Sapienza
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Application of the NM-PCI Protocol to the Study of Lithic Productions and Raw Material Circulations in the Zagros Foothills during the 6th to 3rd Millennia BC

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2020

Facoltà di Lettere e Filosofia

Dipartimento di Scienze dell'Antichità

Scuola di Dottorato in Archeologia

Ciclo XXXII

Tesi di Dottorato

Applicazione del Protocollo NM-PCI allo Studio delle Produzioni Litiche e Circolazione delle Materie Prime alle Pendici degli Zagros tra VI-III Millennio a.C.

di

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Raggruppamento Scientifico Disciplinare L/ANT 01

Anno Accademico 2019-2020

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all the people and istitutions that supported and contributed to the present work. First of all, I would like to thank my thesis supervisor Cecilia Conati Barbaro for having teached me not only how to organise and develop such a complex work, but also how to succesfully publish results. She supported all the stages of the research – from field to laboratory work – and her advices and comments have been precious. I am also grateful to Cristina Lemorini for the countless discussions about my thesis subject and her availability to use her laboratory facilities.

I will be always grateful to Giacomo Eramo for having approached me to the study of chert raw materials. Our different backgrounds allowed us to establish discussions on several research topics, and I think I came out enriched in terms of knowledge, and on a personal level as well. I would like to thank also Emanuela Delluniversità for her availability to exchange materials, opinions and observations about study samples. My sincere gratitude goes also to Alessandro Monno, Pasquale Aquafredda, Mauro Pallara, Cristina Caggiani and Ignazio Allegretta, who contributed in several ways to the project.

This work would not have been possible without the interest and availability of Daniele Morandi Bonacossi and the Land of Nineveh Archaeological Project team. Since 2016, they welcomed me at the mission house in Dohuk and supported my research at their best. They have became more than simple colleagues. In the specific, my gratitute goes to Alberto Savioli, Rocco Palermo, Katia Gavagnin, Costanza Coppini, Marco Iamoni and Riccardo Menis. At the same time, I am extremely grateful to Luca Peyronel, Angese Vacca, Valentina Oselini, Maria Perri and all the Italian and Kurdish colleagues who worked within the team MAIPE. I am proud to be in this project and I hope to develop fruitful future collaborations.

I would like to thank the Directorate of Dohuk Antiquities, Dr. Hassan Ahmad Qasim and colleagues, for their interest in this work. My sincere gratitude goes to my colleague and friend Kovan Eshan. At the same time, I am grateful to Director Kak Nader Babakr Mohammed and the colleagues from the Erbil Civilization Museum, and to Kak Kaifi Mustafa Ali, Director the General Directorate of Kurdistan Antiquities for the interest demonstrated in my research and for having allowed me to export geological and archaeological samples to Italy for specific analyses.

I am also grateful to Massimo Tarantini and Domenico Lo Vetro, for the revision of the manuscript which contributed to greatly improve the final layout of this work. Finally, I would like to thank my colleagues and lithic specialists Florine Marchand and Francesca Manclossi for a fruitful exchange of ideas, information, and documentation during these years that lead us to organise together the next ICAANE session (Bologna 2021) about metal ages lithic technologies in the Near East.
A special thank goes to my parents for having always supported my choices, widened their views and learned something new from the places I visited and people I met. My deepest thank goes to Isabella for having fully supported my research and encouraged me to give the best in all the work circumstances and not only, and to our dog Lucio for having patiently shared the house with me during the writing process.

SUMMARY

CHAPTER 3: THE JEBEL ZAWA CHERT MINES AND THE BLADE-KNAPPING WORKSHOPS

CHAPTER 6: BUILDING A GEOLOGICAL REFERENCE COLLECTION

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ABSTRACT

New research in the North-western Kurdistan Region of Iraq allowed investigating, for first time in the area, the process of supply, production and distribution of Canaanean blades during the 5th to 3rd millennia BC. The area was, by far, essentially unknown since the resumption of the archaeological research in 2012. The present project contributed new and significative data to understand the increasing social complexity and landscape exploitation during the later stages of the Prehistory.

By combining the lithic technological approach and a multi-parametric protocol of chert characterization – the NM-PCI – the present work investigated the evidence of local production and distribution of large blades departing from the knapping workshops of the Jebel Zawa chert source, that were active from the 4th to the 3rd millennia BC. The discovery of this previously unknown raw material source allowed to trace the circulation of the products following a regional perspective, by analysing the huge dataset of blades, resulting from the LoNAP survey.

A specific sampling was performed to build a geological reference collection. The chert samples were studied following a three-step procedure: macroscopic (cortex, structure, colour) and microscopic descriptions (translucence, texture, micropalaeontology), and geochemical analyses (pXRF, Raman micro-spectroscopy). The application of the NM-PCI protocol outlined the compositional variability of the Zawa chert and highlighted the provenance markers which were adopted into the study of the artefacts provenance.

The study focused also on the lithic assemblages from Tell Helawa (Erbil Plain), far distant about 150 km from the previous area, which was occupied from 6th to 4th millennia BC. Here, the almost exclusive exploitation of local raw materials (alluvial pebbles and cobbles) became to be integrated by the supply of Canaanean blades, around the half of the 4th millennium BC.

The results from the application of the NM-PCI protocol on the archaeological artefacts and data comparison with the geological reference collection highlighted the existence of several regional networks, as well as long-distance circulation of Canaanean blades at Helawa, indicating complex systems of production and distribution, as well as relationships between the settlements established along the Zagros piedmont. This new picture, despite being partial, represents a pilot study and the starting point for future research on the subject, implementing the geological reference collection as a powerful tool to investigate these cultural dynamics.

Keywords: lithic technology, Canaanean blades, chert characterisation, multi-parametric protocol, northern Iraqi Kurdistan

INTRODUCTION

Since 2012, the resumption of the archaeological research into the Kurdistan Region of Iraq, interrupted due to political instability of the area and war conflicts, made possible the acquisition of new data and fresh ideas about the so-called "urbanisation process" which involved the northern Mesopotamia starting from the end of the V millennium BC and following millennia, through the growth of the first territorial entities.

The protection and management of the cultural heritage, in the light of the well-known latest political facts and humanitarian issues that affected the Near Eastern regions (Syria and Iraq above all), were the first steps to be practised. Since the earlier stages, intensive surveys and test excavations aimed at the multi-layered (historical, archaeological, geological) knowledge of the area, were also the focus of this process. The collected data revealed a rich variety of archaeological traces, related to long-term settlement patterns and land exploitation (from Early Prehistory to Islamic period). These discoveries allowed the involvement of specialist archaeologists into the field-research groups as well as of different artefact analysts into the field of material culture studies, which made possible a new evaluation of the cultural history of the region, now playing a central role into the development of the urban societies.

The participation of prehistoric specialists from Sapienza University of Rome, headed by Cecilia Conati Barbaro, into the Prin 2015 20154X49JT – SH6 research project "Archaeological Landscapes of Ancient Iraq between Prehistory and Islamic period (ALAI): Formation, Transformation, Protection and Management" headed by the University of Udine (Daniele Morandi Bonacossi), together with the Universities of Milan (Luca Peyronel, Agnese Vacca) and Bari (Giacomo Eramo, Pasquale Acquafredda), allowed to carry out two pilot campaigns (2015-2016) in the northern area of the Kurdistan Region devoted to the knowledge of the prehistoric periods.

In 2016, the discovery of the chert mines and related knapping workshops of the Jebel Zawa (Dohuk), exploited during the 4th to 3rd millennia BC (Late Chalcolithic to Early Bronze age periods), represented a unique opportunity to investigate the process of supply, production and distribution of large blades – the so-called Canaanean blades – which were the target of such chert mining activities. Also, the availability of a huge dataset of survey lithic materials collected by the Land of Nineveh Archaeological Project (LoNAP) of the University of

Udine, which operates since 2012 in the area, represented the starting point for tracing the distribution of the products from the source to the settlements at a regional scale.

At the same time, starting from 2015, the field-research conducted by Italian Archaeological Expedition into the Erbil Plain (MAIPE) headed by the University of Milan at Tell Helawa, far distant about 400 km south-east from the Northern area, evidenced an extremely relevant archaeological sequence for the entire eastern Tigris region. The chrono-cultural sequence, based on a set of radiocarbon dates and techno-typological analyses of the pottery sherds, begins with the Halaf period, and, without interruptions, reveal the evolution of the Helawa village until its complete abandonment during the mid-4th millennium BC, when the settlement was organized and, probably, headed, with a large administrative building built on the top of the mound.

Particularly relevant, in the light of this work, are the findings within the step trench located in the B area, whose several building and re-building phases have been unearthed. The interpretation of these areas as functional spaces in which several domestic activities were conducted, lead to the possibility of analysing several lithic assemblages from well-preserved contexts such as living floors, room fillings, waste pits and productive areas.

Before these discoveries, few data regarding the features and the regional development of the lithic industries of the later Prehistory were available, if compared with the Mid-Upper Euphrates and the Jezirah regions where a more consolidated tradition of studies on this subject were carried out during years, especially by the French, the British and the Deutsch schools of archaeological research.

Most of the available regional data are related to early research carried out in key archaeological sequences investigated during the formative stages of the modern Near Eastern archaeology (i.e. Tepe Gawra, Ninive), and more recent investigations related to the sites submerged due to the construction of the Mosul Lake in the late ’80 of the last century (i.e. Tell Karrana 3). Finally, a preliminary synthesis of the published data was performed, limited to the only Early Bronze age, within the ARCANE (Associated Regional Chronologies of the Ancient Near East) Project (see Thomalsky 2019).

The existing gap in the knowledge gave rise also to partial tentative of tracing general pictures about one of the most debated issues of the last decades: the identification of the core area of supply and production of the Canaanean blades.

Despite the common view that generally agree to a marked simplification of the technical sequences and strategies of lithic raw materials supply during the later stages of the Prehistory in the Ancient Near East, such blades represent the peak of the *savoir-faire* related to the stone knapping in contraposition to the easier strategies of core reduction defined as "ad hoc" by most of the scholars.

The short background above presented represents the archaeological context on which the present PhD project is focused. In the light of the wideness of the themes discussed in this work, which can be defined as a pilot study in the area, the obtained results carried out during the three years of research opened new scenarios. The discovery of a previously unknown chert source, namely the Jebel Zawa, gave new perspectives of research about the networks of lithic raw materials supply, production and exchange into the northern Mesopotamia. The obtained data demonstrated that any Canaanean blades "core area" is identifiable, but several regional networks were active during the Late Chalcolithic and the Early Bronze age. These networks show differences, not only in the use of different chert raw materials but also at workshop level (site's specialization, knapping techniques, blades morpho-technical features).

Secondly, the analysis of the lithic assemblages from Tell Helawa revealed the evolution of the technical systems of lithic production at the site, and showed an unexpected degree of complexity which regards not only the relationship between specialised vs expedient productions, in terms of raw material procurement and knapping technologies, but also in their association within the archaeological units and with other raw materials, such as obsidian. Furthermore, results obtained at Helawa allowed also to investigating the integration of the site into the exchange networks of raw materials and to find elements to validate, or not, the model hypothesized for the exploitation and distribution of the Jebel Zawa chert. The global picture is far from being exhaustively traced, and future research is necessary to collect useful data for the archaeological reconstruction.

The methodological framework of the present work combines fieldwork and analytic procedures conducted in the laboratory. In the specific, the first stage of the fieldwork was the study, following a technological approach, of the archaeological collections coming from the LoNAP survey, the Jebel Zawa lithic workshops and the site of Tell Helawa.

The second stage was to check the regional availability of lithic raw materials, through a dedicated survey conducted in collaboration with local Iraqi geologists. Both primary and secondary sources of lithic resources, mainly chert, have been identified and sampled. Particular attention was devoted to the Jebel Zawa source, carrying out a specific and intensive sampling of its Eocene chert.

The geological samples and a selection of archaeological lithic materials were transported to Italy, at the Department of Earth and Geo-environmental Studies of the University of Bari, where they were studied by applying a non-destructive characterization protocol – the NM-PCI (Non-destructive Multi-parametric Protocol for Chert Investigations) developed by the research group of Delluniversità et al. (2019). The protocol was recently applied to the provenance investigations of the chert raw materials imported in Neolithic sites supposed to be connected to the exploitation of the Gargano chert mines (south-east Italy). The present study represented the opportunity to test the reliability of the method in a different environmental, geographical and chrono-cultural context.

Furthermore, the choice of the features to be described and statistically processed was integrated also by characteristics observed directly on the field (e.g. size and shape of the nodules, post-genetic alterations) and used to hypothesize and explain the technological choices adopted by the knappers at the mines in terms of raw materials selection, suitability and knapping strategies. The integration of these technological observations performed on the archaeological artefacts within the characterization method proposed by the NM-PCI protocol represented the real advantage of the complete workflow, which was managed by the same operator during all the steps.

The obtained results demonstrated also a certain degree of flexibility of the adopted methodology, which gravitates around four main research questions:

a) What are the markers of the provenance of the Jebel Zawa chert?
b) How did the production and distribution of the Northern Iraqi Kurdistan Canaanean blades was organized? How extensive this network was?
c) What are the technological features of this lithic production? Are there any recognizable distinctive features compared to neighbouring regions?
d) How was the stone knapping organized at Tell Helawa through time? Are there any specific lithic raw material networks attested at the site?

To answer these questions and discuss the data in the best way, the present manuscript is organized in two sections: the first one (chapters 1 to 5) is dedicated the presentation of the chrono-cultural background, the methodology utilised, the archaeological sites and contexts analysed and the results of the analyses of lithic assemblages. Specific themes and problems emerged during the study are investigated in the second section, which is dedicated to the application of the NM-PCI protocol on the geological and archaeological samples (chapters 6 and 7). The results, data discussion and final interpretation are shown in chapter 8.

In the specific, the first chapter is dedicated to the chronological and socio-cultural background, the state of the art regarding the study of the Canaanean blades problem, procurement and distribution networks in the Ancient Near East. Chapter 2 explains in detail the methodological framework adopted in this study.

Chapter 3 is dedicated to the archaeological background of the Jebel Zawa chert mines, the analyses of the lithic assemblages, focusing on the results coming from the 2017 survey collection and the 2018 test excavation at site 980 “Old Sharya”.

Chapter 4 aims to illustrate the documentation of large blades collected during the survey and the character of the Late Chalcolithic and Early Bronze age settlements in the region.

Chapter 5 is entirely devoted to the analyses of Tell Helawa lithic assemblages. The site chronology and building phases are illustrated, together with the stratigraphical context of assemblages ‘provenance. The evolution through time of the technical systems of lithic production, raw material economy and evidence of specialised productions (local vs imported ones) are discussed.

Chapter 6 starts with the regional geological stratigraphy and palaeoecological interpretation of the sedimentary *facies* of Northern Iraq and their significance into the general context of the Zagros Thrust Belt. The regional availability of knappable raw materials checked through the specific survey is also outlined. Then, the chapter focuses on the evidence of chert exploitation of the Jebel Zawa. The compositional features of this type of chert are outlined through the application of the NM-PCI protocol, concluding with a critical evaluation of its provenance markers. Furthermore, variables connected to exploitation strategies, raw material selection and suitability are also discussed in the light of the reduction sequences and knapping techniques identified into the archaeological record.

Chapter 7 sees the application of NM-PCI to the archaeological artefacts and the final match with the geological reference collection. The identification of some of the features which were difficult to record on the archaeological artefacts is discussed. Post-depositional modifications of the genetic chert features (i.e. patinas, desilication and other chemical alterations) due to diagenesis, and their effect on the variables of the protocol (i.e. macroscopic features, petrography), are investigated and explained following the concept of the *chaîne évolutive de la silice* (*sensu* Fernandes).

Chapter 8 is dedicated to the final discussion and interpretation of the data, as well as the comparison of the results with data known from the literature.

Attached to this work, three conspicuous appendixes are respectively dedicated to the geological reference collection, complete of all the data acquired and examples of the protocol application as well, and data collected on the archaeological artefacts. This collection represents a first step for the making of an interregional *lithothèque* dedicated to the scholars who deal with chert raw materials provenance studies into the Zagros region.

1. THE ARCHAEOLOGICAL BACKGROUND

1. The large blade "idea"

Large blade productions are a widespread phenomenon thorough the Old World. The appearance of such blades is generally documented since the Early Neolithic period (7th millennium BC) in concomitance with the shift from nomad to sedentary lifestyles, and until the Bronze age (3rd to 2nd millennia BC) when chipped stone industries were in part replaced by metal weapons. The appearance of large blades is related to the adoption of agriculture as a primary economic strategy and the emergence of high-skilled lithic traditions (Pelegrin 2012a). Centers of production, connected with specific outcrops and mining systems (i.e. Gran Pressigny Region, Spiennes Mines, Gargano Promontory), and sites of consumption are testified from western Europe (Pelegrin 1997, 2002) to the Balkans (Manolakakis 1996, 2004, 2017; Gurova et al. 2016) and Greece (Perlès 2018), the Italian Peninsula (Costa and Pelegrin 2004; Guilbeau 2009, 2010, 2012; Collina 2015; Moscone 2020), the Iberian Peninsula (Gibaja and Terradas 2009, and references therein), Egypt (Zampetti and Drudi 2019), and south-eastern Asia (Anderson et al. 1989; Briois et al. 2006; Méry et al. 2007).

1.1. History of the research about Canaanean blades

Large blade components within lithic assemblages are documented since the early times of Near Eastern archaeology. Canaanean blades were first seen as a proper type in the Levant Bronze age by Macalister (1912) and were later defined by Neuville (1930; 1934) who described them as large blades with parallel edges and trapezoidal cross-sections.

This definition was modified by Crowfoot (1935), who noted the presence of faceted butts and prominent bulb of force – whose negatives were also visible on dorsal surfaces as the result of previous removals from cores – as distinctive technological aspects.

Several years later, Hours (1979) by analysing the lithic assemblages of Sidon "Dakerman" in the coastal northern Levant, fixed the existence of a local *débitage cananéen* as an essential technical aspect of the knapping sequence through which these kinds of blades where detached from cores. Also, he emphasized the aspects related to raw materials used by asserting that only specific chert types were selected by knappers settled at the site (i.e. fine-grained varieties of the local Eocene formations). Lately, Rosen (1983, 1997), who conducted territorial research and large-scale typo-technological analyses of lithic assemblages from the Chalcolithic and Early Bronze age of southern Levant, contextualised the Canaanean blades evidence within evolutive trends of local chipped stone industries. He also highlighted the necessity of studying their socio-economic significance within the framework of late prehistoric societies of the Levant and the urgency of understanding modes of production and distribution from specialised workshops to the sites.

