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# Lithic Variability and Techno-Economy of the Initial Upper Palaeolithic in the Levant

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**Abstract:** The Levant forms a geographic bridge between Africa and Eurasia, making it a focal point for research on past human dispersals. The Initial Upper Palaeolithic (IUP) of the Levant is commonly associated with *Homo sapiens*' dispersal from Africa to Eurasia, which is characterised by substantial changes in material culture when compared to the preceding Middle Palaeolithic. While many researchers have noticed considerable variability among these IUP lithic assemblages, a systematic evaluation is currently missing. The study presented here addresses this cavity by employing techno-typological data from relevant Levantine IUP assemblages. Statistical methods, namely principal component analysis (PCA) and linear discriminant analysis (LDA) allow structuring these assemblages into distinct groups. These groups are then reviewed against palaeogeographic data and techno-economic behaviour patterns. Results show that IUP assemblages in the Mediterranean zone are similar to each other in regards to techno-typology, palaeogeography and techno-economic behaviour, being indicative of residential base camps. Contrastingly, assemblages in the semi-arid zone are more variable in regards to techno-typology and techno-economy, indicating more specialised activities such as hunting/butchering, which is often combined with local raw material exploitation.

**Keywords:** Initial Upper Palaeolithic, Middle-Upper Palaeolithic Transition, Levant, Lithics, Techno-Economy, Technological Organization, Human-Environment Interactions

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## 1. Introduction

The geographic position of the Levant, situated between Africa and Europe, has made it a focal point of discussion concerning the dispersal of *Homo sapiens* out of Africa during the Pleistocene [1–14]. While *H. sapiens* emerged in Africa some 300–200 ka BP ago, making their first appearance in the Levant between ca. 200–120 ka BP, settlement in that region is often considered discontinuous and a second, genetically distinct population is expected to have left Africa around 60–50 ka BP [15–17].

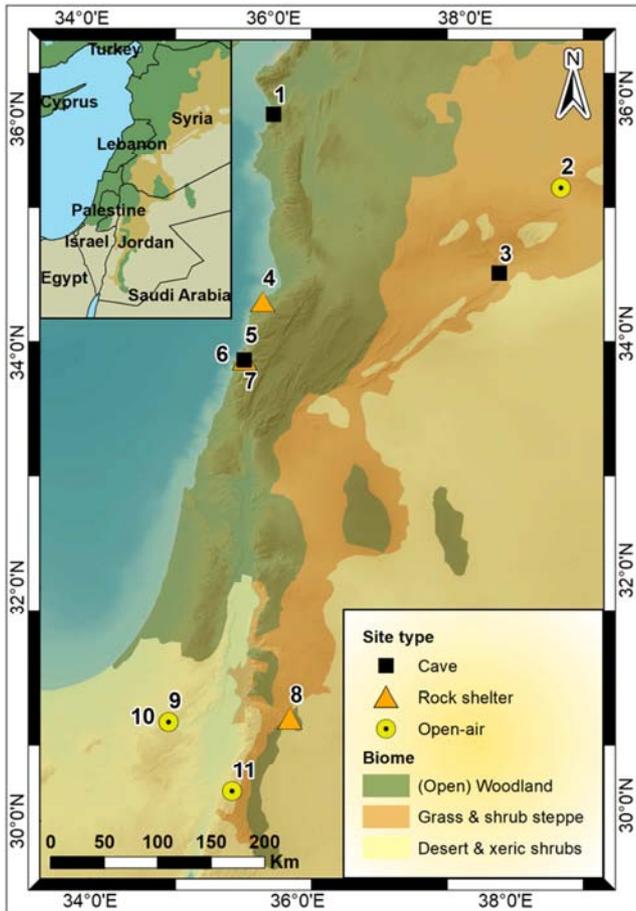
The discovery of a human skull cap from Manot Cave suggests *H. sapiens*' recurrence into the Levant by ca. 55 ka, which is in agreement with palaeogenetic models [18]. *H. sapiens*' recurrence during the late Middle Palaeolithic is succeeded by a change in lithic material culture along with indications of symbolic behaviour expressed in the form of shell beads [19, 20]. These changes in material culture traditions are subsumed under the umbrella terms ‘Middle-

Upper Palaeolithic transition’ or ‘Initial Upper Palaeolithic’ (IUP). While the term transition implies continuation between Middle and Upper Palaeolithic, IUP implies a disentanglement from preceding traditions [4, 10]. As the question of continuity is currently unresolved for most of Eurasia, IUP is preferred here as a more neutral term.

Lithic assemblages assigned to the Levantine IUP were first recognised in Lebanon (Abou Halka, Antelias Cave, Ksar Akil,) and in Israel (Emireh Cave and El-Wad Cave) before WWII, and the differences between both regions were acknowledged early [21–29]. In addition, a number of sites have been excavated since WWII (Ansab 2, Boker Tachtit, Jerf Ajla Cave, Mughr el-Hamamah, Tor Sadaf, Üçağızlı Cave, Raqefet Cave, Umm el Tlel and Wadi Aghar), and were placed within the IUP context, although they have been labelled variedly, e.g. transitional, IUP, Emiran, or intermediate (Table 1.; Figure 1; [30–37]).

**Table 1.** IUP assemblages in the Levant mentioned in the text.

Site	IUP levels	Abbreviation	References
Üçağızlı Cave	I–F	Üç I–F	[30]
Umm el Tlel	IIbase, III2a	UM IIbase	[33–34]
Jerf Ajla Cave	B, C	JA B&C	[31–32]
Abou Halka	IVf, IVe	AH IVf–IVe	[4, 22, 27, 38]
Ksar Akil	XXV–XXI	KA XXV–XXI	[4, 27–29, 38]
Antelias Cave	V–VII	AN V–VII	[26], this study
Tor Sadaf	A, B	TS A&B	[35]
Boker Tachtit	1–4	BT 1	[35, 39, 40]
Ansab 2	-	ANS2	[37], this study



**Figure 1.** Sites and assemblages mentioned in the text. (1) Üçağızlı Cave. (2) Umm el Tlel. (3) Jerf Ajla Cave. (4) Abou Halka. (5) Ksar Akil XXV–XXII. (6) Ksar Akil XXI. (7) Antelias Cave. (8) Tor Sadaf. (9) Boker Tachtit 1–3. (10) Boker Tachtit 4. (11) Ansab 2. Biomes are based on modern data changed after [42] since no biome data was available for MIS 3.

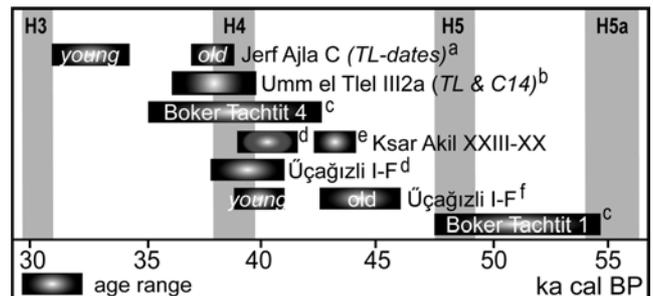
Dating efforts in recent years have shown that IUP assemblages were deposited broadly between Heinrich 4 and 5, i.e. during 10–15 ka. Although various age estimates are under discussion, Boker Tachtit 1 would currently represent the oldest assemblage – presupposed that renewed dating can confirm the conventional  $C^{14}$  dates – and Umm el Tlel III2a would represent the youngest assemblage (Figure 2).

