépôts quaternaires dans la région de Joubb Jannine (Béqaa méridionale, Liban). Hannon (Revue libanaise de Géographie) 6, 29–135.
Besançon, J., Sanlaville, P., 1981. Aperçu géomorphologique sur la vallée de l'Euphrate Syrien. Paléorient 7 (2), 5–18.
Besançon, J., Sanlaville, P., 1984. Terrasses fluviatiles au Proche-Orient. Bulletin de l'Association Française pour l'Etude du Quaternaire 186–191.
Besançon, J., Sanlaville, P., 1993. La vallée de l'Oronte entre Rastane et Aacharné. In: Sanlaville, P., Besançon, J., Copeland, L., Muhusen, S. (Eds.), Le Paléolithique de la vallée moyenne de l'Oronte (Syrie), Peuplement et environnement. British Archaeological Reports, International Series, 587, pp. 13–39.
Besançon, J., Copeland, L., Hours, F., 1972. Tableaux de Préhistoire libanaise (Part 1). Hannon (Revue libanaise de Géographie) 7, 61–88.
Besançon, J., Copeland, L., Hours, F., Sanlaville, P., 1977. Sur le quaternaire de la région de Lattaquié (Syrie). Comptes Rendus de l'Académie des Sciences, Series D 284, 1971–1974.
Besançon, J., Copeland, L., Hours, F., Sanlaville, P., 1978. The Palaeolithic sequence in Quaternary formations of the Orontes river valley, northern Syria: a preliminary report. Bulletin of the Institute of Archaeology London 15, 149–170.
Besançon, J., Copeland, L., Sanlaville, P., 1988. Réflexions sur les prospections géo-préhistoriques au Proche-Orient. Paléorient 14, 31–39.
Boëda, E., Courty, M.-A., Fedoroff, N., C. Griggo, I., Hedley, G., Muhusen, S., 2004. Le site acheuléen d'El Meireh, Syrie. In: Aurenche, O., Le Mière, M., Sanlaville, P. (Eds.), From the River to the Sea: The Palaeolithic and the Neolithic on the Euphrates and in the Northern Levant. Studies in Honour of Lorraine Copeland., British

Archaeological Reports International Series 1263. Archaeopress, Oxford, pp. 165–201.
Bridgland, D.R., 2000. River terrace systems in north-west Europe: an archive of environmental change, uplift and early human occupation. Quaternary Sci. Rev. 19, 1293–1303.
Bridgland, D.R., 2014. John Lubbock's early contribution to the understanding of river terraces and their importance to geography, archaeology and Earth science. Notes Records R. Soc. J. History Sci. 68, 1. https://doi.org/10.1098/rsnr.2013.005.
Bridgland, D.R., Westaway, R., 2008. Climatically controlled river terrace staircases: a worldwide Quaternary phenomenon. Geomorphology 98, 285–315.
Bridgland, D.R., Westaway, R., 2012. The use of fluvial archives in reconstructing landscape evolution: the value of sedimentary and morphostratigraphical evidence. Netherlands J. Geosci. 91, 5–24.
Bridgland, D.R., Westaway, R., 2014. Quaternary fluvial archives and landscape evolution: a global synthesis. Proc. Geol. Assoc. 125, 600–629.
Bridgland, D.R., Philip, G., Westaway, R., White, M., 2003. A long Quaternary terrace sequence in the Orontes River valley, Syria: a record of uplift and of human occupation. Curr. Sci. 84, 1080–1089.
Bridgland, D.R., Maddy, D., Bates, M., 2004. River terrace sequences: templates for Quaternary geochronology and marine–terrestrial correlation. J. Quaternary Sci. 19, 203–218.
Bridgland, D.R., Antoine, P., Limondin-Lozouet, N., Santisteban, J.I., Westaway, R., White, M.J., 2006. The Palaeolithic occupation of Europe as revealed by evidence from the rivers: data from IGCP 449. J. Quat. Sci. 21, 437–455.
Bridgland, D.R., Westaway, R., Daoud, M., Yassminh, R., Abou Romieh, M., 2008. River Terraces of the Nahr el Kebir, NW Syria, and their Palaeolithic record. CBRL Bulletin 3, 36–41.