The discovery of large blade assemblages – including cores and untransformed blanks – at the Late Chalcolithic site of Hassek Höyük (Behm-Blancke 1991; Otte and Behm-Blancke 1991), in the middle Euphrates region of northern Mesopotamia, lead to detailed investigations about the knapping techniques employed (Pelegrin and Otte 1991). The identification of the indirect percussion (or punch technique) using a copper point as the main technique adopted to detach the blades at the site, justified the regularity of the blades, their unusual length, their trapezoidal cross-section, and evident cracks on the butts in correspondence with impact points (Pelegrin and Otte 1991). In addition, observations carried out on cores, confirmed such assumptions highlighting high degrees of specialisation visible in core volumes preforming, laminar surface managing, and platform preparation.

1.2. Current definitions

During the late '90s and early '00s, research conducted by Chabot, in collaboration with Pelegrin, on Jezirah Early Bronze age lithic assemblages (i.e. Tell 'Atij, Tell Gudeda), allowed to change the previous technological perspective by identifying the stigmas of the pressure technique on specimens from the lithic collections. This was certainly possible due to advances reached by Pelegrin in experimenting the pressure technique with the lever system, which was fixed as the prevailing technique employed to detach these large blades in the Jezirah region (Chabot 1998; Chabot and Pelegrin 2012).

Subsequently, Chabot and Eid (2003) published a synthesis work aimed at reconsidering the evidence from the whole Fertile Crescent by giving a new definition of Hour's *débitage cananéen* as the large blade production process carried out by the employment of the lever pressure system with a copper point. In addition, they focused on the specialised character of such production, highlighting the high degree of specialisation in mastering the complex lever mechanism and the functional destination of such blades to produce composite sickles or *tribulum* inserts. They also recognised northern Mesopotamia as the core region of this technical innovation from which such technique and tools spread out in the nearby areas.

During the same years, Coqueugniot (2006) strengthened this definition by asserting that such technology was already known in concomitance with the urban growth of settlements

during the Late Chalcolithic period, in relation to an increasing demand of blanks to manufacture agricultural tools.
Lately, the revision of lithic collections from Hassek Höyük and Tell Kutan, allowed to confirm the lever mechanism as the main technique adopted to produce the blades (Chabot and Pelegrin 2012). The analyses allowed also to differentiate blades produced by the lever from those produced by indirect percussion, these latter interpreted as expedients belonging to the same technical sequence and specifically aimed at initialising the production by crest detachments or at managing the core volume (Chabot and Pelegrin 2012).
In the light of such results, and following the publication of complete experimental series of blades produced by the lever system (Pelegrin 2006, 2012), large blade assemblages from the southern Levant have been in-depth studied, and the adoption of such technique was identified in several Early Bronze age settlements (Shimelmitz 2009; Manclossi 2016; Manclossi et al. 2016; Zutovski and Bar 2017; Manclossi et al. 2019).
However, such theoretical assumption seems to fall in specific contexts where more than one mode of applying pressure are identified or several techniques of blade production coexisted. Issues are also rising when such distinctions are not equally supported by the functional destination of the blades. This is the reason why Marchand (2014) preferred to speak about imported macro-blades produced by the lever system and locally produced macro-blades by the direct percussion technique.
In our opinion, this latter would have been the preferred approach to face the problem during systematic analyses of lithic collections, which do not flatten the dynamism in choices and economic strategies carried out by prehistoric communities. However, if the *débitage cananéen* concept represents a valid argument to diversify large blades produced by pressure within the lithic assemblages studied in this work, the observations carried out on such materials demonstrate that variability in pressure techniques adopted might exist and there is no evident border between metrical attributes of the blades (see chapters 3 and 5). Indeed, some problems still exist from an experimental point of view (see paragraph below). For these reasons, we will refer to Canaanean blades as large blades produced by pressure where such dimensional feature is given by a specific "idea" as a technological choice.

2. Experimental *débitage* of large blades

As shown, most of the recent history of research about Canaanean blades is related to advances in experimental practices. It is worth to illustrate such issues to clarify, on the one hand, methodological concepts on which diagnosis on blade productions have been carried out, and on the other, issues explaining current doubts about the link between Canaanean blades and the lever system as exclusive pressure mode of production.

2.1. "From smaller to bigger" concept

Following Inizan (1991), pressure blades *débitage* represents a specific cultural choice made by prehistoric societies to produce their blades and bladelets, and it represents the highest peak in the evolution of laminar industries' complexity throughout the world. The whole concept revolves around curated processes of core preforming, the adoption of a core-blockage mechanism, and tools (e.g. hand-held *baguettes*, short and long crutches, levers) used to detach blades depending on their size. The adoption of these composite toolkits needs specific knowledge and *savoir-faire* to produce standardised series of blades and it is strictly connected with constraints imposed by raw material availability which determines the choice (Inizan 1991).

Experimental replication of ancient modes of producing pressure blades using chert raw materials were carried out by several scholars (Crabtree 1968; Texier 1984; Pelegrin 1984a) who stressed the importance of the above-cited factors, and that different raw materials can exhibit specific mechanical properties (e.g. different varieties or heat-treated cherts).

In the light of this work, a key point is represented by the assumption made by Crabtree (1968) that *the wider the blade, the bigger the force* needed to detach the blades, highlighting an existing direct link between toolkits adopted, gestures, and width of blanks produced.

This subject has been for many years the research goal of the work conducted by Pelegrin (1988, 2006, 2012b) who experimented several "modes" of applying pressure aimed at reproducing archaeological pressure blade series from several sites and chronologies, to compare experimental technical stigmas with archaeological ones.

The author proposed 5 experimental modes as many as the toolkit prototypes involved. Position of the body, ways in which the force is applied (and related materials used), length of the pressure sticks, and hardness of pressure tips (i.e. organic materials, copper alloys) constitute the variables experimented and discussed (Pelegrin 1988, 2012b). A further variable is constituted by the knapper itself and involves individual skills and gestures, the transmission of knowledge, and, at a broader scale, technological variability and innovation (Pelegrin 2012b).

Although a complete explanation of these modes is beyond the scope of this work, only modes 4-5 will be considered as they are directly involved with the production of large blades. Indeed, after Pelegrin's work, several other scholars focused on the problem and the next paragraph will be devoted to showing the full range of results obtained through different experimental variants of such modes specifically on chert raw materials.

2.2. Big levers

Pelegrin's mode 5 is related to the adoption of a lever system with a copper point (Fig. 1, a) and represents the mechanism that allows detaching the longest blades of his experimental series, reaching about 30 cm in length and 3-4 cm in width (Pelegrin 2012b). By the lever system, human force is transmitted to the core 10 or 15 times more respect other modes (i.e. hand-held baguettes, crutches). Finally, the adoption of a metal point exerts a higher force than an organic one. The author reports that *a strict immobilization of the core is required to adequately perform this technique [...]. I concluded that the whole device should be made from one single piece of wood, which could be a tree trunk about 20 cm wide, in which both the socket of the lever and the core would be fixed. Again, the groove principle can work here (with a double frontal support and a bottom rest), carved through the wood so that the detached blade 'flies' through it.*

Thanks to the development of such a mechanism, all the blades produced by mode 5 would have widths from 2 cm onwards, as a relative limit to the size of the blades is only represented by the homogeneity of the chert raw material and the starting size of the selected nodule.

A similar system is adopted by Heredia (2015), with some variations regarding the architecture of the wooden sustain which is vertical, allowing the frontal fixing of the lever arm (about 2 m) and a core blockage mechanism placed in a raised position with respect Pelegrin's lever (Heredia 2015). With this system, and using a copper tip, Heredia has been able to replicate the famous Varna Cemetery large blade (Manolakakis 2004) of about 43 cm in length (Heredia 2013a).

Over the last years, a new lever mechanism has been proposed by Marchand et al. (2020) which has its novelty in being more flexible and portable (Fig. 1, b). The basic mechanical principles are similar to the previous prototypes. A wooden box is placed on the ground and allows the core blockage. The lever arm is of about 1,50 m and frontally fixed through lateral sockets. A set of compressors of several lengths with interchangeable copper points of different diameters allows producing blades from 13 to 35 cm of length and from 2 to 6 cm of width, depending on the target of the knapping activity (Marchand et al. 2020).

As shown, all the scholars yielded lower and maximum values of their blade productions, but unfortunately, no specific characterisations of their experimental series are available (e.g.

median values or tendencies), apart from technical stigmas, which make their comparison with other techniques very difficult at the present stage.

2.3. Small lever

An interesting lever prototype of reduced size has been developed by Arrok (Abbes 2013). The device reproduces the lever mechanism in a portable way (Fig. 1, c) and allows to set the position of the lever arm (of about 1 m) thanks to several holes placed frontally in a wooden structure, depending on the desired force to be transmitted to the core, which is placed in a classical wooden box as an integral part of the whole system.

Using such a system, the operator can produce a wide range of products, partially overlapping with blades produced by both the lever system and the long crutch (see the next subparagraph) and for a maximum length of 25 cm and 2 cm of width. Unfortunately, no detailed information is available at the moment.

2.4. Long crutches

Following Pelegrin's experiments (2012b), by *[...] using the full weight of the body, flint blades up to 20–21 mm wide (for an antler tip, add 1 or 2 mm with a copper tip) can be detached with a well-adapted long crutch. The main shaft is made of boxwood or another strong wood, with a slight curve to produce a discrete but clear bending elastic effect [...].*

As highlighted by the author, the potential use of the entire body weight, exerted by pectoral pressure in a standing position, is a determinant factor to detach regular and large blades. This is particularly true if we compare variability in blade size among multiple knappers.

As an example of the variability given by the body weight, Heredia by using a long crutch with a copper tip can produce average blades up to 23 cm in length and a maximum width of 2.8 cm, thus entering the lower range of the lever system (Heredia 2013b).

More recently, Vosges (2019) has proposed a significative variant of this technique, namely *béquille pectorale à 3 opérateurs* (Fig. 1, e). This system represents a real upgrade of the long crutch concept by adding lateral handles managed by additional two operators that exert the force in coordination with the main operator who has also the role to address the whole force in a specific point of the core platform.

The employment of this system in blade production restituted very interesting results from a technological point of view and a socio-economic perspective. As for the blade features, it allowed obtaining very regular and long products, from 13 to 20 cm of length and 2 to 3 cm of width, once again overlapping the lever outputs (Vosges 2019).

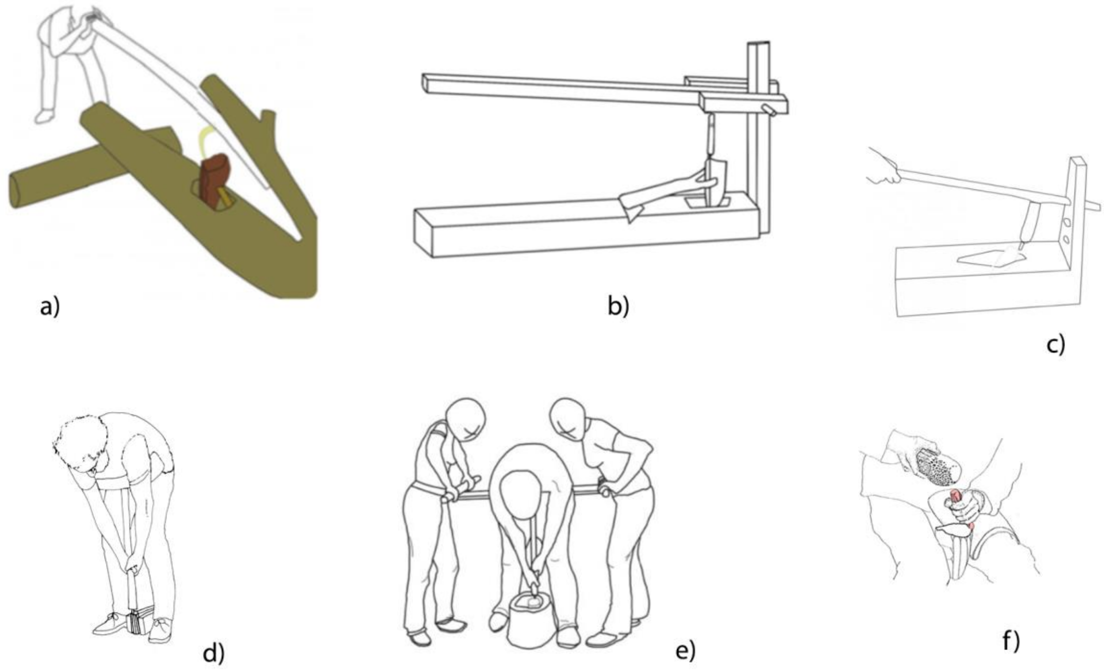


Fig. 1 Schematical representation of the experimental techniques involved with large blade productions (Modified from Inizan et al. 1999; Abbes 2013; Ménager 2017; Vosges 2019; Marchand et al. 2020). Pelegrin's big lever (a), Marchand et al. lever prototype (b), Arrok's small lever prototype (c), long crutch system (d), *béquille pectorale à 3 opérateurs* (e), indirect percussion technique (f).

From a socio-economic perspective, the present system does not need the further acquisition of knowledge and skills than the ones already owned by the knapper (Vosges 2019) or being involved in cultural transmission phenomena as hypothesized by Pelegrin for the diffusion of the lever system which is seen by the author as a real turning point among the systems of blade production by pressure (Pelegrin 2012b). Conversely, it emphasizes aspects related to group cooperation and mobility (Vosges 2019).

2.5 Indirect percussion

In the field of percussion techniques, indirect percussion represents the other technique that allows producing large blades. Until the rediscovering of the lever pressure system, it was assumed to be the exclusive one. For this reason, it is important to illustrate the basic principles of its functioning (Inizan et al. 1999). It consists of the adoption of a hammer to beat an intermediate tool, namely punch, having the role of removing the blank by punctual contact with the core platform (Fig. 1, f).

Through this technique, it is possible to detach regular blades reaching a length of 20 cm (Pelegrin 2006). Although the real potential of such a technique in producing standardised blades has been not experimentally investigated or extensively published (Ménager 2017), Pelegrin (2006, 2012b) reports that indirect percussion blades tend towards being sometimes larger and irregular than pressure ones. However, following the author's work, substantial differences between the two techniques are given by technical stigma observation (see chapter 3).

A further difference regards the adoption of metal-tipped punches, which have been found unstable especially on flat and non-prepared platforms (Pelegrin 2012b). However, the indirect percussion is often used as a complementary technique during the débitage of large blades by pressure, to initialise the production by removing the first blades, core and platform shaping, and crest delineation (Pelegrin 2012b; Vosges 2019).

3. Function

The presence of glossed edges and bitumen residues on most of the Canaanean blades from the Levant was interpreted by early scholars as the result of their adoption as sickle inserts in agricultural activities (Macalister 1912; Neuville 1930; Crowfood-Payne 1960; Gauvin 1968). Lately, Van Gijn (1988) analysing the artefacts from Tell Leilan III period (Early Bronze age) by using the microwear approach to use-wear traces confirmed such observations.

During the ‘90s, Inizan and Anderson (1994) identified at Kutan (Mosul Dam, Northern Iraq) their use as teeth inserts of a *tribulum*, a sort of threshing sledge pulled by bovids and used for separating carioxides from stems during cereal processing and after the harvesting phase. The advantages of such practice, resumed from ethnographic and present-day documentation (Anderson 2014; Van Gijn et al. 2014 and cited references) and controlled experimental replicas (Vargiolu et al. 2003; Anderson et al. 2006), are twofold: on the one hand, the *tribulum* allows to process large quantities of cereals, and on the other, permits to exploit secondary products (straw) as food resources for animals, building material (e.g. mixture for mudbricks) and craft productions (i.e. basketry).

Tribulum micro-polishes were also found on specimens from several Early Bronze age sites of northern Mesopotamia (Anderson and Chabot 2001; Anderson et al. 2004). The standardised character of Canaanean blades inserts and socio-economic implications of the *tribulum* adoption, lead some scholars to define it as la *première machine agricole* of the whole antiquity (Anderson and Chabot 2004).

However, evidence from Arslantepe VII (Late Chalcolithic 5), investigated by a systematic approach to all the artefacts, revealed that Canaanean blade fragments were used in a large

Fig. 2 *Tribulum* use at the present-day village of Eymür (Turkey). (Modified from Whittaker 2014).

number of activities (i.e. sickle and *tribulum* inserts, scraping and cutting different soft materials), suggesting a variability of uses and highlighting a certain degree of recycling or changing functional destinations during their use-life (Lemorini 2010). This functional variability has been also recently observed in Tell ‘Arqa (Marchand 2014). Finally, Canaanean blades are also documented as being involved as specialised tools in pottery manufacture (Groman-Yaroslavski et al. 2013).

4. The large blade “idea” and the Mesopotamian socio-economic context

Since the late 5th millennium BC, the development of large settlements along the Upper and Middle Euphrates valleys, as far as the Jezirah steppe, was strictly connected to growing social complexity and territorial re-organization (Akkermans and Schwartz 2003; Al Quntar et al. 2011). The establishment of monumental public areas for administrative purposes, and specialised activities within the settlements, suggests the emergence of new needs and strategies of resource management within the Near Eastern communities (Frangipane 2018). Depending on the different areas, new relationships between these large centers and their peripheries emerged. Such tendencies can be explained on the basis that natural resources, on which settlements based relevant parts of their economies, were often located in marginal areas (peripheries) and were therefore exploited by establishing direct or indirect links with communities living in such territories (McMahon 2019).

This phenomenon is visible since the early stages of the Late Chalcolithic and it is supported by several archaeological indicators. First, the growing size of many settlements, which absorbed the surrounding villages and their inhabitants, gave rise to large urban agglomerates where a new focus of specialised activities and supply-demand dependencies were established (e.g. Tell Brak, Hamoukar). Secondly, the consolidation of long-distance trade systems (e.g. obsidian, precious stones, timber) strengthened the links between distant regions (Khalidi et al. 2016; McMahon 2019; Benati 2019). In this context, the material culture started to change not only its formal aspect but also its technological features. Indeed, increasing standardisation of the pottery types is attested during the early Late Chalcolithic, even if specific types continued to circulate at regional level indicating the persistence of local traditions, raised during the Ubaid period (McMahon 2019).