Charcoal from Boker Tachtit was dated by conventional radiocarbon dating, resulting in large standard deviations [36].

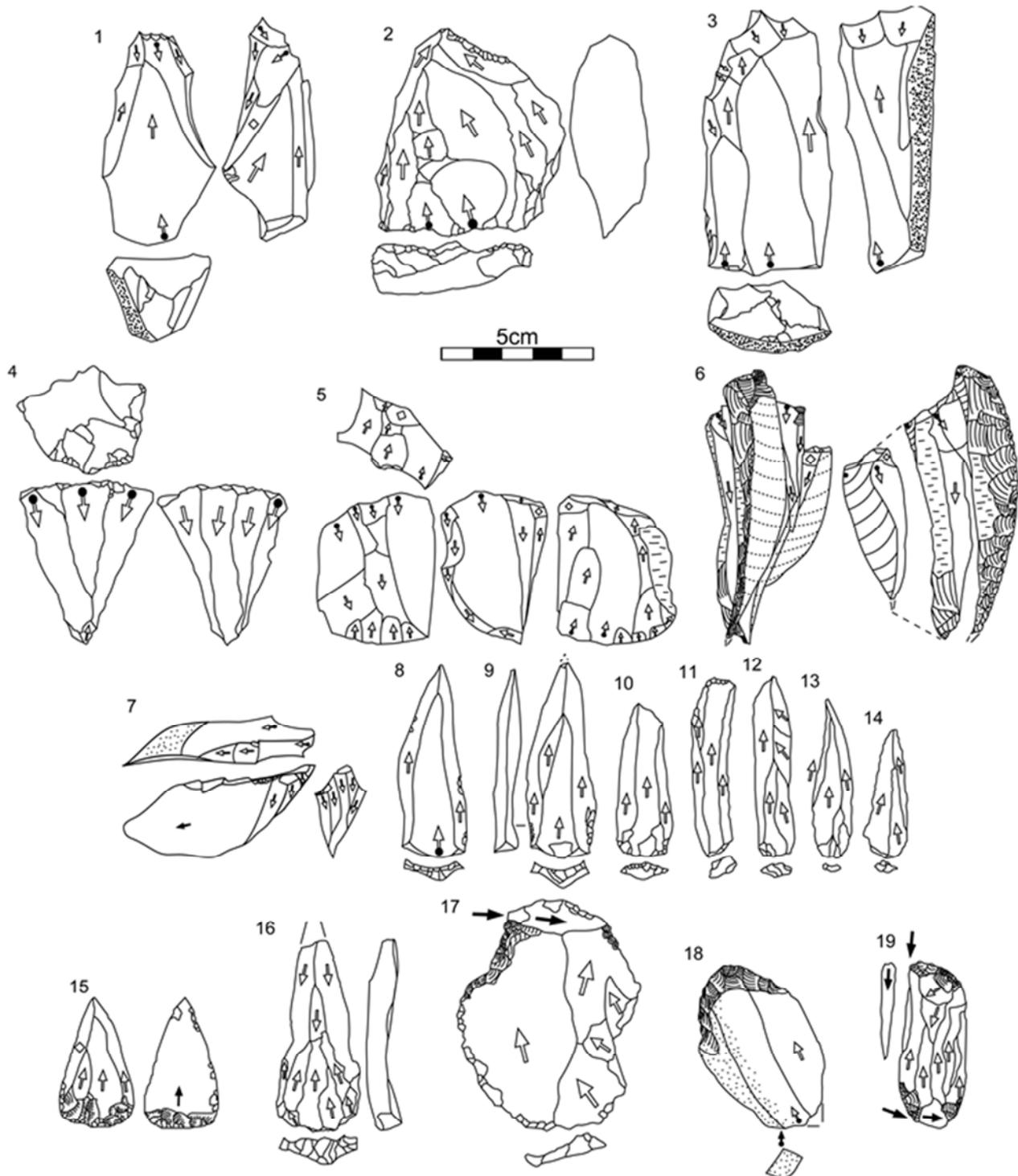
Based on dated sea shells, two age models exist for Ksar Akil with an age difference of some 2–3 ka between them [20, 41]. Dated charcoal from Üçağızlı shows a bimodal distribution resulting in a younger data set and an older one for the same layers. While the authors support the older results, more recent radiocarbon dating on sea shells coincide with the younger set [30, 41]. Comparable issues concern the TL dates of Jerf Ajla, which also created two different age sets [32]. Only the older one would overlap with age estimates from the nearby Umm el Tlel site that yielded consistent age estimates generated by TL & radiocarbon dating [33–34]. Accordingly, most IUP sites seem to date around 40–45 ka cal BP, with Boker Tachtit possibly being older and two or three sites being younger than 40 ka cal BP.

Lithic assemblages of the Levantine IUP involve diverse blade production systems on a) hierarchically organised cores (along-axis cores/recurrent convergent Levallois cores) and b) volumetric cores (Figure 3 (1–7); [4, 38, 43, 44]). Tool kits consist of typical Upper Palaeolithic tool types such as endscrapers, burins, and truncations plus numerous edge-retouched pieces, and in some cases, chamfered pieces, Emireh points or Umm el Tlel points (Figure 3 (15–19)). The convergent blank, sometimes called elongated (non-) Levallois point, is mutual to all IUP assemblages and a function as hunting/cutting tools, analogues to Levallois points, is assumed (Figure 3 (8–9); [45]).

Considerable variability among the various IUP lithic assemblages has been acknowledged for some time, but a clear outline is still missing. Consequently, this paper aims to investigate the techno-typological variability of Levantine IUP assemblages in a systematic manner, and to test for consistency regarding palaeogeographic factors and techno-economy.



**Figure 2.** Radiometric age estimates of IUP sites in the Levant. All dates are radiocarbon dates unless indicated otherwise. Only calibrated dates are used, while estimates based on Bayesian modelling had to be excluded for reasons of better comparability. a: [32], b: [33–34], c: [36], d: [41], e: [20], f: [30].



**Figure 3.** Typical lithic artefacts of the Levantine IUP. (1) preferential convergent along-axis core. (2) recurrent convergent along-axis core. (3) parallel along-axis core. (4–5) volumetric cores. (6) refitted blanks from blade core-on-flake. (7) bladelet-core-on-flake. (8–9) convergent blades. (10–11) blunt blades. (12–14) pointed blades. (15) Emireh point. (16) Umm el Tel point. (17) chanfrein. (18) endscraper; (19) burin-chanfrein. (1, 3, 8–9) redrawn from [26], (2, 4, 10–14, 17, 19) redrawn from [27], (5–7, 18) own work, (15) redrawn from [46], (16) redrawn from [39].