Bridgland, D.R., Westaway, R., Abou Romieh, M., Candy, I., Daoud, M., Demir, T., Galiatsatos, N., Schreve, D.C., Seyrek, A., Shaw, A., White, T.S., Whittaker, J., 2012. The River Orontes in Syria and Turkey: downstream variation of fluvial archives in different crustal blocks. Geomorphology 165–166, 25–49.
Chauhan, P., Bridgland, D.R., Moncel, M.-H., Antoine, P., Bahain, J.-J., Briant, R.M., Cunha, P., Locht, J.-L., Martins, A., Schreve, D., Shaw, A., Voinchet, P., Westaway, R., White, M., White, T., 2017. Fluvial deposits as an archive of early human activity: progress during the 20 years of the fluvial archives group. Quaternary Sci. Rev. 166, 114–149.
Copeland, L., 2000. Yabrudian and related industries: the state of research in 1996. In: Ronen, A., Weinstein-Evron, M. (Eds.), Toward Modern Humans: Yabrudianand Micoquian, 400–50 Kyears Ago, BAR International Series, 850, pp. 97–117. Oxford.
Copeland, L., 2004. The Palaeolithic of the Euphrates Valley in Syria. In: Aurenche, O., Le Mière, M., Sanlaville, P. (Eds.), From the River to the Sea: The Palaeolithic and the Neolithic on the Euphrates and in the Northern Levant. Studies in Honour of Lorraine Copeland, British Archaeological Reports International Series, 1263. Archaeopress, Oxford, pp. 19–61.
Copeland, L., Hours, F., 1978. La séquence Acheuléenne du Nahr el Kebir, région septentrionale du littoral Syrien. Paléorient 4, 5–31.
Copeland, L., Hours, F., 1979. Le Paléolithique du Nahr el Kebir. In: Sanlaville, P. (Ed.), Quaternaire et préhistoire du Nahr el Kébir septentrional. Les débuts de l'occupation humaine dans la Syrie du nord et au Levant. Collection de la Maison de l'Orient Méditerranéan no. 9, Série Géographique et Préhistorique no. 1. CNRS, Paris, pp. 29–119.
Copeland, L., Hours, F., 1993. The Middle Orontes Palaeolithic flint industries. In: Sanlaville, P., Besançon, J., Copeland, L., Muhusen, S. (Eds.), Le Paléolithique de la vallée moyenne de l'Oronte (Syrie); peuplement et environment, British Archaeological Reports International Series, 587. Archaeopress, Oxford, pp. 63–144.
Cordier, S., Harmand, D., Frechen, M., Beiner, M., 2006. Fluvial system response to Middle and Upper Pleistocene climate change in the Meurthe and Moselle valleys (Eastern Paris Basin and Rhenish Massif). Quat. Sci. Rev. 25, 1460–1474.
Demir, T., Westaway, R., Seyrek, A., Bridgland, D., 2007. Terrace staircases of the River Euphrates in southeast Turkey, northern Syria and western Iraq: evidence for regional surface uplift. Quaternary Sci. Rev. 26, 2844–2863.
Demir, T., Seyrek, A., Westaway, R., Guillou, H., Scaillet, S., Beck, A., Bridgland, D.R., 2012. Late Cenozoic regional uplift and localised crustal deformation within the northern Arabian Platform in southeast Turkey: investigation of the Euphrates terrace staircase using multidisciplinary techniques. Geomorphology 165–166, 7–24.
Devyatkin, E.V., Dodonov, A.E., Gablina, S.S., Golovina, L.A., Kurenkova, V.G., Simakova, A.N., Trubikhin, V.M., Yasamanov, N.A., Khatib, K., Nseir, H., 1996. Upper Pliocene–Lower Pleistocene marine deposits of western Syria: stratigraphy and paleogeography. Stratigr. Geol. Correl. 4, 67–77.
Dubertret, L., 1966. Liban, Syrie et bordures des pays voisibns. 1e partie:tableau stratigraphique avec carte géologique au millonième. Notes et Mém. Moyen-Orient. 8, 249–358.
Duman, T.Y., Emre, Ö., 2013. The East Anatolian Fault: geometry, segmentation and jog characte- ristics. In: Robertson, A.H.F., Parlak, O., Ünlügenç, U.C. (Eds.), Geological Development of Anatolia and the Easternmost Mediterranean Region, 372. London, Special Publications, Geological Society. https://doi.org/10.1144/SP372.14 (35 pp.).
Evans, J., 1863. Account of some further discoveries of flint implements in the drift on the Continent and in England. Archaeologia 39, 57–84.