However, this model is not valid everywhere. Some areas followed original trajectories and did not develop urban characteristics until late periods (e.g. Tigris basin). Other areas experienced strong increases in the number of settlements, as documented in the middle Euphrates region. Here, some of the sites were ex-novo founded and showed peculiar characteristics in the fields of architecture, material culture, as well as the socio-economic organisation by revealing strong southern Mesopotamian influences.

These latter dynamics are known in the literature as "Southern Uruk expansion" and are dated between 3500 to 3000 BC. Scholars questioned for a long time whether this breakthrough in local archaeological sequences was effectively due to movements of people from the southern alluvium rather than gradual integration of uses and cultural aspects from distant areas (Algaze 1989, 2013; Postgate 2002).

Today, it is generally accepted that some sites are to consider as true Uruk foundations (e.g. Habuba Khabira) while others were only influenced by such developments (e.g. Jebel Aruda, Hacinebi, Hassek Höyük) indicating the coexistence of mixed indigenous and foreign cultural traits, stimulated by constant relationships in terms of trades and exchanges (Helwing 1999).

In the Upper Euphrates valley, the site of Arslantepe is a key site to understand these dynamics as it revealed a local evolution culminating with the emergence of an elite-based society exhibiting a strong centralising tendency during the Late Chalcolithic 5 (Frangipane

2007, 2012, 2018a). These elites exerted their power in many ways. They probably lived in monumental buildings located in the upper part of the mound, accumulated resources externally supplied and owned objects and symbols related to prestige (e.g. metal daggers). These people also directly managed food resources (grain storage rooms found in the "palace") through "ceremonial redistributions" to individuals who did not take part in any of the socially relevant activities, such as administration and ruling (Frangipane 2016a, 2016b).

However, at Arslantepe the productive unit is that of the household, where basic activities were related to the subsistence of the single living units (Piccione et al. 2010), in contraposition with specialised craft areas which were, once again, centralised around the palace sphere (Frangipane 2018b).

Specialised workshops are attested in many of the large settlements of northern Mesopotamia and are related to high-intensity processing of various raw materials. However, agriculture was the primary basis of the economy for a large part of the population, but pastoralism provided a necessary supplement and may have dominated some subregions during bad years for farming (McMahon 2019).

At the onset of the 3rd millennium BC, this system suddenly failed and most of the sites were abandoned or reoccupied by different populations. The collapse of the Late Chalcolithic world leads to the ruralisation of many environments which saw the emergence of local traditions in material cultures. The Syrian and Iraqi Jezirah were involved in the raise of the Ninevite 5 culture (Rova 2013).

The distribution of the sites is mostly related to dry-farming zones and the village economies are characterised by widespread intensification of agricultural practices and pastoralism. Only a reduced number of sites continued their expansion, as documented at Tell Leilan where a fortification wall was built (Rova 2013). However, a renewed urbanism became evident during the half of the 3rd millennium BC, leading to the formation of the first city-states that exerted formal control over large territories (Cooper 2006).

The present is a summary of the events which saw the contemporary emergence of large blade productions as socially accepted "ideas" among the communities living in northern Mesopotamia. However, the phenomenon is wider and involves also the Levant area with apparently no evident frontiers. From a chronological point of view, it will be highlighted that previous experiences of large blades productions are testified in some specific areas and can constitute a point of reflection to identify earlier areas where such tradition originated.

The only marginal territory is represented by the southern Mesopotamian alluvium which preserved original and local trajectories of lithic technologies developments through time as well as socio-political events culminating with the rise of the first Sumerian dynasties and city-states during the early 3rd millennium BC.

In the following paragraphs, all the available documentation regarding the issue will be exposed and discussed for each region by considering chronological factors, evidence related to on-site knapping activities, organisation of the *chaîne opératoires*, technological aspects, and interpretations given by several authors who studied the lithic collections. The Levant and southern Mesopotamia state of the knowledge will be also briefly discussed, as the former area owns a long tradition of studies focused on the problem, while the second constituted a real barrier to large blades diffusion.

However, the available documentation is not exhaustive for most of the sites. Old excavation reports, indeed, lack specific data regarding contexts and materials associations. The artefacts are often presented as "selected categories" of interesting pieces and are only rarely described by providing exhausting graphical illustrations or photos.

After the '80s, published analyses reserved specific attention to these problems and provided accurate quantifications and morphometrical data, as well as interpretations of lithic assemblages treated as remains of different activities, in which, relationships between certain artefacts categories have been researched to reconstruct knapping sequences and techniques, raw materials and *débitage* economies.

For these reasons, we will refer to Canaanean blades, in the light of the recent definition given by Chabot and Eid (2003), only for the specimens belonging to 5th to 3rd millennium BC when reliable diagnosis about the materials are available. On the contrary, the broader and generic term of "large blades" will be adopted.

Since these are researches mostly related to solving intra-site issues, no data regarding chert sources have been ever reported nor specific projects have been carried out to investigate problems related to lithic procurement and dynamics of transport to the sites. In this picture, lithic raw material descriptions are often fragmentary and aimed only at isolating macro-categories by visual descriptions, on basis of subjective criteria as colour and texture.

The only exception is represented by obsidian which, however, can claim a longer history of research and characterisation studies focused on the Anatolian and Transcaucasian sources, due to its importance in building models of interregional connections between distant communities in the area since the early periods of the Near Eastern archaeology development (Renfrew and Can 1966; Dixon et al. 1968).

Date	Periods			
BC	*South Lev.*	*North Lev.*	*North Mesop.*	*South. Mesop.*
2300	EB IVa (ESL 6)	EB IVa (ECL5)		ED III a/b (ESM 4)
2500		EB III (ECL4)		ED II (ESM 3)
2800	EB III (ESL 5)	EB II-III (ECL3)	EBA	ED I (ESM 1-2)
3000	EB II (ESL 4)	EB I (ECL2)		Jamdat Nasr (ESM 1)
3100	EB Ib (ESL 3)		LC5	Late Uruk
3200		Amuq G		
3300	EBA I		LC4	Middle Uruk
3600			LC3	
3900	Gassulian	Amuq F		Early Uruk
4200			LC2	Ubaid 5
4500	Early Chalcolithic	Amuq E	LC1/post Ubaid	Ubaid 4
5000		Amuq D	Northern Ubaid	Ubaid 3

diffusion of Canaanean blades

poor data available

Tab. 1 Chronological comparative table showing the occurrence of Canaanean blades through time within the macro-regions of the Fertile Crescent (after ARCANE 2011, Marchand 2014; Vallet et al. 2015). Northern Levant chronology is based on the stratigraphic sequences of the Amuq area for the earlier periods, and the sequence of Tell ‘Arqa, for the Early Bronze age. This latter is compared with coastal Levant chronology. The northern Mesopotamian chronology is simplified to include all the regions, as well as the Anatolian area. ECL = Early Coastal Levant; ESL = Early Southern Levant; ESM = Early Southern Mesopotamian.

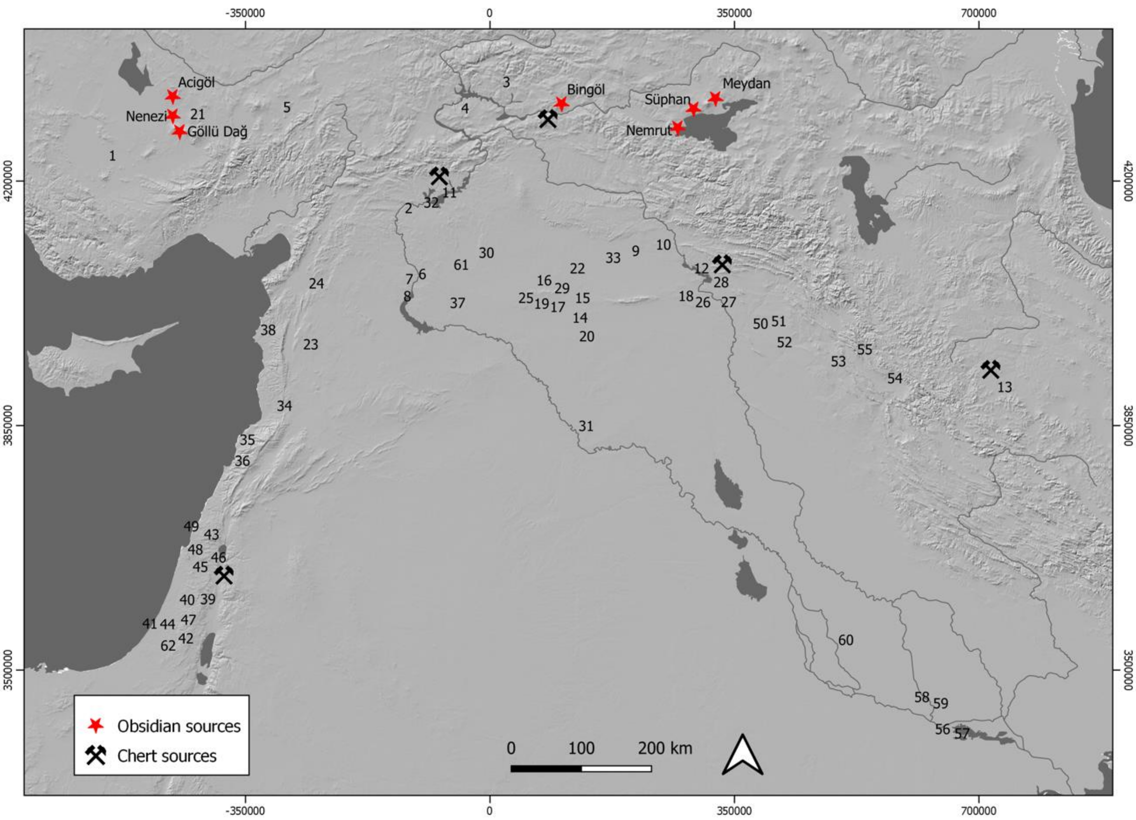


Fig. 3 Map of sites and localities with large blades quoted in the text. 1- Çatalhöyük West, 2- Hacinebi, 3- Noršuntepe, 4- Arslantepe, 5- Kültepe, 6- Koshak Shamali, 7- Jebel Aruda, 8- Habuba Khabira South, 9- Tell Leilan, 10- Hamoukar, 11- Hassek Höyük, 12- Tell Karrana 3, 13- Pasar 23, 14- Tell Atij, 15- Raqai, 16- Nutsell, 17- Tell Gudeda, 18- Telul eth Talathat V, 19- Tell Kashkashok, 20- Tell Bderi, 21- Tepecik, 22- Tell Mozan, 23- Tell ʻAcharneh, 24- Judaidah, 25- Jebel 'Abd al-'Aziz, 26- Tell Kutan, 27- Ninive, 28- Tepe Gawra, 29- Tell Abu Hujeirah I, 30- Tell Chuera, 31- Mari, 32- Titris Höyük, 33- Tell Brak, 34- Tell ʻArqa, 35- Byblos, 36- Sidon, 37- Hammam et-Turkman, 38- Ras Shamra-Ougarit, 39- Fazael 2/4, 40- Gezer, 41- Afridar, 42- Gat Govrin, 43- Nahal Gush Halav 2, 44- Horvat Ptora, 45- Megiddo, 46- Bet Yerah, 47- Tell Yarmuth, 48- Har Haruvim, 49- Qiryat Ata, 50- Helawa, 51- Surezha, 52- Bash Tepe, 53- Logardan/Girdi Qala North Mound, 54- Gird-i-Shamlu, 55- Kunara, 56- Ur, 57- Abu Tbeirah, 58- Uruk, 59- Larsa, 60- Abu Salabikh, 61- Sabi Abyad, 62- Tell Halif.

4.1. Anatolia

The Anatolian area is historically considered as a core region for understanding socio-economic developments related to the raise of technical traditions based on the *débitage* of blades through the pressure technique, for having been a place of one of the earliest Neolithic occupation of the Fertile Crescent. However, if settlement continuity is testified during the late prehistoric periods and new sites are currently under investigation, such a large potential lacks specific research for what regards the lithic evidence.

Macro-region	Type of evidence	Authors
Central and southwestern Anatolia		
Çatalhöyük West (EAC IV)	blades	Ostaptchouk 2020
Norşuntepe (LC)	cores, blades	Schmidt 1996
Arslantepe (LC-EBA)	blades	Caneva 1973, 1978, 1993; Lemorini 2010; Lemorini and Zampetti *forth.*
Kültepe (EBA)	blades	Sudo 2018; Sudo forth.
Northern Mesopotamia, Tigris basin and the Western Zagros regions		
Hacinebi (LC)	cores, waste, blades	Edens 1998, 1999
Koshak Shamali (LC)	blades	Nishiaki 2003
Jebel Aruda (LC)	blades	Hanbury-Teninson 1983; Sela 2009
Sheik Hassan (LC)	cores, waste, blades	Müller-Neuhof 2016
Habuba Khabira South (LC)	cores, waste, blades	Schmidt 2014
Tell Leilan (LC-EBA)	blades	Van Gijn 1988
Hamoukar (LC)	blades	Khalidi et al. 2013
Tell Brak (LC)	cores, blades	Oates and al. 2007; Oates and Oates, 1993
Tepe Gawra (LC)	core, blades	Tobler, 1950; Rothman 2002; Angevin 2018
Surezha (LC)	blades	Stein 2018
Kunara (EBA)	blades	Tenu 2016, 2019; Tenu et al. 2018; Marchand 2020
Helawa (LC)	blades	Peyronel et al. 2019; Vacca et al. 2020
Girdi Qala North Mound (LC)	blades	Manclossi *forth.*
Logardan (LC-EBA)	blades	Manclossi *forth.*
Gird-i-Shamlu (LC-EBA)	blades	Manclossi forth.
Bash Tepe (LC-EBA)	blades	Angevin 2015
Hassek Höyük (LC-EBA)	cores, blades	Otte and Behm-Blancke 1991; Pelegrin and Otte 1991; Chabot and Pelegrin 2012
Tell Karrana 3 (LC-EBA)	cores, waste, blades	Brautlecht 1993
Pasar 23 (LC-EBA)	knapping workshop	Müller-Neuhof 2013
Hammam et-Turkman (LC)	blades	Leenders 1987
Tell 'Atij (EBA)	blades	Chabot 1998, 2002; Anderson and Chabot 2001; Anderson et al. 2004; Chabot and Pelegrin 2012
Raqai (EBA)	blades	Anderson et al. 2004; Eid 2004
Nutsell (EBA)	blades	Anderson et al. 2004; Chabot and Eid 2007
Tell Gudeda (EBA)	blades	Chabot 1998, 2002; Anderson and Chabot 2001; Chabot and Pelegrin 2012
Telul eth Talathat V (EBA)	blades	Fukai et al. 1974; Anderson et al. 2004; Nishiaki 2017
Tell Kashkashok (EBA)	blades	Anderson et al. 1994; Anderson and Chabot 2001; Anderson et al. 2004
Tell Bderi (EBA)	blades	Chabot 1998; Anderson et al. 2004
Jebel 'Abd al-'Aziz (EBA)	blades	Hole and Kouchoukos 1995; Anderson 2003; Anderson et al. 2004
Tell Kutan (EBA)	blades	Anderson 1994, Anderson and Inizan 1994; Anderson 2000; Anderson et al. 2004; Chabot and Pelegrin 2012
Tell Abu Hujeirah I (EBA)	technical items, blades	Nishiaki 2012
Tell Mozan (EBA)	blades	Chabot and Eid 2009
Tell Chuera (EBA)	knapping workshops	Helms et al. 2013; Helms 2014
Mari (EBA)	blades	Angevin 2020

Titris Höyük (EBA)	knapping workshops, artisanal quartier	Hartenberger et al. 2000
Northern Levant		
Sidon (LC-EB)	cores, blades	Hours 1979; Yazbeck 2006
Ras Shamra-Ougarit (C-EB)	blades	Courtois 1962
Judaidah (EB)	blades	Crowfoot Payne 1960; Anderson et al. 2004
Tell 'Arqa (EB-BR)	blades	Coqueugniot 2006; Marchand 2011, 2014, 2017; Marchand et al. 2020
Tell 'Acharneh (EB)	blades	Chabot et al. 2007
Southern Levant		
Fazael 2 (LC-EB)	core, blades	Bar and Winter 2010
Gezer (EB)	cores, blades	Macalister 1912
Afridar (EB I)	core	Milevski 2013
Gat Govrin (EB I)	cores	Shimelmitz 2009; Milevski et al. 2011
Nahal Gush Halav 2 (EB I)	cores	Frankel et al. 2001
Horvat Ptora (EB I)	blades, technical items	Milevski 2013; Manclossi et al. 2019
Megiddo (EB Ib)	blades	Schimelmitz and Adams 2014
Bet Yerah (EB I-III)	blades	Schimelmitz and Rosen 2014
Fazael 4 (EB Ib)	blades and waste elements	Manclossi 2016; Zutoski and Bar 2017
Qiryat Ata (EB Ib-II)	blades	Groman-Yaroslavski et al. 2013
Tell Yarmuth (EB II-III)	nodules, rough preforms, blades	Manclossi et al. 2016
Har Haruvim (EB II-III)	knapping workshop	Shimelmitz et al. 2000
Tell Halif (EB III)	cores, waste, blades	Futato 1996
Megiddo (MB-LB)	blades	Anderson et al. 2004

Tab. 2 Canaanean blades evidence according to the knapping sequences identified in the sites belonging to the macro-regions of the Fertile Crescent area (south-western and central Anatolia, northern Mesopotamia, Zagros region, northern and southern Levant). Only published/forthcoming accurate analyses (typological descriptions, technological, and/or functional studies) have been reported.

4.1.1. Central Anatolia

Blades larger than usual, made from obsidian, begin to appear at Tepecik-Çiftlik and dates to the Late Neolithic (level 3, ca. 6300-6000 BC) and Early Chalcolithic (level 2, ca. 6000 BC onwards) periods of site occupation (Vinet and Gilbeau 2018). If knapping workshops of obsidian prismatic blades are known in the area, specifically in the nearby of the Göllü Dağ source (Fig. 3) since the PPN (between 8700 and 8200 cal. BP) at Kömürcü-Kaletepe (Binder and Balkan-Atli 2001; Binder 2007, 2008), nothing is known regarding the steps which led to the formation of large blade-knapping traditions on chert raw materials.