## 2. Materials and Methods

### 2.1. Data Sources, Data Assessment and Data Processing

Lithic assemblages and geographic information from Levantine IUP sites form the basis of this study (Tables 2–4).

While most of the data were extracted from published works (Üçagizli I–F, Umm el Tlel I base, Jerf Ajla B&C, Abou Halka IVf/IVe, Ksar Akil XXV–XXI, Antelias VI–VII, Tor Sadaf A&B, Boker Tachtit 1–4), some assemblages have been studied by the author (Table 1; Antelias V, Ksar Akil XXV, XXII, Abou Halka IVf, Ansab 2). Whenever

technological differences were deemed minor in previous publications, assemblages from the same site have been combined in this study in order to simplify data handling and analysis.

Lithic assemblages from sites in Lower Galilee (Emireh Cave, El-Wad Cave and Raqefet caves) could not be included due to taphonomic issues, and published information from two other sites in Jordan - Mughr el-Hamamah and Wadi Aghar - are currently too preliminary to be considered [44, 47–50].

Not all publications provided information in the desired resolution due to different research goals and methods, and in some cases, different terminologies, making direct comparisons a challenge. Therefore, where quantitative data was not available, inferences were made from detailed written descriptions. Accordingly, when quantitative data were indeed provided in published works, data concerning the same variables were processed in the same way, so that inter-assemblage comparisons could be facilitated. In a few cases however, the selected variables could not be quantified at all. Additionally, some assemblages excavated before WWII did employ excavation standards that are not comparable to modern ones, impacting data quality, such as blank:tool ratios at Lebanese sites [23, 27].

Information obtained through these various sources were

computed as standardised variables to make them serviceable in multivariate statistical analyses using the PAST 3.17 software [51]. Inter-assemblage variability was tested in three categories a) techno-typology, b) palaeogeography and c) techno-economy (Tables 2–4).

Principal component analysis (PCA) was individually performed on all three categories to identify major variables that underlie the observed inter-assemblage variability. PCA scores of the individual assemblages were then used to determine assemblage groups according to the aforementioned categories via linear discriminant analysis (LDA). Only groupings that resulted in 100% correct classifications when jackknifing was applied, were accepted. The consistency of these groups across the three predefined categories, i.e. techno-typology, paleogeography and techno-economy, was then assessed using linear regression analysis.

In respect to techno-economy data, tool kit richness and tool kit evenness have been calculated in order to estimate the range of activities performed with each tool kit (richness) and their functional specialisation (evenness). Menhinicks richness index was employed to calculate richness and the Shannon-Weaver index was employed to calculate evenness. Both account for tool kit size rather than simply providing tool type counts.

**Table 2.** Technological data of the various IUP sites employed in PCA & LDA.

Variables	Data type	Üçagizli I–F	Umm el Tlel IIbase	Jerf Ajla B & C	Abou Halka IVf–IVe	Ksar Akil XXV–XXII	Ksar Akil XXI	Antelias V–VII	Tor Sadaf A & B
Core type abundance									
along-axis (A-A)	relative abundance	2	2	2	2	2	2	2	2
volumetric	relative abundance	2	0	0	2	2	2	2	2
Levallois	relative abundance	0	1	1	0	0	0	0	0
narrow-fronted	relative abundance	0	1	2	0	0	0	0	0
bladelet-core-on-flake	relative abundance	0	1	1	0	0	0	1	0
Core subtype abundance									
A-A preferential convergent	relative abundance	1	3	3	1	1	1	3	1
A-A recurrent convergent	relative abundance	2	0	0	2	2	2	0	2
A-A parallel	relative abundance	2	1	1	2	2	2	1	2
core preparation (A-A, Levallois)	relative abundance	2	3	3	2	2	2	1	2
Blank percentages									
convergent blanks	percentage	1.6	9.1	20.9	10.2	12.2	7.6	14.0	3.0
blades	percentage	57.0	41.0	48.5	52.1	64.4	84.4	53.0	31.2
bladelets	percentage	0.0	20.7	1.0	5.2	0.3	1.8	4.7	10.8
Various technological indices									
cresting (among blanks)	percentage	2.1	0.0	0.0	4.7	1.8	0.7	1.0	0.1
faceted & dihedral butts	percentage	51.0		58.4	62.7	64.1	66.4	60.7	25.5
punctiform/linear butts	percentage	7.7			14.0	6.5	4.2	23.0	
convergent scars	percentage				23.0	25.4	60.4	45.5	
parallel scars	percentage				15.4	36.1	34.0	40.0	
bidirectional scars	percentage				12.7	20.3	14.8	15.0	
bidirectional scars on blades	percentage				16.8	12.7		16.9	10.0
blade elongation (length/width)	ratio				2.5	2.7	2.9	2.3	3.0
hard hammer percussion	relative abundance	3	2	2	3	3	3	3	2
soft/marginal percussion	relative abundance	0	1	1	0	0	0	0	1
blade:flake tool ratio	relative abundance	2	2	2	1	1	2	1	2
convergent blade:flake ratio	percentage	85.0	80.0	80.0	65.0	78.5	90.0	60.0	90.0
Special tool types									
chanfrein	present/absent	1	0	0	1	1	0	1	0
Umm el Tlel points	present/absent	0	1	1	0	0	0	0	0
Emireh points	present/absent	0	0	0	1	0	0	1	0

Table 2. Continued.

Variables	Data type	Boker Tachtit 1	Boker Tachtit 2–3	Boker Tachtit 4	Ansab 2
Core type abundance					
along-axis (A-A)	relative abundance	3	3	0	0
volumetric	relative abundance	1	1	3	3
Levallois	relative abundance	0	0	0	0
narrow-fronted	relative abundance	0	0	0	0
bladelet-core-on-flake	relative abundance	0	1	0	0
Core subtype abundance					
A-A preferential convergent	relative abundance	3	3	0	0
A-A recurrent convergent	relative abundance	0	0	0	0
A-A parallel	relative abundance	1	2	0	0
core preparation (A-A, Levallois)	relative abundance	1	1	0	0
Blank percentages					
convergent blanks	percentage	0.9	0.6	2.0	1.9
blades	percentage	33.2	37.1	52.4	62.8
bladelets	percentage				6.5
Various technological indices					
cresting (among blanks)	percentage	3.2	3.7	1.3	0.1
faceted & dihedral butts	percentage	42.1	47.1	40.2	35.4
punctiform/linear butts	percentage				6.7
convergent scars	percentage				47.4
parallel scars	percentage				33.3
bidirectional scars	percentage	39.8	38.0	19.7	6.4
bidirectional scars on blades	percentage	50.9	46.5	17.1	7.0
blade elongation (length/width)	ratio	2.6	2.5	2.5	2.7
hard hammer percussion	relative abundance	3	3	3	3
soft/marginal percussion	relative abundance	0	0	0	0
blade:flake tool ratio	relative abundance	2	1	2	2
convergent blade:flake ratio	percentage	68.6	77.6	66.7	66.7
Special tool types					
chanfrein	present/absent	0	0	0	0
Umm el Tiel points	present/absent	1	1	0	0
Emireh points	present/absent	1	1	0	0

Table 3. Palaeogeography data of the various IUP sites employed in PCA &amp; LDA.