Goren-Inbar, N., 1988. The lower Palaeolithic–synthesis. Paléorient 14, 109–111.
Hauck, T., Wojtczak, D., Wegmüller, F., Le Tensorer, J.-M., 2010. Variation in Lower and Middle Palaeolithic land use strategies in the Syrian Desert steppe: the example of Hummal (El Kowm area). In: Conard, D., Delagnes, A. (Eds.), Settlement Dynamics of the Middle Palaeolithic and Middle Stone Age, III. Kerns, Tübingen, pp. 145–162.
Hours, F., 1981. Le Paléolithique inférieur de la Syrie et du Liban. Le Point de la question en 1980. In: Cauvin, J., Sanlaville, P. (Eds.), Préhistoire du Levant: Chronologie et organisation de l'espace depuis les origines jusqu'au VIe millénaire, Colloques Internationaux du Centre National de la Recherche Scientifique, 598. Centre National de la Recherche Scientifique, Lyon, pp. 165–183.
Hours, F., 1994. Western Asia in the period of *Homo habilis* and *Homo erectus*. In: de Laet, S.J. (Ed.), History of Humanity: Vol. 1 Prehistory and the Beginnings of Civilization. UNESCO, pp. 62–77.
Jelinek, A., 1990. The Amudian in the Context of the Mugharan Tradition at the Tabun Cave, Mount Carmel (Israel). In: Mellars, P. (Ed.), The Emergence of Modern Humans. An Archaeological Perspective. Edinburgh University Press, Edinburgh, pp. 81–90.
Le Tensorer, J.M., Le Tensorer, H., Martini, P., von Falkenstein, V., Schmid, P., Villalain, J.J., 2015. The oldowan site aïn al fil (El kowm, Syria) and the first humans of the Syrian desert. L' Anthropologie 119, 581–594.
Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene–Pleistocene stack of 57 globally distributed benthic δ^{18}O records. Paleoceanography 20, PA1003. https://doi.org/10.1029/2004PA001071.
Lubbock, J., 1862. On the evidence of the antiquity of man, afforded by the physical structure of the Somme Valley. Nat. History Rev. 2, 244–269.
Macklin, M.G., Fuller, I.C., Lewin, J., Maas, G.S., Passmore, D.G., Rose, J., Woodward, J. C., Black, S., Hamlin, R.H.B., Rowan, J.S., 2002. Correlation of fluvial sequences in the Mediterranean basin over the last 200 ka and their relationship to climate change. Quaternary Sci. Rev. 21, 1633–1641.
Maddy, D., Bridgland, D.R., Green, C.P., 2000. Crustal uplift in southern England; evidence from the river terrace records. Geomorphology 33, 167–181.
Maddy, D., Bridgland, D., Westaway, R., 2001. Uplift-driven valley incision and climate-controlled river terrace development in the Thames Valley, UK. Quat. Int. 79, 23–36.
Meignen, L., Bar-Yosef, O., 2020. Acheulo-Yabrudian and Early Middle Paleolithic at Hayonim Cave (Western Galilee, Israel): continuity or break? J. Hum. Evol. 139, 102733.
Merritts, D.J., Vincent, K.P., Wohl, E.E., 1994. Long river profiles, tectonism, and eustasy: a guide to interpreting fluvial terraces. J. Geophys. Res. 99, 14031–14050.
Mishra, S., White, M.J., Beaumont, P., Antoine, P., Bridgland, D.R., Howard, A.J., Limondin-Lozouet, N., Santisteban, J.I., Schreve, D.C., Shaw, A.D., Wenban-Smith, F. F., Westaway, R.W.C., White, T., 2007. Fluvial deposits as an archive of early human activity. Quaternary Sci. Rev. 26, 2996–3016.
Muhusen, S., 2002. The Earliest Paleolithic Occupation in Syria. In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), Neanderthals and Modern Humans in Western Asia. Kluwer Academic Publishers, New York, pp. 95–105.
Prestwich, J., 1860. On the occurrence of flint-implements, associated with the remains of animals of extinct species in beds of a late geological period, in France at Amiens and Abbeville, and in England at Hoxne. Philos. Trans. R. Soc. London 150, 277–317.
Roe, D.A., 1964. The British Lower Palaeolithic industries: some problems, methods of study and preliminary results. Proc. Prehistoric Soc. 30, 245–467.