Little information is available for Çatalhöyük West Mound which yielded back the oldest exemplars of large chert blades produced by lever pressure system (Ostaptchouk 2020). The mound, placed about 300 m west from the well-known earliest occupation of the eastern mound, testifies the transition between the Late Neolithic and Early Chalcolithic (7th to 6th millennia BC) as well as a gradual settlement shift through the West Mound as a consequence of deep social and economic transformations occurred in the area (Biehl and Rosenstock 2012; Marciniak and Czerniak 2007).

The items are fragments of glossed blades of 30-35 mm of width, exhibiting retouch and made from a fine-grained chert (Ostaptchouk 2020). Not all the blades are thought to be produced by pressure; a consistent amount is believed to be detached by indirect percussion and interpreted as “secondary products” of the main reduction sequence carried out by pressure (Ostaptchouk 2020). Differences in chert raw materials have been also observed and might suggest the existence of local workshops in the area – which is also rich in obsidian outcrops – during the Early Chalcolithic period (EAC IV/6000-5500 BC).

During the Early Bronze age, large blades made from several chert raw materials are attested at Kültepe (Sudo 2018). They are mostly represented by mesial fragments, of width included between 27 and 43 mm and of different lengths, showing glossed edges and patterns of retouch (Sudo 2018). A more detailed analysis is in course of publication (Sudo *pers. comm.*).

4.1.2. Upper Euphrates basin

The emergence of early traditions of obsidian blades produced by the lever system technique in the area is testified at Çayönü Tepesi, during the late Pre-Pottery Neolithic period (7340 to 7080 cal. BC). At the site, large blades (the biggest is up to 40 cm in length) coexist with smaller blades and bladelets made from both obsidian and chert raw materials using a small crutch device to exert the pressure (Altinbilek et al. 2012).

Very few data are available for the Early Chalcolithic (Ubaid period, 5th millennium BC) at Değirmentepe where residues of a huge knapping workshop have been found in one tripartite building (building F, layer 7) together with remains of metalworking activities interpreted as a workshop (Helwing 2003; Er 2011). However, poor information is available for what concerns the nature of the finds (ca. 23000 pieces) (Balkan-Atli 1995; Healey 2000).

Although data from Değirmentepe reveal the existence of specific areas within the 5th millennium BC settlements where different kinds of productive activities were carried out, the evidence from the nearby site of Arslantepe shed light about the socio-economic dynamics connected with large blades consumption which can be traced out throughout the long excavated sequence (Caneva 1993).

During period VII (Late Chalcolithic 3-4, 3900-3500/3450 BC) these blades are made from a coarse-grained light-brown chert, which seems to be the raw material used also during the following periods alongside with other varieties (author *pers. comm.*). No evidence of *in situ* knapping activities is recorded throughout the sequence (Caneva 1993).

The subsequent period VIA (Late Chalcolithic 5, 3350-3000 BCE) is characterised by administrative buildings, public areas, and articulated dwellings that testify the presence at Arslantepe of an elite-based society at that time (Frangipane 2012). Segments of large blades are a huge component of the lithic assemblages (Lemorini and Zampetti *forth.*) and are mostly connected with plant processing activities, even if several other worked materials are recorded (Lemorini 2010; Lemorini and Zampetti *forth.*). The proximal fragments show the features of the pressure technique and fit with the adoption of the lever system with a copper tip (author *pers. comm.*). The transition to the Early Bronze age (3rd millennium BC onwards) at the site shows the collapse of previously established dominant elites through the destruction of the palace and the settling of transhumant groups from the Transcaucasian area (Frangipane 2012b). In this context, large blades continued to be supplied and used, until they represented the almost exclusive chipped stone tool until the abandonment of stone raw materials in favour of metal tools during the Middle Bronze age (Caneva 1993).

The nearby site of Norşuntepe yielded back some cores dating back to the Late Chalcolithic 1 (4500-4200 BC) and 2 (4200-3850 BC). Blades have been removed by exploiting a coarse-grained chert raw material (Schmidt 1996). However, evaluation of blade removals on their knapping surfaces suggests that "medium-sized" blades were detached from such cores at the limit of the possibilities offered by the long crutch and low-limit of the lever system (Schmidt 1996). This is comparable with the evidence from Arslantepe period VII (LC 3-4) (author *pers. comm.*). Technological affinities between these sites are also noted for what concerns the large blades belonging to the Early Bronze age period (Schmidt 1996; author *pers. comm.*).

4.2. Northern Mesopotamia

Northern Mesopotamia offers rich documentation about the presence of large blades within the archaeological sites of the Late Chalcolithic and Early Bronze age periods. This is certainly due to a more prolonged tradition of archaeological research on the field which led to detailed surveys and extensive excavations which, up today, constitute the reference for regional periodisation and material culture interregional comparisons over the long period. As will be shown, differences are substantial between regions especially for what concerns the trajectories of urbanisation between the western sector (Middle Euphrates, Jezirah regions) and the eastern regions (Tigris basin, western Zagros Mountains).

4.2.1. Middle Euphrates basin

As highlighted for Central Anatolia and Upper Euphrates regions, evidence of earlier large obsidian blades productions by the lever system are present in the Balikh valley during the Late PPNB and Early Pottery Neolithic at the site Sabi Abyad. All the items are imported from the northern sources (Altinbilek et al. 2012). A nearly complete obsidian blade (estimated length of about 32 cm) was recovered from Sabi Abyad I - Op. 2 (6200 BC) within the courtyard of a storage building (Astruc 2011; Altinbilek et al. 2020). Additional six fragments were recovered from the nearby areas of the site, while three fragments come from Sabi Abyad I - Op.3 (6500-6100 BC) (Altinbilek et al. 2012).

There is a consensus (Thomalski 2012; Angevin 2018; Manclossi 2020) toward the earliest attestation of large blade segments made from chert raw materials at Koshak Shamali Post-Ubaid layers (Nishiaki 2003). At the site, according to radiocarbon dates, the Final Ubaid corresponds to 4500-4400 BC, while Post-Ubaid layers dates until 4300 BC (Matsutani and Nishiaki 2001) which corresponds to the Late Chalcolithic 1-2 at a broader scale (Tab. 1).

At the coeval site of Hammam et Turkman, few sickle blades belonging to the “Canaanean blades types” dates to the Late Chalcolithic 1 horizon (Hammam VI) period. Unfortunately, no specific information is reported (Leeders 1988).

Evidence of *in-situ* reduction of cores to produce large blades is testified at Hacinebi and is dated to the Late Chalcolithic 2-3 periods (4200-3750 BC). At the site, which also revealed a Southern Uruk influence in pottery styles within some areas of the settlement, two distinct knapping sequences have been identified: a first sequence, in association with local Late Chalcolithic pottery, aimed at producing large blades through pressure (mean values of width around 25 mm), while a second was aimed at producing smaller blades within the structures containing Uruk pottery (Edens 1998, 1999). These two sequences at least might have been even unified by detaching smaller blades from bigger cores (Edens 1999). Following the author interpretation, the Uruk community at Hacinebi included specialist knappers who employed the blade technologies familiar to southern Mesopotamia (see 5.2.5 paragraph) as they likely lacked the skills needed to produce Canaanean blades that, indeed, were produced by local knappers for all the consumers settled at the site (Edens 1999).

A similar situation is recorded at Sheik Hassan (3700-3600 BC), where also some large cores have been found (Müller-Neuhof 2016), as well as at Habuba Khabira South (3500 BC), which has been interpreted as a true Uruk colonial foundation, where different trajectories of reduction (over-exploitation?) are testified on two cores made from a light-brown opaque chert (Schmidt 2014).

Dualism between smaller and larger blades is attested at Jebel Aruda (3350-3040 BC) which shows Uruk influences within the material culture (Hanbury-Teninson 1983; Wright and Rupley 2001). At the site, the whole laminar production is made from fine-grained chert raw materials of grey shades (Sela 2009). Smaller blades, of width comprised between 8 and 18 mm, coexist with larger blades, from 20 up to 46 mm of width, this latter showing faceted and dihedral prepared platforms indicating the adoption of the lever pressure system (Sela 2009). Differently from Hacinebi, no cores have been found at the site.

However, the most interesting documentation for the 4th millennium in the area is certainly the one from Hassek Höyük, which dates to the Late Chalcolithic 5 period (3350-3200 BC). At the site, the dynamics of Uruk cultural elements integration within the indigenous culture have been hypothesized (Helwing 1999). The excavations at the site restituted 40 chert large blade cores stored in a room of a large building used for cereal storage and processing (Behm-Blancke 1991; Pelegrin and Otte 1991). A recent revision of the blade productions allowed to reconduct the whole assemblage to the adoption of the pressure technique by the lever system, as well as some irregular blades to by-products of this main knapping sequence (Chabot and Pelegrin 2012).

The Early Bronze age period restituted extraordinary evidence in two main sites of the area. Data on knapping techniques and equipment come from the site of Tell Chuera (3100-2900 BC), where hard-stone hammers, a *cache* with complete and unused blades, and a chisel-like copper point – possibly the tip of a lever pressure device – have been found close to each other in a domestic and productive context of the Upper Town. Four large blade cores were also found in area P (half of the 3rd millennium BC) (Helms 2014).

At Titris Höyük (43 ha of extension), which is considered being a real city emerged during the late Early Bronze age (2600-2100 BC) in concomitance with the reflourishing of the urbanisation, the Lower Town restituted evidence of an entire artisanal quartier devoted to stone-knapping (Hartenberger et al. 2000). The area consisted of domestic structures and rooms having stone floors, mortars, and organised waste disposal in large pits excavated within the pavements. Several *caches* testify the presence of prepared large blade cores (total number of 1600 cores) for delayed use and about 3200 complete blades ready to be distributed (Hartenberger et al. 2000). The available documentation indicates that all the steps of the knapping sequence were carried out on-site (Hartenberger et al. 2000). Unfortunately, these finds have been never extensively studied nor accurately published.

However, according to the excavators, the location of this complex outside the Upper Town, which was the city's administrative center, suggests that these activities were independent from the institutional and political sphere managed by the local elites. Indeed, the production of large blades – as utilitarian goods – might have been driven by economic needs in response to the local demand for everyday life activities (Hartenberger et al. 2000).

4.2.2. Jezirah steppe

If the middle Euphrates region highlights changing dynamics of workshop organisation through time, which culminated with the rise of specialised urban lithic workshops during the advanced stages of the Early Bronze age at Titris Höyük, in contrast, the Jezirah region offers wide documentation of large blades consumption sites dating to the same period. However, the appearance of large chert blades can be fixed starting from the beginnings of the Late Chalcolithic period where evidence of wide processes of urbanisation is documented in the area which saw the emergence of very large settlements.

Tell Hamoukar is certainly one of these "mega-sites" and consists of several mounds for a total of 300 ha of urbanised area. On the top of the mound named "Southern Extension", an extensive domestic and productive area was occupied during the late 5th millennium BC (LC 1-2, ca. 4400-3800 cal. BC) (Al Quntar et al. 2012). In such a context, large blades, medium-sized and small obsidian blade(let)s and cores have been found in a specialised workshop area (up to 5000 pieces) (Khalidi et al. 2016). Analyses of the obsidian provenance indicate that rough blocks were imported from the Nemrut Dağ (higher %) and Bingöl and Meydan Dağ (lower %) sources of Eastern Anatolia (Khalidi et al. 2016). Few large chert blades are associated with the workshop (Khalidi et al. 2016), but the non-obsidian assemblage remains to be published.

Conversely, at Tell Leilan (Op. 1) chert raw materials constitute about 2/3 of the whole lithic evidence (Van Gijn 1988). Large blades presence can be traced through the long sequence excavated at the site: from period V-III (Early to Late Uruk, LC 2-3 to 5) to period III (Early Bronze age). Fine-grained chert raw materials characterise these objects and amongst the excavated material no nodules, blade cores, or technical elements were found, suggesting that the items were imported as finished products (Van Gijn 1988).

Tell Brak is the other large site of comparable extension (ca. 300 ha). The main mound is about 40 ha, for a height of ca. 40 m (Oates et al. 2007). In level TW-20, dated between the late 5th and early 4th millennia BC, an "industrial building" was built on a smaller and more domestic scale, respect other ones located in the nearby sector, but revealed a remarkable intensity and variability of craft activities – bone, clay, mollusk shells, obsidian – together with extensive evidence for chert knapping including an unusually large brown-chert blade

(26 cm of length) (Oates et al. 2007) believed to be produced by lever pressure system (Angevin 2018). Unfortunately, no additional documentation is available.

Some cores (n=3) of pyramidal shape have been unearthed in Phase 12, dated between the end of the 4th and the early 3rd millennia BC, inside a building and in association with pottery (Oates and Oates 1993). They have been reconducted to a possible workshop presence that served the site, as blade segments are very numerous in coeval sectors of the inhabited area (Oates and Oates 1993) but, at the present stage, no published materials are available.

Along the Khabour river course, a large cluster of sites featuring small-to-medium dimensions, and economies mostly related to agriculture, characterise an area of large blades consumers without apparently any evidence of local workshops.

All the sites share a common Early Bronze age occupation (Ninevite 5 period): Tell Atij (Chabot 1998, 2002; Anderson and Chabot 2001; Anderson et al. 2004; Chabot and Pelegrin 2012), Nutsell (Anderson et al. 2004; Chabot and Eid 2007), Tell Gudeda (Chabot 1998, 2002; Anderson and Chabot 2001; Chabot and Pelegrin 2012), Raqai (Anderson et al. 2004; Eid 2004), Jebel 'Abd al-'Aziz (Hole and Kouchoukos 1995; Anderson 2003; Anderson et al. 2004), Tell Kashkashok (Anderson et al. 1994; Anderson and Chabot 2001; Anderson et al. 2004), Tell Bderi (Chabot 1998; Anderson et al. 2004), Tell Mozan (Chabot and Eid 2009) and Tell Abu Hujeirah I (Nishiaki 2012).

Canaanean blades are present in large quantities as segments, often associated with bitumen and glossed edges indicating their use in agricultural activities as part of composite sickles or *tribulum* inserts (Anderson and Chabot 2001; Anderson et al. 2004). From a technological point of view, the productions are quite homogenous and show typical dihedral-acute (higher %) or convex-faceted platform preparations (Chabot and Pelegrin 2012).

From a raw material perspective, the variability of chert types recorded share similarities with varieties spread in the Middle Euphrates region. Colour photos and macroscopic descriptions of types from Tell Abu Hujeirah I seem to confirm such assumptions (Nishiaki 2003). Indeed, all the authors relate the absence of workshops in the area to imports from the Anatolian/Euphrates regions where evidence of local productions are testified (Anderson and Chabot 2001; Chabot and Eid 2007; Nishiaki 2012) and connections are also highlighted through obsidian imports (Frahm 2014).

4.2.3. Tigris basin and the Western Zagros

Scholars only marginally consider the area due to the lack of specific studies. Earlier Pre-Pottery Neolithic blade-knapping traditions suggest that, unlike the Upper and Middle

Euphrates regions, no large blade productions are spread in the area. Evidence from Nemrik (Kozlowski and Szymczak 1989) and Mlefaat (Kozlowski et al. 1998) indicates that during the early PPN period (respectively 9th and 8th millennia cal. BC) lithic assemblages were characterised only by bladelets and microblades produced by pressure on both local chert pebbles and imported obsidian raw materials. Heat treatment is also documented on Nemrik chert bladelet productions, suggesting adaptations to the locally available raw materials (Tixier and Inizan 2001). Further south-east, the situation is comparable. In fact, at Bestansur and Shimshara sites (ca. 7700 to 7100 BC), located along the Zagros Foothills in the Sulaymaniyah area, blades and bladelets characterise the lithic assemblages and a great homogeneity of blade widths is recorded for both chert and obsidian productions (medians around ca. 10 mm of width) (Matthews et al. 2020). At the coeval site of Halawezha/Bijian (Giraud et al. 2019) similar blade assemblages morpho-technical features have been described. Finally, at Jarmo (5270-4630 cal. BC), located in the Kirkuk province of Iraqi Kurdistan, only a few larger chert blades are reported by the excavators (Braidwood and Braidwood 1950).

The 5th to 3rd millennia BC sequences of Ninive (Kuyunjik) and Tepe Gawra, were excavated during the first half of the 20th century. Unfortunately, the lithic assemblages from these sites have been not in-depth studied. The sequence of Tepe Gawra is certainly better studied and understood due to reviews of documentation, contexts and associated materials that occurred through time (Speiser and Tobler 1935; Tobler 1950; Rothman 2002) and constitutes the reference stratigraphy for the Tigris basin (Peyronel and Vacca 2015).

At the site, clues about the appearance of large blades are testified during the early phase of occupation in level XVI (Terminal Ubaid, 4500 BC) where, interestingly, coexistence between chert and obsidian products can be observed (Tobler 1950). No evidence of *in-situ* production of such blades is reported by the excavators (Tobler 1950).

In level XII (Post Ubaid, ca. 4400-4300 BC) a pyramidal blade core is associated with large blades (Rothman 2002). In layer IX (late LC2, ca. 3800 BC) a prismatic blade core lies with full production blades as well as large cortical and technical blades suggesting *in-situ* core reduction. This seems to be also the case of level VIII (early LC3, ca. 3700 BC) (Rothman 2002).

A selection of artefacts from Ninive (Kuyunjik) is reported by Campbell-Thompson and Mallowan (1933). Although no specific analyses have been carried out, Angevin (2018) claimed that changing technologies of blade production can be traced out through time at the site. The author reports that increasing blade widths and regularity are observable in layers

45-37 (LC3). The trend is quickly replaced by the appearance of smaller blades in layers 37-31 (LC 4-5), in concomitance with growing Southern Uruk influence in northern Mesopotamia (Angevin 2018).

Sites excavated during the construction of the Mosul Dam (early '80s of the last century) led to the archaeological investigation of Tell Karrana 3. The excavations at the site allowed to identify a small Late Uruk (LC5) and a very Early Bronze age (Ninevite 5) occupation, probably pertaining to a small single farmhouse settlement (Wilhelm and Zaccagnini 1993). Analyses of the lithic materials revealed that *in-situ* knapping activities to produce large blades were carried out by pressure and exploiting a specific nodular chert[1], probably of regional supply (Brautlecht 1993).