Assemblages	Proximity to water	Fauna	Biome	Proximity to primary raw material	Proximity to secondary raw material	Site type
Üçagizli I–F	1	1	1	0	1	1
Umm el Tiel Ilbase	1		2	1	0	3
Jerf Ajla B & C	1	2	2	1	0	1
Abou Halka IVf–IVe	1	1	1	0	1	2
Ksar Akil XXV–XXII	1	1	1	1	1	2
Ksar Akil XXI	1	1	1	1	1	2
Antelias V–VII	1	1	1	1	1	1
Tor Sadaf A & B	1	3	2	0	1	2
Boker Tachtit 1	1		2	1	1	3
Boker Tachtit 2–3	1		2	1	1	3
Boker Tachtit 4	1		2	1	1	3
Ansab 2	1		2	1	1	3

Proximity to water: 1= < 1km distance, 0= >1km distance; fauna: 1= cervids, boar, goat, 2= gazelle, wild ass, 3= gazelle, hare, tortoise; biome: 1= Mediterranean, 2= semi-arid; proximity to primary/ secondary raw material: 1= < 5km distance, 0= > 5km distance; site type: 1= cave, 2= rock shelter, 3= open-air

Table 4. Techno-economy data of the various IUP sites employed in PCA &amp; LDA.

Assemblages	points/backed pieces	endscrapers chanfreins truncations	other tool types	tool kit richness	tool kit evenness	blank: core ratio	blank: tool ratio	tool: core ratio	site function
Üçagizli I–F	5.53	37.4	57.07	0.3326	2.013	29.9	3.7	8.2	1
Umm el Tiel Ilbase	65.22	8.7	26.09	0.5934	1.648		7.3		2
Jerf Ajla B & C	22.36	16.15	61.49	0.8669	2.194	13.6	4	3.4	1
Abou Halka IVf–IVe	10.48	44.34	45.17	0.6871	2.17			3.5	1
Ksar Akil XXV–XXII	17.65	46.92	35.43	0.2468	1.973			6.6	1
Ksar Akil XXI	6.61	43.92	49.47	0.386	1.686			4.5	1
Antelias V–VII	24.13	45.45	30.42	0.7096	1.935			16.8	1

Assemblages	points/ backed pieces	endscrapers chanfreins truncations	other tool types	tool kit richness	tool kit evenness	blank: core ratio	blank: tool ratio	tool: core ratio	site function
Tor Sadaf A & B	43.65	16.41	39.94	0.2782	1.211	42.1	14.2	3	2
Boker Tachtit 1	48.31	11.24	40.45	0.954	1.639	62.8	40.9	1.5	3
Boker Tachtit 2–3	29.2	11.68	59.12	0.6645	1.941	40.4	33.9	1.2	3
Boker Tachtit 4	39.9	26.94	33.16	0.5759	1.603	72.4	19.5	3.7	3
Ansab 2	34.21	31.58	34.21	0.9733	1.614	14.4	18.2	0.8	3

Points/backed pieces represent hunting/ cutting activities; endscrapers, chanfreins & truncations represent hide working activities; other tool types represent tool maintenance activities; site function: 1= residential site (broad spectrum of activities), 2 = hunting/butchering + maintenance, 3= hunting/butchering + tool maintenance + workshop

## 2.2. Techno-Typological Variables

As not every reader might be familiar with all techno-typological variables mentioned in this study, they are briefly outlined in following (Table 2; Figure 3). For more detailed accounts, the reader is referred to the primary literature however (Table 1).

The first block in Table 2 entails the major core concepts characterising the IUP. The most commonly shared concept is represented by along-axis cores (A-A cores), i.e. hierarchically organised cores with an upper exploitation surface opposite to a lower preparation/ maintenance surface (Figure 3 (1–3)). Some authors subsume A-A cores under Levallois cores, while others set them apart due to more volumetric configurations and lack of centripetal preparation [52, 53, 4, 38, 43]. Typical Levallois cores on the other hand are rare, and were mostly found in Syria [31–34].

Volumetric narrow-fronted cores bear a single exploitation surface used for the production of narrow blade/lets. The exploitation surface was located at the narrow front of the raw nodule [31–34, 54]. In some IUP sites flakes and/or blades were used as cores for the production of bladelets ([34, 39]. These are referred to as bladelet-core-on-flakes here (Figure 3 (7)).

In the next block, A-A cores are subdivided in three groups. The goal of A-A preferential convergent cores was the production of a single convergent blank per reduction sequence (Figure 3 (1)), whereas the production of convergent blanks in A-A recurrent convergent cores was embedded in a continuous blade reduction process (Figure 3 (2); [4, 38, 43]. Furthermore, parallel-sided blades were produced on parallel A-A cores (Figure 3 (3); [38, 43]). The variables employed in the next two blocks are commonalities in Palaeolithic research that should not need further explaining.

The three tool types in the final block can be found in some assemblages, but not in others. An oblique burin scar placed at the distal end of an endscraper defines chamfered pieces, also called chanfreins (Figure 3 (17–18); [22]). This chamfering technique is thought to have aimed for re-sharpening endscrapers, however, use-wear studies remain to be carried to confirm this [55]. Chanfreins were discovered in abundance from Lebanese IUP sites, while few specimens

have been reported from Üçağızlı Cave [30, 55].

Umm-el Tlel points are characterised by the thinning of their dorsal-proximal part via convergent bladelets (Figure 3 (16); [32, 40]). These bladelets were removed just before the point was detached from its core. Umm-el Tlel points were reported from Central Syria and from Boker Tachtit in the southern Negev Desert.

Emireh points are elongated, triangular blanks, mostly of blade proportions, that are characterised by proximal thinning on both the dorsal and the ventral side (Figure 3 (15); [39, 46]. Emireh points were found in Lebanon and at Boker Tachtit abundantly. Basal thinning in both point types is thought to have facilitated hafting in organic shafts.

## 3. Results

### 3.1. Techno-Typological Variability of the Levantine IUP

The first principal component related to technological variability (PC1 = 44.35%) is made up of the various scar patterns, the relative abundance of Levallois, narrow-fronted, bladelet-core-on-flake and A-A preferential convergent cores respectively, as well as, the application of the soft hammer/marginal percussion technique and the presence/absence of Umm el Tlel points (Table 5). Therefore, PC1 sets apart the assemblages of Umm el Tlel and Jerf Ajla in Central Syria.