Roe, D.A., 1968. British Lower and Middle Palaeolithic handaxe groups. Proc. Prehistoric Soc. 34, 1–82.
Sanlaville, P., 1977. Etude géomorphologique de la region littorale du Liban. Université Libanaise, Beyrouth (2 vol., 859 pp).
Sanlaville, P., 1979. Étude géomorphologique de la basse-vallée du Nahr el Kébir. In: Sanlaville, P. (Ed.), Quaternaire et préhistoire du Nahr el Kébir septentrional. Les débuts de l'occupation humaine dans la Syrie du nord et au Levant. Collection de la Maison de l'Orient Méditerranéan no. 9, Série Géographique et Préhistorique no. 1. CNRS, Paris, pp. 7–28.
Scott, B., 2011. Becoming Neanderthals: The Earlier British Middle Palaeolithic. Oxbow, Oxford.
Seyrek, A., Demir, T., Pringle, M., Yurtmen, S., Westaway, R., Bridgland, D., Beck, A., Rowbotham, G., 2008. Late Cenozoic uplift of the Amanos Mountains and incision of the Middle Ceyhan river gorge, southern Turkey; Ar–Ar dating of the Düziçi basalt. Geomorphology 97, 321–355.
Shahack-Gross, R., Berna, F., Karkanas, P., Lemorini, C., Gopher, A., Barkai, R., 2014. Evidence for the repeated use of a central hearth at Middle Pleistocene (300 ky ago) Qesem Cave, Israel. J. Archaeol. Sci. 44, 12–21.
Shaw, A.D., 2008. The Earlier Palaeolithic of Syria: Settlement History, Technology and Landscape-use in the Orontes and Euphrates Valleys (Unpublished Ph.D Thesis). University of Durham.
Shaw, A.D., 2012. The Earlier Palaeolithic of Syria: Reinvestigating the Evidence From the Orontes and Euphrates Valleys. Archaeopress, Oxford.
Shaw, A., 2017. Lower and Middle Palaeolithic of Lebanon. In: Enze, Y., Bar-Yosef, O. (Eds.), Quaternary of the Levant: Environments, Climate Change, and Humans. Cambridge University Press, Cambridge, pp. 555–566.
Šibrava, V., 1986. Correlation of European glaciations and their relation to the deep-sea record. Quaternary Sci. Rev. 5, 433–442.
Starkel, L., 2003. Climatically controlled terraces in uplifting mountain areas. Quaternary Sci. Rev. 22, 2189–2198.
Stiner, M.C., Barkai, R., Gopher, A., 2009. Cooperative hunting and meat sharing 400–200 kya at Qesem Cave, Israel. Proc. Natl. Acad. Sci. U. S. A. 106, 13207–13212.
Stiner, M.C., Barkai, R., Gopher, A., 2011. Hearth-side socioeconomics, hunting and paleoecology during the late Lower Paleolithic at Qesem Cave, Israel. J. Hum. Evol. 60, 213–233.
Tchernov, E., 1987. The age of the 'Ubeidiya Formation, an Early Pleistocene hominid site in the Jordan Valley, Israel. Isr. J. Earth Sci. 36, 3–30.
Tchernov, E., 1999. The earliest hominids in the southern Levant. In: Proceedings of the International Conference of Human Palaeontology, Orce, Spain, 1995. Museo de Prehistoria y Paleontologia, Orce, Spain, pp. 389–406.
Vandenberghe, J., 1995. Timescales, climate and river development. Quaternary Sci. Rev. 14, 631–638.

Vandenberghe, J., 2002. The relation between climate and river processes, land-forms and deposits during the Quaternary. Quat. Int. 91, 17–23.
Vandenberghe, J., 2003. Climate forcing of fluvial system development; an evolution of ideas. Quaternary Sci. Rev. 22, 2053–2060.
Vandenberghe, J., 2007. The fluvial cycle at cold–warm–cold transitions in lowland regions: a refinement of theory. Geomorphology 98, 275–284.
Westaway, R., 2004. Kinematic consistency between the Dead Sea Fault Zone and the Neogene and Quaternary left-lateral faulting in SE Turkey. Tectonophysics 391, 203–237.
Wojtczak, D., Le Tensorer, J.M., Demidenko, Y.E., 2014. Hummalian industry (El Kowm, Central Syria): core reduction variability in the Levantine Early Middle Palaeolithic. Quartär 61, 23–48.