Early Bronze age lithic assemblages from the area are scarcely published (Thomalski 2019). At Telul eth Talathat V, on the left bank of Tigris River, the contraposition between domestic flake productions and imported large blades used as sickle inserts is shown (Fukai et al. 1974; Anderson et al. 2004; Nishiaki 2017). At Tell Kutan, a few kilometers north-west of Ninive, large blade segments used as *tribulum* inserts are testified during the early 3rd millennium BC (Inizan and Anderson 1994). No elements connected with on-site knapping activities have been found at the site. The chert raw material used finds comparison with Tell Karrana 3 and consists of a fine- to medium-grained chert of grey shades (Inizan and Anderson 1994). Recent revaluation of the knapping techniques on proximal blade fragments allowed to identify the stigmas of the pressure technique adopting the lever system with a copper point, on large faceted or dihedral-convex butts showing differences with the Jezirah coeval sites (Chabot and Pelegrin 2012).

Moving south-east along the Zagros Foothills, research carried out after 2011 yielded new lithic assemblages which are in course of analysis. A preliminary report of the lithic assemblages unearthed at Helawa, in the Erbil Plain, has been recently published (Peyronel et al. 2019) and a specific analysis will be the focus of chapter 5. The nearby site of Surezha yielded back comparable evidence of large chert blades consumption starting with the LC3 (Stein 2018). A few kilometres south-east, at the site of Bash Tepe, imported Canaanean blades fragments, made from various chert raw materials, belong to the Early Bronze age period (Ninevite 5 to ED III). The long sequence unearthed at the site starts with the Late Chalcolithic period and analyses of earlier lithic assemblages are ongoing (Angevin *pers. comm.*).

[1] Discussion and hypotheses about chert raw materials exploited at Tell Karrana 3 will be made in chapters 6 and 8, based on the published descriptions.

Further south, in the Sharizor Plain (Sulaymaniyah province of Iraqi Kurdistan), the site of Gird-i-Shamlu restituted an occupation dated to the Late Chalcolithic and Early Bronze age periods. The lithic assemblages belong to distinct chrono-cultural horizons: LC3 and a transitional phase between LC and EBA periods. The earliest assemblages show the occurrence of imported large chert blades produced by the lever pressure system alongside with local production of pressure bladelets. The frequency of imported larger products seems to decrease during the latter period of site occupation (Manclossi *forth.*).

Conversely, at Girdi Qala North Mound (LC 3-4) very few imported large blades produced by the lever pressure system coexist with local production of bladelets and an *ad-hoc* flake industry (Manclossi *forth.*). Finally, at the nearby site of Logardan, few large blades are attested in ED III layers, while significative amounts of artefacts are not available for the early periods of site occupation (4^{th} to early 3^{rd} millennia BC) (Manclossi *forth.*).

Currently, exhausting documentation about chipped stone industries of the Early Bronze age in the Western Zagros area is related to the site of Kunara. Within the Upper Town, two imported large chert blades show the technical features indicating the adoption of the lever pressure system (Marchand 2020). Segmented items are numerous as well (Tenu 2016, 2019; Tenu et al. 2018).

Finally, the site of Pasar 23 (Kermanshah province of southwestern Iran) is currently the only chert source and associated large blades knapping workshop in the area (Müller-Nehuof 2013). Although located on the eastern side of the Zagros Mountains, it is worth briefly to highlight that such context revealed evidence of southern Mesopotamian Uruk-type pottery sherds in spatial association with the knapping area (Müller-Nehuof 2013). The raw material is described as a coarse-grained and tabular chert of red-brown shades. A large quantity of prismatic cores has been found on the ground alongside complete blades of 2 cm maximum in width and up to 16 cm in length (Müller-Nehuof 2013). However, bigger blades fragments are attested in a significative amount. Although the whole assemblage is carefully described and assumes the features of a standardised production (Müller-Nehuof 2013), no knapping techniques are proposed for what concerns the detachment of the blades.

4.3. Southern Mesopotamia

Although published assemblages are very poor and no specialistic analyses are available for most of the sites, no evidence of large blades is available in the area. It is important to highlight that given the geomorphological setting of the region, consisting of alluvial sediments, no suitable lithic raw material sources are available to carry out systematic productions of large blades (Moscone 2019).

Indeed, bladelet productions on chert raw materials are testified during the Uruk period (4th millennium BC). Continuity is conceivable from the Late Ubaid period documented at Tell ‘Oueili, where the pressure technique to produce bladelets is well documented on fine-grained chert raw materials (Inizan and Tixier 1983; Coqueugniot 1996), at Tello/Girsu (Inizan and Tixier 1983) and Ur (Woolley 1950).

Such phenomenon is testified by lithic assemblages unearthed at Uruk-Warka (Heinz and Müller-Neuhof 2000) and also characterises the blade assemblages of Early Dynastic (first half of the 3rd millennium BC) sites such as Larsa (Coqueugniot 2003), Abu Salabikh (Crowfoot Payne 1980) and Abu Tbeirah, where the blades have been mostly produced using a long crutch in a standing position (Moscone 2019).

Finally, several kilometers north from the southern Mesopotamian alluvium and along the Euphrates river course, evidence of consumption of large blades is attested at Mari I (ca. 2900-2650 BC). The position of the site, placed at the junction between different cultural entities (Middle Euphrates, Jezirah, Tigris basin, and Southern Mesopotamia), is reflected in the lithic industries which exhibit northern traits as well as southern ones (Angevin 2020).

4.4. Levant

Although it is not the goal of this work to in-depth discuss the Levant documentation regarding Canaanean blades, few words are necessary to illustrate the current state of the art in the area. Indeed, the Levantine area shows original trajectories of lithic technologies development (Rosen 1988, 1997).

4.4.1. Northern Levant

Documentation available from Judaidah indicates that a shift in blades dimensions occurred through time at the site. During the Chalcolithic (Amuq F layers), the blades appear to be short and narrow (width mean values 15 mm) (Crowfoot Payne 1960). At the onset of the 3rd millennium BC (Amuq G) and during the Early Bronze age (Amuq H, ECL 2) wider blades characterise the assemblages (width mean values 30 mm).

The presence of Canaanean blades is testified at the Early Bronze age settlement of Tell ‘Acarneh, where, despite few data are still available, techno-functional analyses indicate that the items were off-site produced by the lever pressure system and used as *tribulum* inserts in agricultural practices (Chabot et al. 2007). Poor data are available for Tell Mardik-Ebla, where a large blade distal fragment belonging to the EB III horizon has been recently published (Vacca 2020).

Moving on the coast, the site of Ougarit-Ras Shamra shows the occurrence of few large blades associated with small ones, both functionally described as sickle elements, in strata groups B-H (niveau III) which are contemporary to a Final Ubaid and early Late Chalcolithic northern Mesopotamian horizon (Courtois 1962). Several kilometers south, the sequence of Byblos also highlighted the presence of large blades (Gauvin 1968). Unfortunately, wide chronological issues prevent the synchronization of the archaeological sequence within a broader regional framework due to the lack of specific documentation regarding the architectural phases (Thalmann 2008). Large blades are also testified in two neighbouring sites: at Late Chalcolithic Sidon "Dakerman", large laminar products are associated to cores, suggesting the eventuality of *in-situ* core reduction activities (Hours 1979), and at the Late Chalcolithic to Early Bronze age Sidon "College Site", where only a few items can be interpreted as large blade products within prevalent flake assemblages (Yazbeck 2006).

However, the most relevant archaeological sequence for the periods under examination is that unearthed at Tell 'Arqa (Thalmann 2006). Canaanean blades are reported from several chronological horizons: from EB IV, BM II to BR, and find strict technological and morphometrical comparisons with specimens from Amuq G-H layers of Judaidah (Coqueugniot 2006). Ongoing research conducted on new (excavations from 2005 to 2012) and old lithic assemblages from the site, allowed to fine-tune local developments of lithic technologies (Marchand 2014, 2017). Indeed, locally produced large blades detached by direct percussion are attested during the first half of the 3rd millennium BC in layer 17 (EB III, 2700-2500 cal. BC). However, large blades produced by the lever pressure system (up to 25 cm of length) are related only to imported items starting with layers 16-15 (EB IV, ca. 2500 BC) relatively late respect to what happens in the whole region (Marchand 2017).

4.4.2 Southern Levant

For what regards the southern Levant, Canaanean blades appear during the Early Bronze age, which begins very early respect the whole Fertile Crescent (ca. 3600 BC), and it is contemporary with Late Chalcolithic developments in northern Mesopotamia.

Very few contexts are interpreted as specialised knapping workshops. The earliest of them is represented by Fazael 2 (Bar and Winter 2010), located in the Jordan Valley, and dated to a transitional phase between the Late Chalcolithic and the Early Bronze age (ca. 3900-3600 BC). However, evidence of massive workshops belongs to the periods EB Ib-III (ca. 3100-

2500 BC); Tell Halif (Futato 1996), Har Haruvim (Shimelmitz et al. 2000) and Fazael 4 (Manclossi 2016; Zutovski and Bar 2017) represent high-intensity core reduction sites.
Evidence of cores within settlements is found at EB I sites of Gezer (Macalister 1912), Afridar (Milevski 2013), Gat Govrin (Shimelmitz 2009; Milevski et al. 2011), and Nahal Gush Halav 2 (Frankel et al. 2001). Finally, indirect traces of on-site knapping activities are recorded at Horvat Ptora (Milevski 2013; Manclossi et al. 2019) where knapping waste products, core trimming elements and technical blades have been found, and at Tell Yarmuth (Manclossi et al. 2016), where nodules, roughouts, and waste products are associated to caches of complete blades.
The Early Bronze age I seems to be the period in which Canaanean blades are spread in many sites as imported blades, constituting the exclusive blade component of the lithic assemblages (Rosen 1997, Eid 2004). As recorded for the other regions, a massive adoption as sickle inserts is highlighted (Manclossi and Rosen 2015). However, use-wear analyses are very few and, when performed, they revealed a higher complexity as showed for the site of Qiryat Ata (EB Ib-II), where the blades relate to pottery manufacture (Groman-Yaroslavski et al. 2013).
There is general agreement that Canaanean blades disappeared at the end of the Early Bronze age in the area, replaced by new technologies and systems of sickle manufacture (Shimelmitz 2012; Manclossi and Rosen 2015; Manclossi et al. 2019). A certain continuity through the Middle and Late Bronze age periods, however, is attested at the Megiddo cemeterial area where the blades form part of the grave goods within the necropolis (Anderson et al. 2004).

5. Current hypotheses and discussion

All the documentation available point out through the social acceptance on a broad scale of a "large blade idea" in the Near East during the 5th and 3rd millennia BC. As has been shown, such a concept implies complex phenomena of supply, production, and distribution that exhibit differences on a regional scale both in time and space.
The production of large blades started during the PPNB period (8th millennium BC) in Anatolia using obsidian raw materials and was spread out of the region throughout the Neolithic (7th millennium BC) when radical socio-economic transformations occurred among Neolithic societies (Abbès 2015).
However, it is only during the Chalcolithic period and specifically during the late part (5th millennium BC onwards) that it is possible to find a clear tendency towards the systematic choice of chert raw materials to produce large blades by pressure. Although the exploitation

of Anatolian obsidian sources to produce blades and bladelets never ceased overtime – on the contrary, the diffusion of obsidian products reached a peak during the early Late Chalcolithic 1-2 periods in the whole northern Mesopotamia – the present phenomenon implies a changing interest towards raw materials possibly more easily accessible on a local scale along the arc of the Zagros Mountains.

According to some scholars, the introduction of Canaanean blades might be related to the first urbanism of the early 4th millennium BC and connected not only with the growing demand for utilitarian goods but also to a capillary exploitation/exploration of territories, in particular of the peripheral mountain range where chert sources can be found.

However, such trends predate the Uruk presence in northern Mesopotamia and only occasionally Canaanean blade cores are testified in sites featuring true Uruk occupations (e.g. Habuba Khabira South). Evidence from Hacinebi supports this assumption and suggests that the necessary skills and knowledge to produce large pressure blades were owned by the indigenous population at the site.

By examining the available documentation, only at Hassek Höyük, located on the middle Euphrates region, a significant number of cores associated with unused blades and waste products indicates on-site systematic knapping operations. Cores' position at the edge of room 29 of a storage building, indicates that the items might have been deliberately stored to be exploited. At the present stage, it is unknown if such evidence stood for a consolidated practice in coeval sites. Certainly, cores have been found in several settlements spanning from LC1 to LC5 as sporadic findings and, specifically, as discarded items (e.g. Norşuntepe, Sheik Hassan, Tell Brak, Tepe Gawra and Tell Karrana 3).

This small number becomes relevant once we consider the documentation of most of the contemporary settlements, which indicates they only received finished products for daily consumption. However, it is worth to consider that exploited cores once discarded can be worked by completely changing targets of productions, thus considerably limiting the archaeological evidence.

The situation is different in Ninevite 5 sites, where cores are virtually absent from all the settlements. Evidence from Tell Chuera is the only comparable Early Bronze age context that shares some similarities with 4th millennium BC sites. However, it must be considered that information regarding chipped stone industries for many contexts are very incomplete or even absent.

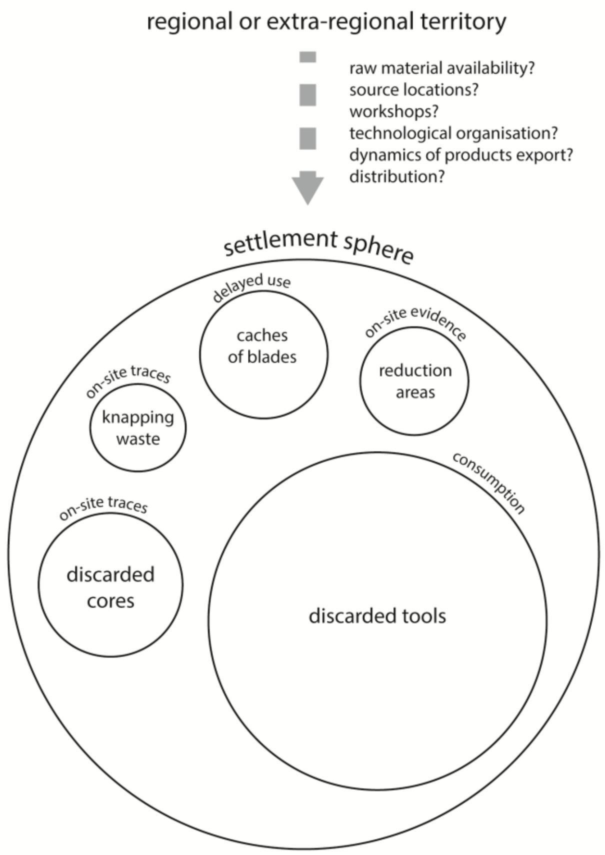


Fig. 4 Schematic representation of the available documentation regarding the Canaanean blade evidence. Circles' size is directly related to the number of clues in all the sites considered in the chapter.

The evidence from Titris Höyük (2600-2100 BC) is something different from earlier attestations. It is related to a new socio-economic organisation as a response to political developments on the Upper Euphrates which probably led to the rise of full-time specialisations in the field of knapped stones craft productions. The fact that the whole *chaîne opératoire* was carried out at the site with high intensity and in a specific area, can be interpreted as proof of competence division between miners and knappers in the area.

The present picture is very different from the Levantine area, where different kinds of clues, thanks to greater attention paid to the topic, suggest a different model of production and distribution. However, we must consider possible socio-economic implications that a less extensive territory and probably better connected to chert sources might have had on methods of raw materials procurement.

If we exclude Fazael 2, the whole documentation about *in situ* knapping activities belongs to the 3rd millennium BC. Among the sites, only Har Haruvim and Fazael 4 can be considered as true evidence of organised and specialised workshops. The remnant documentation (e.g.

caches, knapping waste products, exhausted cores) points out through limited knapping activities in specific areas of settlements.

This is the reason Manclossi et al. (2016; 2019) hypothesized that the Canaanean blades distribution system was run by itinerant specialised knappers who directly produced blades for local communities and managed their distribution on local scales.

However, while recognising the validity of this model for the southern Levant, nothing is known about the stages before the entry of transformed raw materials into the settlements. Similarly, for northern Mesopotamia, it appears unlikely that sites with evidence of knapping episodes could be at the same time interpreted as centers of redistribution on a local or extra-regional scale. This consideration is valid when considering how research on the subject has been carried out and data on lithic industries are acquired. Indeed, the site-centric model has its limits in considering what is witnessed in the settlements as exhaustive, ignoring the existing relationships between human behaviour, territory, and available resources.

In fact, despite the actual documentation demonstrates that a great variability of chert varieties was exploited, there is a diffused tendency to flatten this complexity by recognising the main role of south-eastern Anatolia as regards the exploitation of sources, based on the location of the known workshops. As a paradox, suitable chert sources to produce large blades are not attested. The source of Kafernaz, which is traditionally linked to settlements such as Titris Höyük and Hassek Höyük, did not return adequate evidence of possible exploitation in this sense, neither on the archaeological level nor in the field of raw material characterisation.

For these reasons, we believe that the topic of this research can contribute significantly to providing further complexity to the phenomenon, demonstrating that the study of chert availability, workshops organisation, and distribution of transformed raw materials in the territory are essential factors to understand technological and cultural choices connected with the problem of Canaanean blades of the Near East.

2. THE THEORETICAL AND METHODOLOGICAL FRAMEWORK

1. Integration of the raw material data into technological analyses

Following recent approaches to the study of prehistoric material cultures, lithic artefacts are seen as evidence of human behaviours in their technical, economic and social dimensions (Pelegrin 1990). Each lithic artifact is, thus, the output of the interaction of three factors (Pelegrin et al. 1988): (1) the object, intended as the target of a knapping activity, as well as tools used during its manufacture; (2) the technical processes (or sequences) through which the raw material is transformed into objects, including action and gestures, techniques and methods adopted; (3) the necessary skills (or *savoir-faire*) to manage technical processes, intended as a set of knowledge (and related transmission or innovation factors) owned by the group or community. Such factors, grouped, constitute the theoretical basis of the *chaîne opératoire* concept (Pelegrin et al. 1988) which has fundament on both its spatial (e.g. sites of extraction, sites of production, sites of consumption and discard) and temporal dimension (e.g. raw material procurement, blank production, tool's management).