The second principal component (PC2 = 19.56%) includes A-A core and bladelet-core-on-flake abundances, cresting and linear/punctiform butt percentages, as well as, the presence/absence of Emireh points. PC2 sets apart the early levels of Boker Tachtit (levels 1–3) in the Negev Desert and the Antelias Cave in the Mediterranean zone in Lebanon.

The third principal component (PC3 = 14.49%) revolves around the relative abundance of recurrent convergent A-A cores, the core preparation techniques applied to hierarchical cores, the percentage of convergent blanks and of faceted and dihedral butts, plus the presence/absence of chanfreins. Thus, PC3 separates assemblages from Üçağızlı, Abou Halka, Ksar Akil, located in the current Mediterranean biome from the southern open-air assemblages of Tor Sadaf, Boker Tachtit 4 and Ansab 2, located in the current semi-arid zone.

**Table 5.** Results of the PCA for techno-typology, palaeogeography and techno-economy data of Levantine IUP assemblages.

PC	Eigenvalue	% variance	Attributes
Techno-typology			
1	11.9746	44.35	all scar patterns, Levallois, N-fronted, bladelet-core-on-flake, Mode A, marginal percussion, Umm el Tlel pts.
2	5.28049	19.557	AA-cores, Mode A, bladelet-core-on-flake, Icr, pct/lin butts, Emireh points
3	3.9113	14.486	Mode B, AA-prep, IF, convergent blanks, chanfrein
Palaeogeography			
1	2.95206	59.041	biome, fauna, site type
2	1.07061	21.412	proximity to secondary raw material
3	0.770454	15.409	proximity to primary & secondary raw material
Techno-economy			
1	4.22937	46.993	site function, points, blank:tool ratio
2	2.19304	24.367	other tools
3	1.04779	11.642	tool richness, tool evenness, tool:core ratio

Preliminary groupings observed in PCA are substantiated by LDA supporting the determination of four groups (Figure 4). Group A contains the assemblages from Üçağızlı, Abou Halka, Ksar Akil and Tor Sadaf that are characterised by convergent blank production from recurrent convergent A-A cores, and, blade production from volumetric cores respectively.

Group B entails the earlier assemblages of Boker Tachtit 1–3 and Antelias V–VII characterised by convergent blank production from preferential convergent A-A cores, as well as, by blade production from parallel A-A cores and from volumetric cores alike. Some flakes and blades were used for a designated bladelet production.

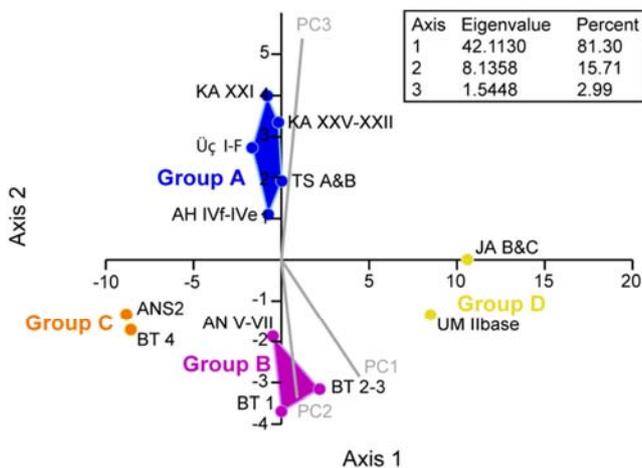
Group C contains the late assemblage of Boker Tachtit 4 and Ansb 2. Blade production was achieved by unidirectional, direct hard hammer percussion on volumetric cores. While convergent blanks appear to be present in these assemblages, they represent a mere by-product of convergent core exploitation on volumetric cores [40].

Ajla) and one rock shelter (Tor Sadaf; Figure 1). All Mediterranean sites are located near wadis [22, 26, 27, 30]. Contrastingly, sites in the current semi-arid biome are found near palaeo water streams, lakes, or marshes indicating improved climate conditions during their time of occupation [35–37, 56, 57].

The faunal records of the Mediterranean sites are composed of *Dama mesopotamica*, *Capra aegragrus*, *Capreolus capreolus*, and *Sus scrofa* pointing towards woodland and rugged, hilly terrain at their time of occupation [20, 22, 30, 58]. There is also evidence of small-game hunting and shellfish consumption [19, 20]. Faunal records from the present semi-arid biome are sparse. At Tor Sadaf, consumption of *Gazella gazella*, *lepus sp.* and *testudo sp.* confirms the past semi-arid biome and proximity to marshy wetlands [35]. No faunal remains survived in Boker Tachtit, but pollen data suggests slightly wetter conditions than today [59]. Preliminary studies from Jerf Ajla and Umm el Tlel suggest exploitation mainly of *Gazella gazella* and various *Equidae* [56, 57]. This might be transferrable to other sites in the semi-arid zone where faunal remains either are absent, or have not been published yet.

Considering raw material availability, all IUP sites were placed in close proximity to raw material sources. Prehistoric people in Üçağızlı Cave exploited two secondary sources within a 5km radius, while primary Cretaceous and Tertiary sources, located 20–30 km away, were exploited to a lesser extent [30]. Lithics from nearby secondary sources represent the complete *chaîne opératoire*, whereas distant sources are represented by imported blanks and tools only. Similarly, a range of flint raw materials originating from various primary sources were used in Lebanon, but nodules from adjacent wadis had been exploited too [4, 60]. At Boker Tachtit, people used good-quality Eocene flint from a nearby limestone cliff, and secondary nodules were used from the adjacent wadi [36, 61]. Stone knappers in Jerf Ajla C primarily used local, good-quality Eocene flint (ca. 90%) and to a lesser extent Cretaceous sources that were some 10–12 km away [62]. Although studies are currently in a preliminary stage, a similar pattern emerges from Umm el-Tlel III2b–IIbase [57]. Ansb 2 is located at an Eocene flint outcrop with good to mediocre (cracked) flint blocks and round nodules; both were used in abundance [37].

The first principal component related to palaeogeographic

**Figure 4.** Results of the LDA based on technological data.

### 3.2. Palaeogeographic Variability of the Levantine IUP

Although, information on palaeogeographic aspects of IUP sites is limited, a brief overview can be found below (Table 3). Sites in the current Mediterranean zone are either caves (Antelias, Üçağızlı) or rock shelters (Ksar Akil, Abou Halka), while those in the semi-arid zone are mainly open-air sites (Boker Tachtit, Ansb 2, Umm el Tlel) plus one cave (Jerf

variability (PC1 = 59.04) is comprised of the biome, fauna and site type differentiating Mediterranean from semi-arid assemblages (Table 5). Since the biome was partially reconstructed based on faunal data, a second PCA run without the biome was conducted resulting in the same groupings.

The second principal component (PC2 = 21.41%) revolves around proximity to secondary raw material sources that differentiates Central Syrian sites from southern Levantine ones. The third principal component (PC3 = 15.41%) is constituted by the proximity to both primary & secondary raw materials.