The acquisition of lithic raw materials relates to the early stages of the process. Investigating the problem means understanding criteria of raw material choices, transport strategies to the production/consumption site and modalities of introduction on the site of each type of raw material (raw or preformed blocks, blanks or finished products) (Geneste 1988). By relating technological data with those concerning raw materials it is possible to identify differentiated behaviours regarding the management (or economy) of raw materials (Perlès 1991). Moreover, the identification of several knapping sequences can highlight differences of raw materials composing the series, that allow recognising a preferential use of certain materials for a particular *chaîne opératoire* aimed at producing specific blanks or tools (Perlès, 1991). Regarding this latter aspect, the preferential use of certain materials can be explained by checking the regional availability of knappable resources (i.e. accessibility, quantity, quality) and/or studying technical requirements of specific lithic productions (e.g. blanks which require particular types of materials; see also chapter 3) (Geneste and Rigaud 1989; Andrefsky 1994). When technical requirements are highlighted, the rough blocks must necessarily meet specific morphologies and quality, conditions allowing predetermination of cores and standardised productions (Pelegrin 1995). Conversely, raw materials properties can constitute a constrain to lithic productions, leading to the adaptation or variants of knapping techniques to such particular materials.

Finally, modes of acquisition and management of lithic raw materials are strongly correlated with lifestyles (i.e. sedentary or nomadic) and constitute relevant part of technical systems as these latter are strictly connected with the socio-economic organisation of a given population (Lemonnier 2010).

These strategies are particularly evident in the Near Eastern archaeological record, where, since the Neolithic onwards, structures or well-defined spaces within the settlements are connected with specific activities and economic strategies (i.e. waste pits disposal, caches of cores/blades, knapping areas, domestic and productive units, craft areas) (Astruc et al. 2003; Rosen 2010; Binder 2008; Rokitta-Krumnow 2013).

1.1. Identification of the geographical origin of lithic raw materials

The information provided by raw materials characterisation concerns two complementary research directions: the first is linked to questions regarding the mobility of human groups, while the second one concerns the circulation and management and raw materials according to technical systems (Bressy 2002). These issues do not arise in the same terms depending on the prehistoric period considered (Bressy 2002).

The identification of sources concerning the artefacts can, thus, lead to addressing various problems, evidence of the complexity of the behaviours adopted by the human group or communities. This necessarily leads to recalibrating the strategies of analysis by focusing on aspects (e.g. macroscopic, petrography, or geochemical) that can prove to be significant in achieving the aims of the research in place (i.e. distinguishing between cherts of different geological formations, distinguishing cherts from the same formation, or belonging the same age).

Therefore, the study of the lithic assemblages in relation to the sources can lead to the identification of different areas: (1) the subsistence territory, corresponding to the area whose resources are intensely exploited from the outcrops; (2) the cultural territory, which brings together groups belonging to the same cultural horizon, subjected to social relationships (Geneste 1991).

The nature of these relationships is difficult to grasp in prehistory but they can be approached by identifying allochthonous raw materials which necessarily imply broader dynamics of interaction between populations (Bressy 2002). Regarding the problem, Perlès (2012) emphasizes the technological dimension of the problem, by distinguishing areas for the diffusion of techniques and know-how that would indicate contacts between more populations supporting the hypothesis of real "interactions", from areas of simple diffusion of ideas and/or raw materials through different dynamics, including trades and exchanges.

1.2. Chert sourcing: state of the art

Since the initial stages of the research about chert characterisation, several authors proposed different analytical strategies to better identify key features of chert artefacts useful to distinguish between potential sources represented within lithic assemblages. Although macroscopic approaches are usually employed to describe visible properties of lithic artefacts to compare them with geological samples, the study of chert raw materials is properly a geological issue that has been faced with both petrographic and/or geochemical approaches (Sieveking et al. 1972; Séronie-Vivien et al. 1987; Bressy 2002; Fernandes and Raynal 2006; Tarantini et al. 2016).

1.2.1. Chert definition

Chert is defined as the general group name used for a microcrystalline siliceous sedimentary rock of inorganic, biochemical, biogenic, volcanic, or hydrothermal origin (Tucker 2001). This type of rocks is quite common but not abundant (less than 1% of all sedimentary rocks) in the geological record, although in stratigraphic sequences they are represented since the Precambrian and until the Quaternary era (Boggs 2009). Cherty rocks are distinguished into bedded types resulting from the primary accumulation and nodular types, because of diagenetic processes (Tucker 2001; Stow 2005).

Factors that significantly trigger the diagenesis of marine sediments in which chert usually forms are temperature, burial depth, age, and the limestone host rock facies (Murata and Larsen 1975). Authigenic silica phases are formed according to well-defined solution-reprecipitation transitions from amorphous to more ordered structures: opal-A→ opal-CT→ micro-quartz (Graetsch and Grünberg 2012). Paragenesis of silica phases depends on time, burial depth, and temperature. The dissolution of the organic oozes constitutes the beginning of the diagenesis. Recrystallization processes occur in time with increasing amounts of pressure and temperature, leading to the formation of opaline forms initially deposited as opal-A, an amorphous form including water (up to 12%). During dissolution processes, the transition from opal-A into crystalline opal-CT takes place and can occur in the void space fillings of lepispheres, small spherules of about 5 to 12 μm in diameter (Calvert 1974).

The transformation from opal-CT to micro quartz depends on environmental conditions, and silica impurities can influence the silica transition rate (Isaacs 1982). Metamorphic recrystallization of microcrystalline quartz results in the formation of mega quartz crystals (Graetsch and Grünberg 2012). Petrogenesis of chert also depends on further environmental factors, such as the chemical composition of pore fluids, pH values, and the amount of organic matter (Luedtke 1992).
Luedtke (1979) used the term “source” at a general scale to indicate the area from which the chert was originally collected as raw material. The definition includes primary sources (bedrock deposits) and secondary sources (colluvial, alluvial, beach, and glacial deposits). Schmid (1986) differentiates between primary and secondary chert relative to the calcareous sediments of Nord West European Upper Cretaceous successions, where cherts are broadly widespread. Primary sources are distributed within the Cretaceous sediment in nodules and bedded form, while allochthonous or secondary deposits originate from weathering, transport, and deposition of host rock during the Pleistocene, contain chert relics. Moreover, Schmid (1986) highlights the relevance of the chert inclusions for the provenance study of artefacts and, at the same time, for the stratigraphical zoning. Indeed, chert nodules are an outcome of early diagenetic replacement that preserve original inclusions (argillaceous and organic constituents of chalk sediments). When chalk or limestone sediments include a specific chert type, this occurrence can be used for lithostratigraphic correlation (both intra- and inter-regional). Such type tends to characterise restricted stratigraphical levels. Bressy (2002) discerns between primary sources, when chert is within the host rocks, and sub-primary or secondary chert sources, based on their exposition.

1.2.2. Insights from petrology and petrography studies

The geological approach of Séronie-Vivien et al. (1987), applied to the chert of the carbonate platform of North Aquitaine (France), highlighted that the morphology and textures of chert were connected to sedimentary environments. As the silicification process frequently preserves original textural characteristics, Dunham’s scheme (1962) was applied to describe textural properties of chert nodules. Such work firstly introduced a methodological approach based on a geological terminology to describe chert samples, based on macroscopic and microscopic observations. Therefore, microfacies of rocks and micropaleontological contents were identified and the whole package of features allowed to reconstruct the depositional environment. Although Dunham’s texture classification is quite diffused in chert petrography (e.g. Séronie-Vivien et al. 1987; Bressy 2002; Fernandes and Raynal

2006), it should be noted that its petrological meaning is not the same. In the case of chert, the diagenetic processes and the possible mobilisation of the sediment (e.g. bioturbation, slumping) can yield significant modifications in the chert textures compared to the original ones present in the parent sediment.

The petrographic-mineralogical protocol proposed by Pawlikowski (1989) aimed to standardise petrological investigations of raw materials: the procedure suggests a macroscopic description that includes (1) colour of samples by Munsell Colour Charts (1915), (2) luster according to mineralogical scale and (3) definitions of transparency and fissility. Furthermore, the microscopic description was carried out on a thin section, describing texture, structure, and mineral compositions. Sarabia (1990) proposed a similar approach, with macroscopic descriptions based on (1) the geological age of the formations, (2) the colour measured with Cailleux and Taylor code (1963), (3) texture as a function of touch, grain-size and, (4) several ranges of surface's luster, (5) cortex type and thickness measurements.

These contributions represent the basis of the archaeometric study of chert and early insights toward features standardisation, which, however, are frequently considered subjective or destructive methodologies.

1.2.3. Macroscopic and microscopic approaches

The macroscopic approach represents the focus of Bressy's protocol (2002). She proposed a naked-eye observation in combination with a non-destructive petrographic analysis of samples using a stereomicroscope. This approach is based on the observation of the frequency, dimension and nature of inorganic inclusions, oxides, organic matter and micropaleontological contents. The macroscopic description follows the terminology proposed by Affolter et al. (1999) aimed to describe chert on fresh surfaces of geological samples. However, a more detailed terminology is proposed to define the nature of the cortex. Since cortex and cortex to chert transitions can exhibit peculiarities within primary chert sources, a detailed description is needed (e.g. thickness, colour, type of transition). Moreover, the scholar defined as "neocortex" the outer surface of secondary chert sources. Following her work, modifications due to weathering of outer surfaces of alluvial pebbles/cobbles are consequences of exposition, transport, and climate oscillations. However, the protocol does not consider colour measurements but suggests a terminology to describe luster, fracture, patinae, and structures.

Micropaleontological contents are observed under the stereomicroscope to add useful discriminant information without destroying the samples. Texture properties are defined according to Dunham's scheme. Furthermore, a detailed description of each inclusion within chert matrix and structures allow recognising sedimentary facies and, when possible, to propose a palaeoenvironmental interpretation.

The need to discriminate the age of cherts and depositional environments finds in the micropaleontological approach an appropriate way, particularly aimed at archaeological studies (Bressy 2002). The first implementation of the method dates to the 80's thanks to Masson's work (1981). Subsequently, further aspects have been increased by Affolter (1994, 2002) and Bressy (2002) in the light of provenance studies. Finally, Bertola (2011, 2012) suggested a micropaleontological approach to investigate chert procurement patterns from northern Italy formations. The speed of these methods, their non-destructivity and low-cost toolkits constitute fundamental advantages in archaeological research. The only disadvantages lie in the subjectivity of naked-eye descriptions and the impossibility of applying such methods in case of completely altered pieces.

1.2.4. Geochemical approaches

Variations in geochemical patterns in cherty limestones from different geographical areas were observed by Sieveking et al. (1970; 1972) by carrying out quantitative analyses using Emission Spectroscopy and Atomic Absorption Spectroscopy (AAS) on chert sources from Great Britain and Western Europe. These works showed that variations of trace element content within chert relate to variations occurring within the non-carbonate material (clay and phosphate minerals, organic matter). Therefore, geochemical variations of certain trace elements are a function of depositional environments of chalk in which the nodules form. The same chert artefacts used by Sieveking's group (1972) were subjected to Neutron Activation Analysis (NAA) from Aspinall and Feather (1972) to characterise prehistoric chert mining sites. Their study highlighted wide variations of certain element concentration and the limits of provenance studies due to geological variability.

Luedtke (1978; 1979) dealt with such a problem. The scholar also focused on the extent to which chemical variation can be congruent with a variability of macroscopic features such as colour, texture and structure. The existing chemical variability within formations contradicts the assumption that chert-bearing formations can be considered chemically homogeneous and systematic sampling procedures must be used to characterise each source. Therefore, understanding variations within and between sources is of extreme importance to assign artefacts to specific sources. The limits of such method are related to sources vicinity in time and space, will be chemically similar and scarcely distinguishable.

The NAA technique was also used, in combination with ICP-MS, by Hess (1996) for chert provenance studies in the Columbia Plateau. These techniques produced comparable results. The same author suggested the X-Ray Fluorescence (XRF) technique as a third possibility to carry out chert sourcing and indicated discriminant analysis as the best suited for large-scale provenance analysis. Malyk-Selivanova et al. (1998) approach to chert sourcing proposed geological sampling and analysis by Instrumental Activation Analysis (INAA) to detect trace elements concentration and provide descriptive statistics to process chemical data. Unweathered and unpatinated parts of artefacts should be selected for chemical analysis. The author discerns between the indicators of provenance (1) "key signatures" for discrimination of cherts belonging to different stratigraphic formations or units (i.e. depositional environments) and (2) diagenetic-metamorphic signatures useful to discriminate outcrops within the same stratigraphic unit (e.g. Sr, Rb, Ba).

The Energy-Dispersive X-Ray Fluorescence technique (ED-XRF), applied for chemical characterisation of the obsidian artefacts (Hughes, 1983, 1988; James et al. 1996; Shackley 1988, 1995), has been adopted by Gauthier et al. (2012) to determine Canadian chert sourcing. ED-XRF has been also used by Sánchez de la Torre et al. (2017), who carried out the geochemical characterisation of two chert formations in the Pyrenees, which show similar textural and micropaleontological features, in combination with Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICP-MS). Differences between trace element concentrations detected from the two instruments have been noted.

Finally, over the last decades, X-Ray Fluorescence portable devices (pXRF) have been widely adopted to chemically characterise many archaeological artefacts both on the field and the laboratory, including also obsidian (Craig et al. 2007; De Francesco et al. 2008; Nazaroff et al. 2010; Forster et al. 2011; Sheppard et al. 2011; Forster and Grave 2012; Glascock 2012).

1.2.5. Multi-parametric protocols

A deepened work about chert from variables point of view is certainly that of Luedtke (1992). Her research suggested a standard description of visible properties to facilitate comparisons. This study proposed for the first time a protocol of macroscopic description that involves colour measurements using Munsell Colour Charts (1915), as a more accurate method to record the chromatic features of chert. A method to measure chert translucence was proposed by Ahler (1983), although this visible property depends on the material's thickness. The observations of fracture surface (e.g. uneven, rough, or smooth) relate to textural properties which is a function of porosity, presence or absence of inclusions and micro-cracks around the grains. The gradual or abrupt variations of the structure are defined with an appropriate terminology distinguishing replacement and diagenetic features. Luedtke's work focused on two additional outer layers: she defined cortex only the outer layer that occurred during diagenesis process and recommended the term "weathering rind" in the case of weathering process (Bressy's neocortex).

Her protocol proceeds by examining chert under the stereomicroscope and the Scanning Electron Microscope (SEM). Data are collected at different scales and correlations result between luster and texture, that supply information about grain-size, and between fracture, surface and colour are frequently linked to occurring impurities. Luedtke (1992) argues that interrelation between various chert properties allows predicting some of the properties based on the others. Although this protocol improved the archaeological practice with more reproducible observations and a suitable terminology, some features remained somehow subjective (i.e. colour and luster).

Hess (1996) highlighted that petrographic and geochemical signatures were essential in identifying the provenance of chert artefacts based on the assumption that a given source can be extremely variable in elemental concentrations. This is also the reason supporting that chert provenance analysis based on geochemistry is difficult: unknown changes on trace element concentration on worked artefacts can occur due to natural (e.g. weathering) and anthropic factors (e.g. heat-treatment).

Hess protocol considered time chert macroscopic and microscopic features, and, at the same, chemical elemental concentrations. Macroscopic data considered colour, luster, fracture characteristics, light transmittance and nature of any veins or inclusion. Based on Luedtke work (1992), Hess also describes the nature of outcrop, the chert structure using Luedtke's terminology, and cortex colour and its variability on freshly fractured surfaces. Hess remarked the unavoidable use of petrographic and geochemical signatures for chert provenance analysis, demonstrating the limits of reliability of macroscopic examinations.

2. The evolutionary concept of siliceous sedimentary rocks

The concept is based on the assertion that the mineral structure of siliceous sedimentary rocks undergoes changes during each physicochemical modification of the environment in which they are metastable (Delvigne et al. 2020). Such modifications not only affect the outer rock surface, but its whole volume and can be studied at different scales (i.e. macroscopic, mesoscopic, microscopic, and ultra-microscopic) and through several analytic techniques depending on the main scope.

According to this model, sources can be divided into two main categories: (1) primary sources, where all the characteristics of diagenetic origin are preserved within the hosting geological formation, including volume and shape of the silicifications; (2) secondary sources, when modifications (e.g. mechanical, physical and chemical) due to changing post-genetic environments are highlighted. Among these, Delvigne et al. (2020) also distinguish, based on type and age of the deposits: colluvial, alluvial, beach, fossil shorelines (subjected to wave actions through time), and moraine secondary deposits.

The analytic method involves wide geological samplings to collect the highest possible amount of information to identify "itineraries" along which siliceous rocks moved from a specific source – namely genetic type – by erosion and natural transport and, finally, deposited (Fernandes 2012). The study is carried out by reading the stigmas (e.g. shocks, impacts, patinae) left on samples natural surfaces as depositories a "memory" of such itineraries (Fernandes et al. 2006; Delvigne 2020). The observations on archaeological materials follow the same strategy. In addition, the anthropic agent is considered as the factor determining the final stage of the process in the archaeological context, which implies their burial and related taphonomical processes.

Therefore, Delvigne et al. (2020) essentially identify three main stages of the whole cycle: (1) "genetic type", investigated through petrographic analysis to collect information about the rock genesis; (2) "gitologic" type, a term used to reconduct all the pre-depositional information (before procurement and knapping activities) revealing the rock itinerary readable on the (neo)cortex surface; (3) "taphonomy", to indicate all the post-depositional processes occurred on the knapped surfaces after the artifact discard and burial.

However, these stages can be represented on the same artifact depending on the strategies of procurement carried out by human communities (primary or secondary sources exploitation). Considering our work, attention has been devoted to artefacts post-depositional surface modifications. The study of such modifications allowed to address the analysis in a critical mode, as a necessary step to identify and evaluate the reliability of genetic information preserved in the light of the artefact's provenance (see chapter 7, par. 4.1 and 4.2).

3. Workflow

The present research was carried out following three main steps: (1) study of lithic assemblages according to a techno-economic perspective, to isolate issues connected with the production of large blades within the contexts analysed; (2) survey focused on the identification and extensive samplings of chert sources potentially suitable for the production of such blades; (3) application of the NM-PCI protocol aimed at studying the provenance of archaeological materials as a function of the source identified.

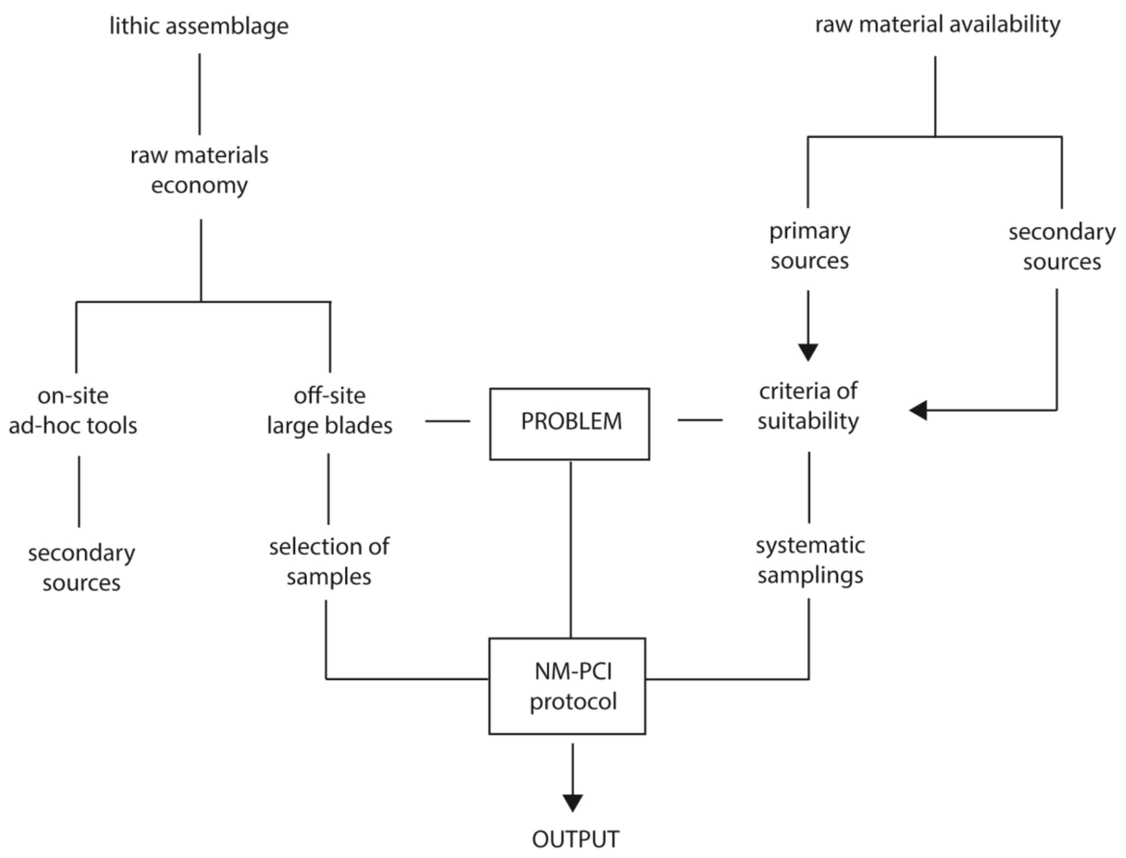


Fig. 1 Conceptual scheme outlining the theoretical and practical organisation of the conducted work.

Regarding the first point, the study necessarily considered all the lithic assemblages available, as well as survey materials, to identify differences between productions and their distribution in the settlement, according to raw materials and artefacts management (Fig. 1). In this way, data obtained were used for a socio-economic reconstruction in which contextualising the evidence regarding large blades consumption (see chapters 4 and 5). In the specific, data collected at Tell Helawa site made possible to reconstruct these trends on a diachronic scale, to understand variations in raw material procurement strategies in relation with the evolution of the technical systems of lithic production at the site through time (see chapter 5).

Once the archaeological problem had been identified, a survey was carried out with two main goals: (1) to reconstruct the availability of chert in the area; (2) to isolate potential suitable sources connected the production of large blades. Regarding the first point, such investigations were carried out within the limits of the area granted to the LoNAP mission (see chapter 6), while surveys were carried out in the nearby of the site of Tell Helawa within the limits imposed by safety (see chapter 5). In the latter, results allowed to exclude potential suitable chert sources as it was only noticed the presence of secondary deposits functional to produce small blanks which, however, are represented at the site in massive quantities (e.g. bladelets, flakes).

A critical issue for this research was represented by the absence of detailed geological cartography. In the present work, the Geological Map of Iraq at 1:250000 scale, compiled by GEOSURV (Geological Survey of Iraq), has been adopted. Although more detailed maps cover part of the region (Sissakian 2018), these have not yet been compiled for the quadrant sheets of our interest: Al-Mosul (Sissakian 2013) and Erbil-Mahabad (Sissakian and Fouad 2014). However, specific field reports regarding local sequences are available and have been adopted in the stratigraphic contextualisation. Finally, thanks to the collaboration with local geologists it was possible to carry out fieldwork and contextualise the chert sources within the regional stratigraphic framework.

The discovery of the Jebel Zawa chert mines and related large blades knapping workshops in the LoNAP area (see chapter 3), undoubtedly influenced the sampling strategies conducted. Such discovery allowed to focus the work on extensive samplings of a series of mining valleys, based on the presence or absence of archaeological evidence of chert exploitation (see chapter 6).

The entire geological sampling, together with a selection of artefacts from different archaeological contexts of the LoNAP area and the site of Helawa were exported to Italy and subjected to the application of the NM-PCI protocol (chapters 6 and 7).

4. The NM-PCI protocol

The NM-PCI is a Non-destructive Multi-parametric Protocol for Chert Investigations aimed at recording mixed data matrix of specific characteristics of chert, such as cortex, structure, texture, fracture and colour (Tarantini et al. 2016). This method was integrated with microscope observation to determine microfacies and micro-palaeontological remains, following the work of Delluniversità et al. (2019). Observations are made on clean fresh surfaces, since weathered and patinated surfaces may significantly alter or obliterate the visible structures of chert. The data are expressed using semi-quantitative and ordinal variables. Geochemical fingerprints are investigated through Raman micro-spectroscopy technique and pXRF. These non-invasive chemical techniques prove to be essential procedures because of archaeological samples characterisation and allow to obtain respectively the mineralogical composition of the specific portions of sample and elemental chemical composition of the chert matrix. The obtained datasets (Fig. 4; see also appendix B and C for a deeper look at datasets built from geological and archaeological samples analysis) allowed the simultaneous use of several variables (n= 43) of different nature (Delluniversità et al. 2019), given the high variability of chert also at intra-nodular scale (Luedtke 1979; Selivanova 1986), and considerably reduced wrong evaluations.

4.1 Geological sampling strategy

A total of 83 geological samples considered in this study were collected from nodules still in place in the primary deposits, at a regular distance of 5 to 10 m, to be representative of the horizontal and vertical development of the geological stratigraphy of the embedding formation (see chapter 6, par. 3.1). Heavy erosion and unsafe areas due to unstable cliffs were an obstacle to a continuous sampling of the chert nodules in some circumstances.
Each sample was positioned with a handheld GPS, numbered and marked with a location code (i.e. SK, SK2, GK, OS). The nodules were photographed in their depositional contexts. Point coordinates were inserted in a GIS model to build distribution maps of chert features and thus investigate their variability at intra- and extra-valley scales (see chapter 6, par. 4.2).

4.2. Macroscopic description

The mixed data matrix is structured in two parts to describe the cortex and the chert (see also Appendix A for some examples). The original protocol also provided for the measurement of luster as a macroscopic chert surface characteristic. Here, this variable was not taken into consideration since all the geological samples did not return a significant signal. Instead, the morphometry of the nodules was considered as an additional variable. Such feature was measured in situ, before the sample collection, to answer specific technological questions (see chapter 6, par. 4.1 and 6).

4.2.1. Morphometry of the silicifications

The nodules were measured according to their visible dimensions (major and minor axes; values are indicated in cm). The rounding and sphericity of chert nodules were also recorded, to better define their morphological characteristics, following the scheme usually adopted for clastic sedimentary rocks (Krumbein and Sloss 1963).

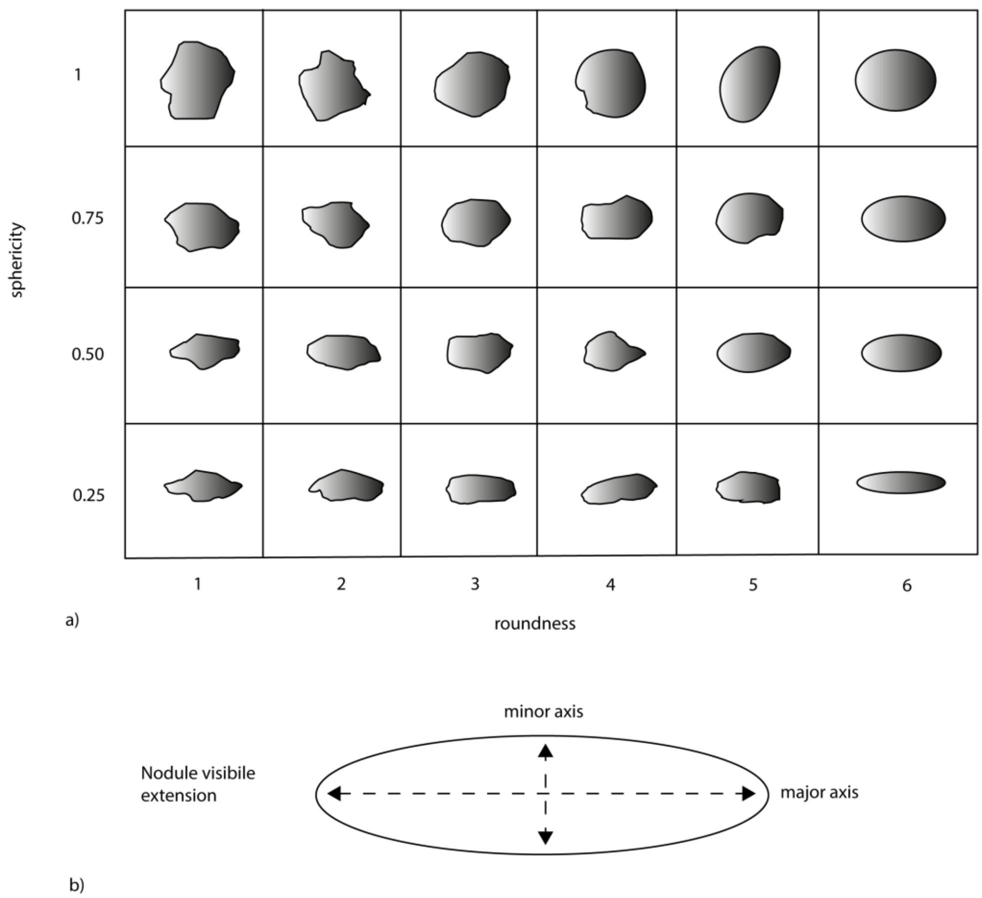


Fig. 2 Strategy of morphometric data collection. Schema adopted to record sphericity and roundness of nodules (modified from Krumbein and Sloss 1963) (a); strategy of nodules measurement (b).

Four classes of sphericity were distinguished (0 – 1), and six classes of roundness (1-6), both expressed as ordinal variables (Fig. 2).

4.2.2. Cortex features

When present, the cortex constitutes the external portion, frequently visible in many chert types: during the process of silicification, the cortex represents the transition zone between the chert and the surrounding bedrock and is characterised by a distinct colour and chemical composition (Luedtke 1992). The cortex area was described according to five macroscopic parameters (Tarantini et al. 2016): “thickness” (values in mm), “nature”, “induration”, “surface” and “boundary”. An acid test was used to determine the chemical nature of the cortex: a drop of 2 % HCl solution was deposited on the fresh cortex surface to discriminate between a carbonate or siliceous composition. The induration, namely “hard” or “friable”, was estimated by scratching the cortex surface with a steel penknife blade. Moreover, the cortex was described as “harsh”, “rough” or “smooth” to the touch. Finally, the boundary, i.e. the visible limit of distinction between chert and cortex, is described as “sharp”, “clear” or “diffuse”, based on the clarity of the boundary.

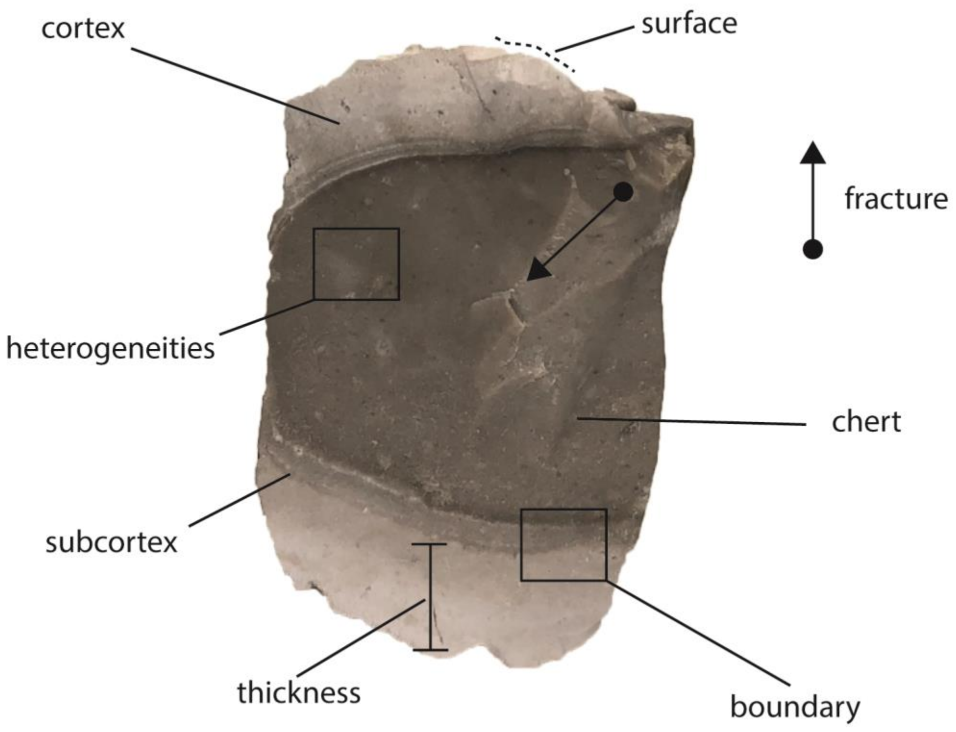


Fig. 3 Macroscopic variables considered by the NM-PCI protocol.

4.2.3. Chert surface features

The macroscopic description (Fig. 3) proceeds with observations of the chert's subcortex, structure and fracture. The subcortex, when present, is the transition area between cortex and chert and is recorded in terms of presence or absence. Seven basic categories have been identified for chert structure: “homogeneous”, “shaded”, “mottled”, “spotted”, “laminated”, “banded”, “streaked”. These variables concern the overall appearance of the rock, including colour distribution, and may regard more than one basic structure (mixed structures). Homogeneous structure refers to a type of chert with a uniform appearance that contains an amount of grains < 10% vol. The remaining six categories describe, singularly or in combination, all the possible degrees of heterogeneity. Small spots of light colour, distributed within the matrix and measuring between 0.63 mm and 4 mm in width, identify a spotted structure. A mottled structure is characterized by pale, blotchy, marbled, uneven inclusions more than four millimetres across. When the inhomogeneity concerns the colour of the matrix that varies with gradual transitions, the chert may be defined as shaded. Based on the thickness of visible layers, the structure is identified as laminated, if the layer thickness is less than one centimetre, and banded if the thickness is above one centimetre. Lastly, a streaked structure indicates those with stretched, lighter and marbled heterogeneities.

MACROSCOPIC	Cortex	thickness	measures in mm
		nature	calcareous; siliceous
		induration	hard; friable
		surface	harsh; rough; smooth
		boundary	sharp; clear; diffuse
	Chert	subcortex	present; absent
		structure	h; sh; m; sp; l; b; st
		fracture	conchoidal; sub-conchoidal; uneven
		colour	CIE L*a*b* colour system
MICROSCOPIC		translucence	translucent; non-translucent
		sorting	well-; moderately-; poorly-sorted
		particle size	l10%; 10% x 50%; 50%
		micropalaeontology	species abundance from 0 to 3 (ordinal var.)
CHEMICAL		Raman micro-spectroscopy	inclusions
		pXRF	chert matrix

Fig. 4 Summary of the whole package of variables considered by the NM-PCI protocol.

The last variable that completes the macroscopic description is the "fracture", a physical property of minerals based on the strength of the crystal structure bonds (Klein et al. 1993) and visible in hand specimens, which describes the way minerals break when subjected to mechanical stress. Fracture patterns can be identified as conchoidal, when marked by smooth and curved surfaces with visible ripples, sub-conchoidal, lacking ripples, and irregular or uneven fracture.

A non-invasive spectrophotometric technique was employed to measure the chert colour. To obtain reproducible colour measurements as continuous variables that are easy to process statistically (Tarantini et al. 2016; Delluniversità et al. 2019), colour coordinates were recorded using the CIE L*a*b* colour system (McLaren 1976), only from the matrix portion of samples. When samples exhibited more than one colour, additional measurements have been considered by defining as dominant colour, the prevalent shade, and non-dominant colour, minor variations in shades (see chapter 6, par. 4.1).

The three coordinates are: L*, lightness (0-100); a*, red/green value (± 100); b*, yellow/blue value (± 100). A portable Konica-Minolta CM-2600d spectrophotometer was used to measure colour data using the CIE L*a*b* colour system, in the wavelength range from 360 nm to 740 nm, with a wavelength step-size of 10 nm. Colour coordinates are obtained by processing the measured reflectance spectra (Konica Minolta instruction manual). The colourimetric information is relevant to the NM-PCI and represented by the three values of L*a*b*.

4.3. Microscopic description

The microscopic description was carried out at low magnification (10x-40x) on wet surfaces of the samples using a stereomicroscope, following the following standardised procedure (Delluniversità et al. 2019).

4.3.1 Translucence

A thin film of water ensures a smoother surface by increasing light reflection from the upper surface, thus improving the optical conditions. Discerning the inclusions below the lit surface at 10x magnification marks the chert as opaque or translucent.

4.3.2. Texture

All the surfaces of each sample were accurately examined and matched with comparison charts (Matthew et al. 1991) to estimate the percentage of inclusions and their size range

(Fig. 5). A sample may be “well”, “moderately” or “poorly sorted”, with three possible ranges of particle content (less than 10%, between 10% and 50%, more than 50%).

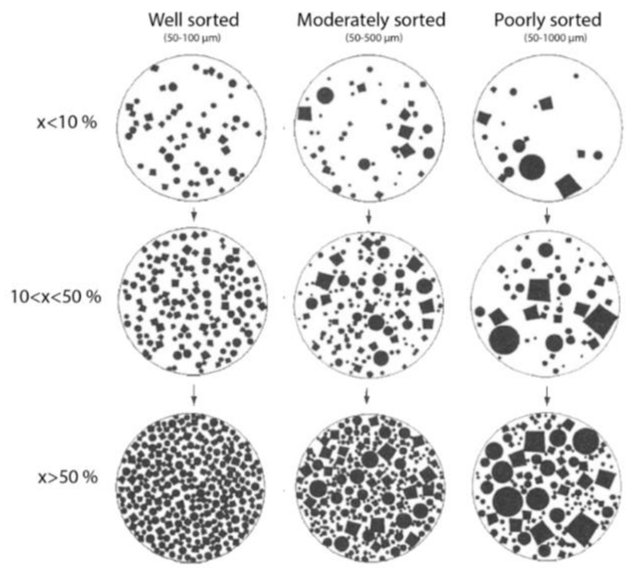


Fig. 5 Comparison charts used to describe chert textures (modified from Matthew et al. 1991).