Preliminary groupings that were already indicated by PCA could be confirmed by LDA, supporting the determination of three groups (Figure 5). Group A contains assemblages from Üçagizli, Abou Halka, Ksar Akil and Antelias, all of which belong to the Mediterranean biome.

Group B is comprised of the Central Syrian sites, Jerf Ajla and Umm el Tlel located in the semi-arid biome. Both are positioned relatively far from secondary raw materials sources. They also yielded the youngest radiometric dates of all IUP sites under study (Figure 2).

Group C entails the southern semi-arid sites that are positioned near both, primary and secondary flint sources (Boker Tachtit, Ansab 2), with the exception of Tor Sadaf. Close proximity to fresh water and flint sources seem to have been critical factors for site selection among Levantine IUP communities, which likely was the case in respect to vital food resources too.

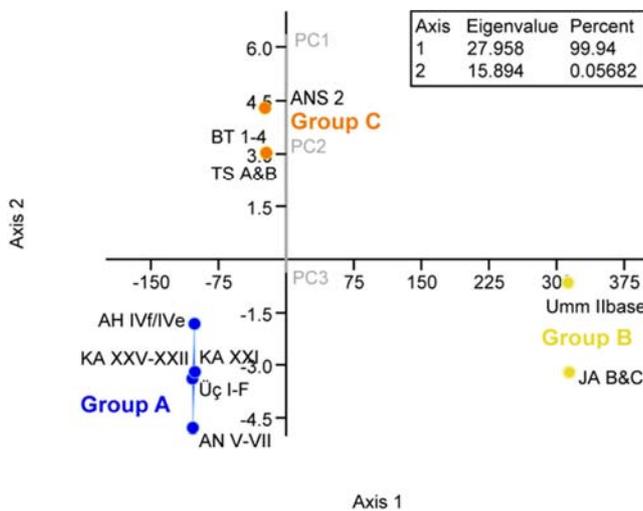


Figure 5. Results of the LDA based on palaeogeography data.

### 3.3. Techno-Economical Variability of the Levantine IUP

In order to investigate techno-economic patterns of the various Levantine IUP sites, a number of proxies were considered (Table 4). Tool types were grouped according to their presumed functions. The various point types should represent hunting/butchering activities analogues to Levallois points [45]. Points are more abundant in the semi-arid zone, particularly in Umm el Tlel. Mediterranean assemblages on the other hand are rich in endscrapers, chanfreins and

truncations, reflecting hide and skin processing activities. The group 'other tools' reflects a broad range of tool maintenance activities, resulting in no apparent clustering.

Tool kit richness is a reflection of the activity range performed with each assemblage (more tool types = richer), while tool kit evenness reflects functional specialisation (more tools of one type = less even, more specialised; [63]). Mediterranean rock shelter sites yielded low richness values (mean = 0.3) as opposed to semi-arid open-air sites (mean = 0.8); cave sites assume an intermediate position. This is indicative of a broad activity range carried out in the semi-arid zone despite relatively small tool kits. Tool kit evenness is higher among assemblages from the Mediterranean biome (mean = 2.0) as opposed to those from the semi-arid biome (mean = 1.7), showing more specialised activities among the latter (hunting/butchering).

Blank:core ratios indicate on-site blank production and are expected to be higher at workshop sites, but they can also reflect import/export of blanks and cores. Blank:core ratios could not be calculated for sites excavated around WWII as not all blanks were retained in contrast to e.g. cores and tools [22, 23]. As expected, assemblages from Boker Tachtit display high blank:core ratios that together with abundant artefact refits and low tool numbers confirm its workshop character (mean = 58.3:1). The low blank:core ratio at the workshop site, Ansab 2, can only be explained by blank export (14:1). Judging from artefact refits, 30-40 blanks per core should be expected. Blank:core ratios of the other assemblages assume intermediate positions.

Blank:tool ratios show the frequency of blanks being transformed into tools, serving as a means to estimate the duration of site occupation. Therefore, during long-term occupations more blanks were transformed into tools, resulting in low blank:tool ratios and vice versa. As expected, blank:tool ratios at southern Levantine open-air sites are quite high (mean = 28.1:1) supporting the notion of short-term occupations combined with on-site blank production (e.g. [62]). In contrast, cave sites (Üçagizli and Jerf Ajla) produced low blank:tool ratios (mean = 3.9:1) that agree with expectations of long-term occupations. Umm el Tlel assumes an intermediate position (7.3:1), partly due to its point abundance (65.2%).

In the absence of reliable blank percentages from pre-WWII sites, tool:core ratios were calculated as an approximate measure of on-site production, assuming tool:core ratios to be low at primary production sites (workshops), and high at long-term residential sites (base camps). As expected, tool:core ratios are high in the Mediterranean biome (7.9:1 or 5.7:1 excluding AN VII-V) in contrast to the semi-arid biome (2.3:1) and semi-arid open-air sites in particular (1.8:1), confirming the residential character of Mediterranean sites. Furthermore, cave sites display the highest tool:core ratios (9.5:1 or 5.8:1 excluding AN VII-V) in comparison to open-air sites (1.8:1) while rock shelters assume an intermediate position (4.4:1) supporting the argument that caves and rock shelters were used for long-term occupations.

The first principal component related to techno-economic variability (PC1 = 46.99%) is comprised of the variables, site function, points and the blank:tool ratio, setting apart residential sites from those with more specialised activities (Table 5). The first group overlaps with the Mediterranean biome except for the only cave site in the semi-arid region, Jerf Ajla. As site function was partially based on data compiled in Table 4, a second PCA run without site function was performed, resulting in the same groupings. The second principal component (PC2 = 24.38%) revolves around 'other tools', which sets apart Boker Tachtit 2-3 and Jerf Ajla B&C. The third principal component (PC3 = 11.64%) entails tool kit richness, tool kit evenness and the tool:core ratio, resulting in no clear patterning.

These partially contrasting group constellations were further investigated by performing a LDA, whose results support the notion of three techno-economic groups (Figure 6). Group A contains the assemblages from Üçagizli Cave, Abou Halka, Ksar Akil and Antelias Cave that belong to the Mediterranean biome plus Jerf Ajla Cave. These sites probably served as residential base camps where similar activities were carried out during each stay. Group B is comprised of Boker Tachtit 2-3 and Ansab 2, workshop sites with moderate numbers of hunting/butchering tools, but with abundant maintenance and/or hide and skin processing tools. Group C is similarly characterised by maintenance plus hunting/butchering activities and, in the case of Boker Tachtit 1 and 4, by workshop activities blurring the boundary with Group B.

To sum up, residential sites display comparatively even tool distribution patterns and they overlap with the Mediterranean biome, with the only noteworthy exception being Jerf Ajla Cave in the semi-arid zone. Other sites in the semi-arid zone indicate more varied activities that revolve around hunting/butchering, workshop and tool maintenance activities. Their activity spectrum is essentially similar to the observed Mediterranean sites, but their activities tend to be more specialised.

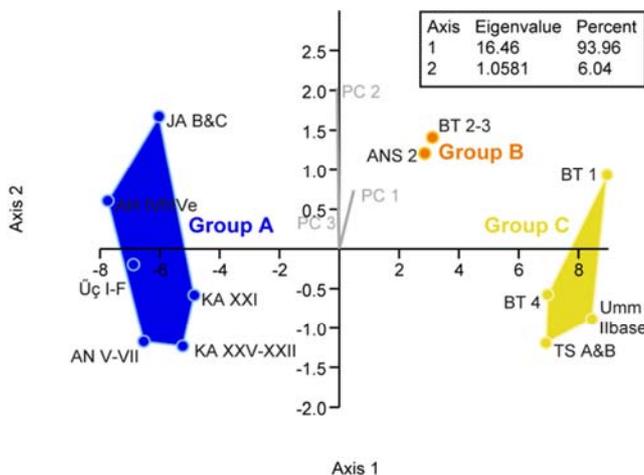


Figure 6. Results of the LDA based on techno-economic data.

## 4. Discussion

Considerable inter-assemblage variability among Levantine IUP lithic assemblages has been acknowledged for a long time now, thus, the aim of this study was to systematically investigate this techno-typological variability and to identify potentially undelaying factors related to palaeogeography and techno-economy.

The study indicates that group associations of Mediterranean sites are consistent across the three investigated categories; techno-typology, palaeogeography and techno-economy, with the single exception of Antelias Cave that is techno-typologically more similar to older assemblages from Boker Tachtit 1-3, located in the Negev Desert (Figure 7). Also, group associations among Central Syrian sites are quite consistent, only Jerf Ajla Cave displays techno-economical constellations that otherwise characterise Mediterranean sites.

Contrastingly, group associations of the southern Levantine assemblages fluctuate considerably; while they form a distinct cluster regarding palaeogeography, they only partially do so in respect to the other two categories. Concerning techno-typology, some of them are more similar to Mediterranean sites (Boker Tachtit 1-3; Tor Sadaf A&B), while from a techno-economic perspective, some are more similar to the northern semi-arid ones (Boker Tachtit 1, 4; Tor Sadaf A&B).

The results suggest that the techno-typological variability observed among all Levantine IUP assemblages neither solely depends on palaeogeography ( $r=0.41$ ,  $p=0.19$ ), nor on techno-economic factors ( $r=0.35$ ,  $p=0.27$ ). Regarding assemblages associated with the Mediterranean biome, the single most influential factor seems to be related to the biome itself (Figure 7), whereas techno-typological variability among assemblages associated with the semi-arid biome display a stronger dependence on techno-economic factors ( $r=-0.79$ ,  $p=0.36$ ) rather than paleogeography ( $r=0.41$ ,  $p=0.03$ ).

While there is no doubt that paleogeography and behavioural economy had an impact on past human techno-typology, some of the observed variability might also be related to cultural/social factors such as cultural transmission or diversification of material culture traditions with time [4, 9, 64]. Figure 8 provides a tentative diachronic perspective, acknowledging the limitations resulting from the few dated sites, differing dating methods and the different materials dated. Some possible cultural/social factors that may have had an impact on the techno-typological variability of the Levantine IUP are discussed below.

Assemblages of the same TechGroups, such as TechGroups A & B (Bokerian A-C) are found in both biomes, i.e. Mediterranean and the semi-arid biome, but display diverse techno-economic and paleogeographic patterns, which would not necessarily be expected in a stringent adaptive system.

Assemblages from the Antelias Cave are similar to those from the open-air site Boker Tachtit, displaying a

standardised core reduction strategy (A-A preferential convergent), that otherwise constitutes but a minor component at the other assemblages in the Mediterranean zone (Ksar Akil, Abou Halka, Üçağizli). Among the latter, convergent blanks were produced via a more flexible core reduction strategy (A-A recurrent convergent), that is comparable to the Levallois recurrent convergent method of the preceding Late Middle Palaeolithic [4, 38, 43]. A possible scenario underlying the observed pattern might be a population of newcomers coming from the Negev to the Antelias Cave, who were equipped with a unique techno-typological set, and who only later adopted and modified Late Middle Palaeolithic core reduction strategies. However, this will have to remain speculative for now, particularly in the absence of precise age estimates for both sites.

Similarly, the techno-typological association of the Tor Sadaf assemblages with those from the Mediterranean zone (TechGroupB, Bokerian B/C), finds no equivalent either in respect to adaptive behaviour patterns or to palaeogeography, yet, they seem to share similar material culture traditions.

TechGroup C (Boker Tachtit 4, Ansab 2) remains enigmatic due to imprecise dating or even absence of dating, henceforth, leaving room for speculation. Besides that, the sudden disappearance of A-A cores, in comparison to older Boker Tachtit assemblages, despite similar blank products, same site function and same palaeogeographic setting, makes adaptive strategies a less likely factor for explaining these shared techno-typological attributes. If the temporal position around 40 ka cal BP was correct, then this might imply a diachronic trend seen in long stratigraphic sequences all over the Levant (Ksar Akil, Üçağizli Boker Tachtit), when hierarchically organised core concepts became less frequent, while volumetric ones gained ground, ultimately, resulting in Early Upper Palaeolithic material culture traditions [5, 27–29, 30, 54].

The most distinctive assemblage cluster, the TechGroup D (Jerf Ajlan) in Central Syria, also provides the youngest age

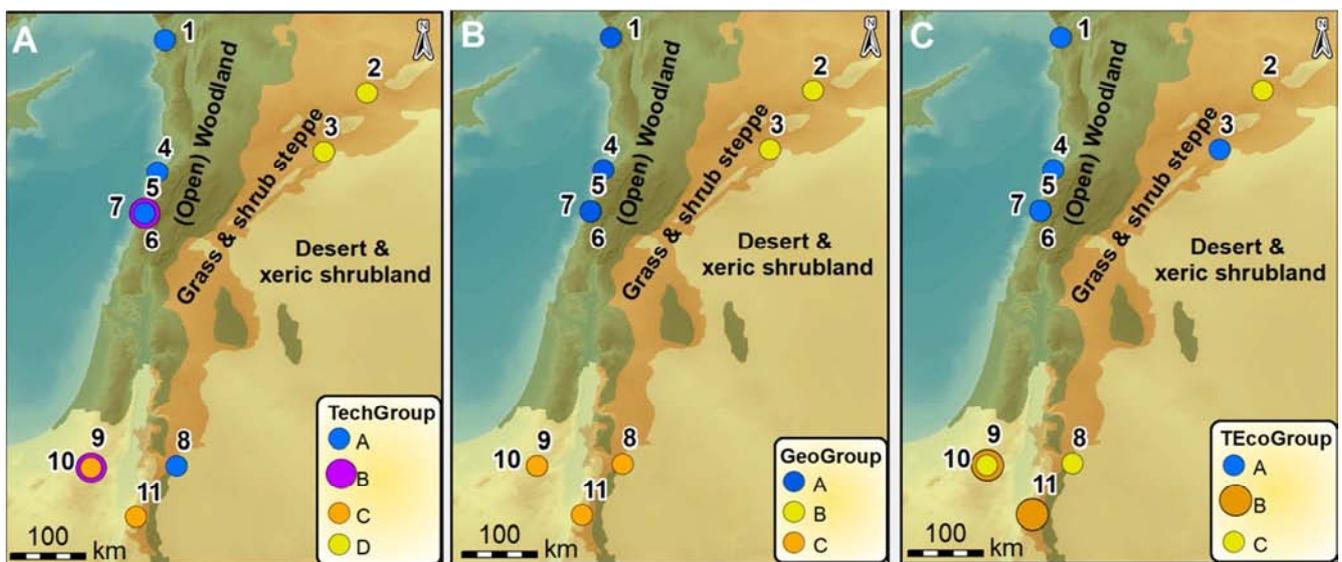
estimates of all IUP sites, and displays unique techno-typological features. Dissimilar to other IUP assemblages, recurrent convergent cores (A-A cores or Levallois) were initiated by centripetal flakes rather than by along-axis blade removals or cresting. In addition, N-fronted cores, that otherwise characterise contemporaneous Early Upper Palaeolithic assemblages, were employed for the production of bladelets [34, 54].

## 5. Conclusion

This study has forwarded three major findings concerning the Levantine IUP, a) there is considerable techno-typological inter-assemblage variability, b) techno-typological variability to some extent depends on palaeogeography and techno-economy and c) while assemblages in the Mediterranean zone are comparatively similar to each other, those in the semi-arid zone display much more variability regarding techno-typology and techno-economic behaviour.

Analogues to palaeoeconomic factors that had an impact on assemblage variability, and as was outlined throughout this paper, there is a need for a more thorough understanding of cultural/social factors that may have contributed to the lithic variability of the Levantine IUP. However, this must be left to future work for now.

Positioned at the cross-roads between Africa and Eurasia, the considerable variability of the Levantine IUP regarding techno-typology, palaeogeography and techno-economy evidenced in this study, conforms to previous arguments for regional and temporal diversity (Figure 8; [4, 6]). This bears implications for the Eurasian IUP in general, where analogues to the Levant, one should equally expect considerable variability that was likely conditioned by a multitude of factors, including adaptive behavioural strategies, different material culture traditions, and multiple human dispersals [10].



**Figure 7.** Maps of group clusters resulting from LDA. Note the differences between groups based on (A) Techno-typology, (B) Palaeogeography and (C) Techno-economy. (1) Üçağizli Cave. (2) Umm el Tlel. (3) Jerf Ajla Cave. (4) Abou Halka. (5) Ksar Akil XXV-XXII. (6) Ksar Akil XXI. (7) Antelias Cave. (8) Tor Sadaf. (9) Boker Tachtit 1-3. (10) Boker Tachtit 4. (11) Ansab 2.

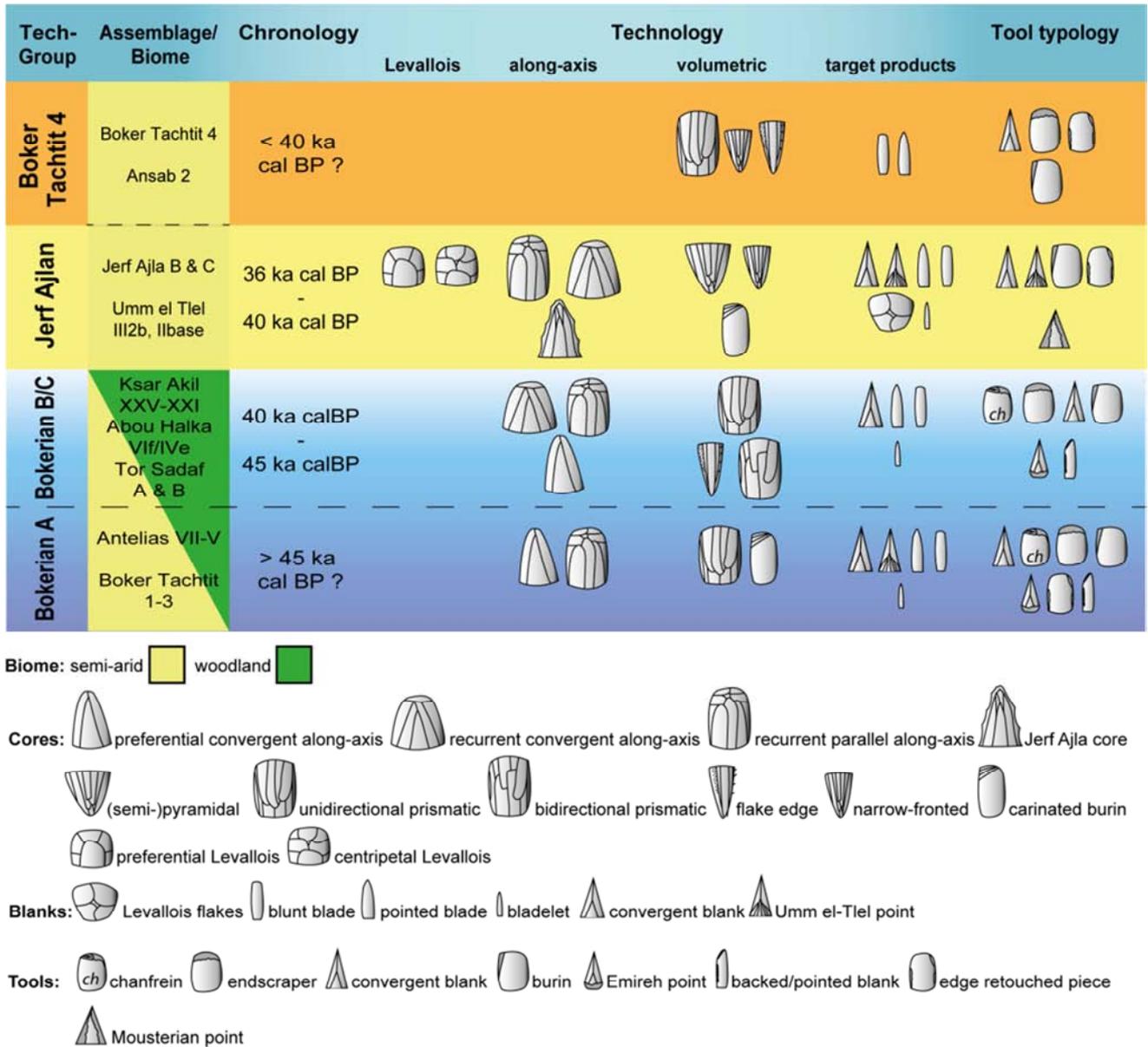


Figure 8. Techno-typological properties of the various TechGroups after Leder 2014 in regard to their regional and tentative chronological patterning.

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