4.3.3. Micropalaeontology

The preserved fossil assemblages were identified at 40x magnification (i.e. foraminifera, sponge spicules, algae, gastropoda). A semiquantitative scale (0-3) was used to indicate fossil abundance, where 0 means absence, 1 up to three fossils (traces), 2 corresponds to minor amounts (four to ten fossils), and 3 indicates major amounts (more than ten fossils).

Methods of determination and description were based on Bressy’s protocol (2002). However, microfossils assemblages analysis was only focused at highlighting differences in their frequency at intra- and extra-valley scale of the Jebel Zawa outcrops to identify possible distinctive features useful for the study of archaeological artefacts (see chapters 6-7). Although a palaeoenvironmental interpretation of microfacies was out of the scope of present work, our diagnoses found correspondence with data available from previous works carried out on the geological formation investigated (Mid-Upper Pila Spi limestone formation, Sissakian and Al-Jiburi 2014).

4.4. Geochemistry

Geochemical analytic techniques were applied to the study of both geological and archaeological samples. Raman micro-spectroscopy was carried out on a selection of geological samples to explore the reliability of the technique on fresh surfaces with the aim of collect information regarding the inclusions within the chert.

Conversely, pXRF technique was applied on both geological and archaeological samples and data obtained constituted a further set of continuous variables to be statistically processed.

4.4.1. Raman micro-spectroscopy

A total of 30 geological samples were chosen to be analysed by Raman micro-spectroscopy, selecting a representative number for the whole geological context, according to their position in the outcrop (see chapter 6, par. 5.1.1).

The Raman analyses were conducted using an Xplora (Horiba, France) spectrometer, associated with an Olympus (Japan) microscope. Samples with the lowest thicknesses and flattest surfaces possible were preferred to carry out non-invasive measurements; furthermore, an Olympus X50 Long Working Distance objective (N.A.=0.50) was employed to focalise the chosen spot, because of the irregular shape of the samples. In the analyses, the production of the mineral species' spectra required a wavelength of 532 nm. Despite its fluorescence, it proved to be better suited compared to wavelengths of 638 and 785 nm. A 2400 gr/mm grating was employed. The spatial resolution was estimated at about 2 μm, and therefore one spot analysis represents a very small part of the sample: measurements were taken on 10 spots per sample on average, on areas with different colours and morphological characteristics.

4.4.2. X-Ray Fluorescence

Elemental analysis was carried out on, a selection of 40 geological samples and 56 archaeological artefacts, using a portable Thermo-NITON XL3t XRF spectrometer. The device was equipped with an Ag collimator source operating at maximum 2 W and an SDD detector. The spot size was 3mm in diameter and the resolution of the detector was lower than 160 eV. To quantify both light and heavy elements, a total of 120s of real-time acquisition was used. Specifically, the sample was analysed for 60 s at 40kV and 50μA, for 30s at 50kV and 40μA and finally for 30s at 20kV and 100μA. At least two measures on the matrix of each sample were acquired. The concentration of eight elements (Ca, Fe, K, Sr, Ni, Mn, Ti, Ba) was determined since they present few values under the limit of detection (LOD) and good accuracy of measurement compared to the standards. The LOD is determined through a three-sigma detection limit.

The set of standards used for calibration is that produced by SARM (Service of Analyzes des Roches et des Minéraux, CRPG-CNRS, Vandoeuvre-Les-Nancy, France), which offers a wide variety of geological standards, in particular of silicate rocks.

3. The Jebel Zawa chert mines and the blade-knapping workshops

1. The LoNAP survey

Active in the Dohuk and Ninawa (Mosul) provinces of Northern Kurdistan Region of Iraq, the Land of Nineveh Archaeological Project (LoNAP) is a multidisciplinary territorial research project headed by the University of Udine, in collaboration with the Universities of Milan, Venice and Rome.[1] Since the reprise of archaeological fieldwork in Iraq in 2012, the region emerged as a fundamental area for understanding the complex processes behind the economic and social transformation of the human communities in the northern Mesopotamia (Kopanias et al. 2015). The project aims to investigate central themes in the near eastern archaeology such as the appearance of the earliest urban centres and state formation during the Late Chalcolithic (LC) and Early Bronze age (EBA), the impact of empires of the Iron Ages and later periods on landscape and settlement patterns (Morandi Bonacossi and Iamoni 2015). To explore and explain these issues, two main field strategies have been adopted: intensive and extensive surveys, and test excavations in key sites of the region (Morandi Bonacossi et al. 2018).

Since 2012 to 2018, the surveys have been conducted in an area approximately of 2,900 sqm by integrating the already available documentation with remote satellite imagery observations and associate fieldwork (Morandi Bonacossi and Iamoni 2015). The study area (Fig. 1) is delimited by the plain of Dohuk and the Zagros foothills to the north, the lake formed by the Eski Mosul Dam to the west, the piedmont plain that extends to the Jebel Maqlub and Bardarash regions to the south, and the River Al-Khazir to the east (Conati Barbaro et al. 2016). Starting from 2015, an interdisciplinary team from the Universities of Udine, Rome and Milan, started a dedicated extensive survey devoted to the investigation of the earliest phases of human occupation (Conati Barbaro et al. 2016).

The survey aimed to outline the chronological and cultural aspects characterising the region during the prehistory, from the Lower Palaeolithic to the EBA, and to relate

[1] The Land of Nineveh Archaeological Project conducted fieldwork in collaboration with the General Directorate of Antiquities of the Kurdistan Regional Government (directed by Kak Kaify), the Directorate of Antiquities of Dohuk (directed by Hassan Qasim Ahmad) and the State Board of Antiquities and Heritage in Baghdad.

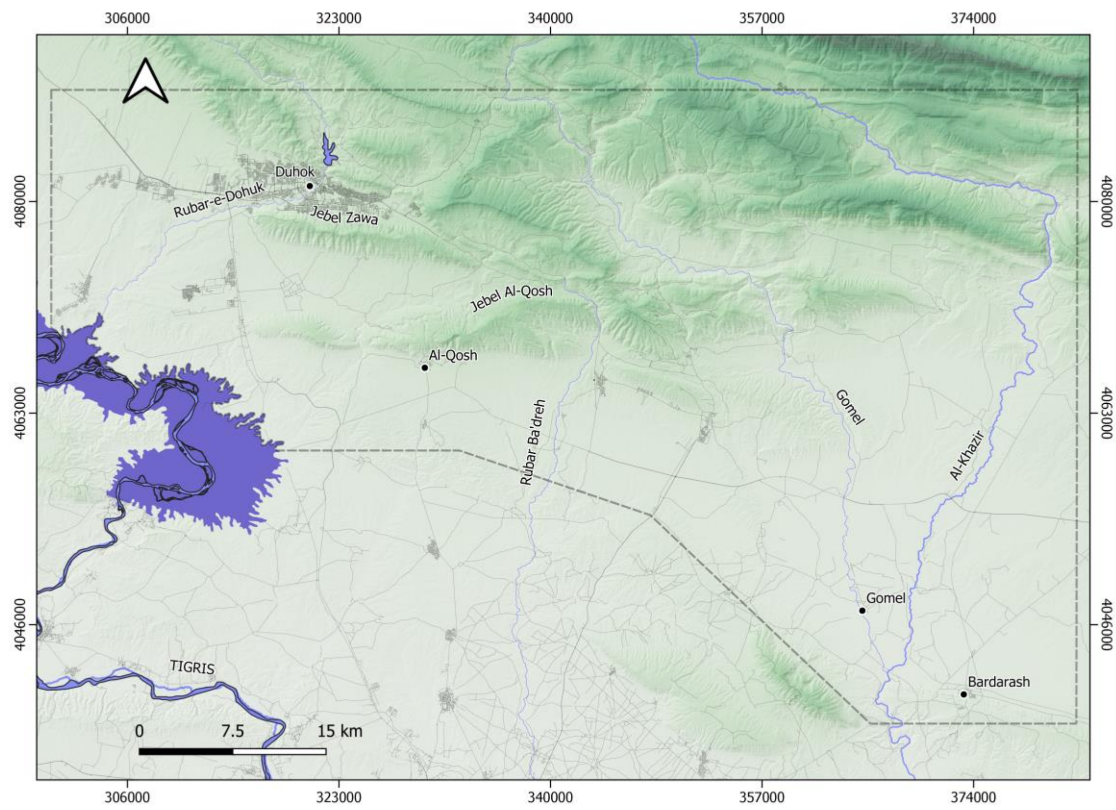


Fig. 1 Map showing the study area.

human settlements to the geomorphological units of the landscape and the availability of Fig. primary resources, such as water, raw materials and – for the later periods – agricultural soils (Conati Barbaro et al. 2019).

After six years of field investigations more than 1,000 archaeological sites, covering a wide chrono-cultural range, have been identified and studied (Morandi Bonacossi et al. 2017). Moreover, the prehistoric periods are well represented, starting from the early periods to the EBA. Although, the preliminary results seem to suggest that between the fourth and the third millennium BC, the Zagros piedmont area to the east of the Upper Iraqi Tigris was not home to widespread and significant urbanisation found in the neighbouring regions to the west but followed completely new trajectories of socio-political developments (Morandi Bonacossi 2016).

2. The Jebel Zawa chert mines

The first evidence of chert mining activities in the region was identified during the 2015 prehistoric survey campaign, in the innermost valley of the Jebel Al-Qosh (Çiya Al-Qosh), located in the nearby of the homonym Christian town of Al-Qosh, which directly opens in the Ninive Plains.[2] The Jebel Zawa (Çiya Zawa) mines were indeed discovered at the end of the 2015 campaign by the LoNAP team. Thereafter, a three-year (2016-2018) intensive survey was carried out, aimed at mapping the archaeological evidence of chert mining and processing. At the same time, the analyses of surface lithic collections coming from intensive surveys of the *tell* sites of the study area, identified through remote sensing and conducted by the LoNAP team from 2012 to 2015, yielded back massive evidence of chert blades in settlements featuring LC-EBA occupations. The circumstance spurred us to open a new line of specific research to be discussed in this chapter. The investigation of possible links between the Jebel Zawa mines exploitation and the existence of local/extra regional distribution networks of lithic raw materials and/or finished artefacts addressed this research at finding out traces of raw material exploitation and possible knapping workshops in the nearby of the mines.

Despite we were able to perform a careful exploration of the mining areas and realizing test excavations of knapping contexts, no radiocarbon dates are still available. The chrono-cultural attribution of the mining evidence is, for the moment, based on techno-typological observations carried out on the lithic materials and their relative presence in the sites of the region which have been dated through the analyses of the collected pottery (Gavagnin et al. 2016).

2.1. The geomorphological setting

The Jebel Zawa, or Dohuk anticline, is an isolated relief standing to the south of the modern city of Dohuk, in the Northern Kurdistan Region of Iraq (Fig. 1). It lies a few kilometres from the former course of the Tigris River, which today flows into the Eski Mosul Dam. The mountain has an NW-SE orientation and reaches a maximum height of 1000 m asl; it has an irregular profile which gradually increases in height in the easternmost part. The geology of the relief is entirely characterized by the Middle-Upper Eocene (40 Ma) Pila Spi limestone Formation,[3] deposited in suspended basins on a passive plate margin configured by an

[2] The site is called Şkeft Zêr by the locals and known to be destination of field trips. Therefore, due to modern frequentations, the context resulted to be very damaged and not suitable to detailed archaeological research (see Conati Barbaro et al. 2015; 2016).

[3] The original geological documentation pertaining with the Pila Spi Fm belongs to several type-sections reported in two unpublished reports (Lees 1930; Wetzel 1947) of the British Geological Survey. However, they are summarised in Buday 1980, pp. 168-169 and in Bellen et al. 1959, p.220-221. In this work we will refer to the Pila Spi Fm as latest research and data revision suggest in Kadhim and Hussein 2016, as well as in Numan et al. 1998. The Pila Spi Fm section of the Jebel Zawa is described in Agha et al. 1978.

Fig. 2 Overview of the Jebel Zawa as seen from the Jebel Al-Qosh (a), a view of the Pila Spi Fm and relative karstic cavities (b), view of the inclined geologic strata from the top of a valley (c).

extensional tectonic regime during the Alpine orogeny (Numan et al. 1998). The Pila Spi Fm represents the terminal lagoonal *facies* of the Late-Lower Eocene – Upper Eocene Cycle (Buday 1980).

From the top downwards, this formation consists of a succession containing a series of lithified limestones to well-bedded dolostones and massive cherty limestones interbedded with marls. The overall carbonate content of the Pila Spi Fm is extremely high (Buday 1980). The soluble nature of these rocks has led to the development of strong karstification, although not as intensive as that observed in the Zagros mountains (Stevanović et al. 2009). The karstic system consists of galleries, caves, and springs, some of which are still seasonally active in the south-eastern part of the Jebel.

Due to uplifting and folding movements, the formation is often visible and accessible in the southern valleys, where it is characterized by strong inclination, while the northern part of the relief overlooks the valley strongly urbanized by the city of Dohuk and features slope deposits alternated to fluvial sediments, deposited during the Plio-Pleistocene period.

The wadis flowing from the Jebel form valleys with very steep and eroded slopes, filled with rock debris and colluvial sediments transported by seasonal wadi floods to the foothills. The actual morphology of the area appears thus to be deeply changed due to the weathering susceptibility of the limestones and dolostones, especially the ones exposed on the top of the anticlinal ridges.

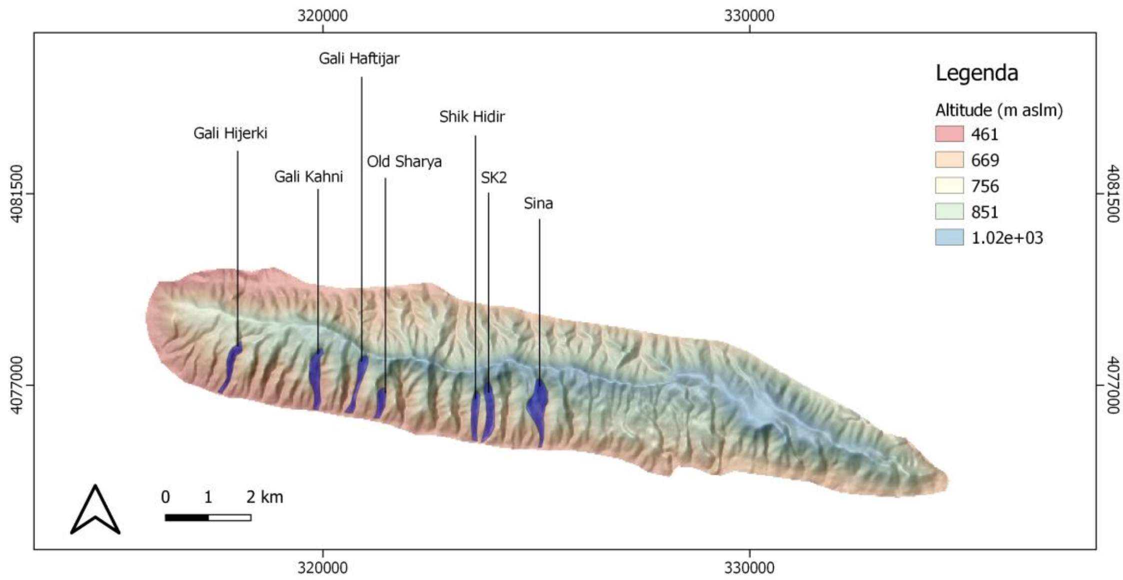


Fig. 3 Map showing the extension of the Jebel Zawa and the explored valleys.

2.2. Mining evidence

A total of 7 valleys of the Jebel have been explored, allowing us to collect a large quantity of data to understand the patterns of raw material exploitation and the landscape transformations occurred during ancient times.

Starting from the westernmost part, the valleys were selected based on their accessibility and the nature of the chert outcrops. Gali Hijerki, Old Sharya and Sina are nowadays frequented by modern shepherds living in small autonomous villages – Zawa, Sharya Qadim, Shik Hidir, Sina – at the mouth of these valleys, were some water tanks have been also recently installed. The eastern area of the Jebel, due to its geomorphology, the lack of raw material exposures, and modern urbanization was not selected to be surveyed.

Indeed, four out of the seven valleys explored so far revealed evidence of chert extraction.

Chert occurs in the shape of small nodules sporadically on the western part of the Jebel, along the small and less deeply cut valleys which correspond to the highest part of the Pila Spi Fm (i.e. Gali Hijerki). Conversely, dolostone and limestone layers containing chert nodules are very well exposed in the central part of the Jebel along the deeply cut valleys.

These features may also explain the different patterns of human occupations and exploitation strategies of the stone resources available in the Jebel. Gali Hijerki valley has been exploited mainly for limestone quarrying in historical times, as evidenced by a massive area of regular stone blocks extraction, using specialised metallic tools, on both

Valley	Chert availability	Mining evidence	Knapping workshops
Gali Hijerki	low; small nodules	historical limestone quarries	–
Gali Kahni	high; large nodules and few lists	–	site n. 1022 long-term occupied rock-shelter; minor knapping waste scatters undatable (1021)
Gali Haftijar	high; large nodules and few lists	mining traces within karstic galleries (sites n. 1026; 1027; 1028; 1029; 1037; 1038; 1039; 1040)	site n. 1042 (ws8); minor knapping waste scatters undatable
Old Sharya	high; large nodules and few lists	open-air extraction niches; systems of karstic galleries with mining traces (sites n. 981; 1002)	site n. 980 (ws9)
Shik Hidir	high; large nodules and few lists	open-air extraction niches; mining traces within karstic galleries (sites n. 1014; 1017; 1018; 1079; 1080)	sites n. 977 (ws1); 1009 (ws2); 1010 (ws3); 1015 (ws5); 1019 (ws6); 1020 (ws7); minor knapping waste scatters undatable
SK2	high; large nodules and few lists	*in-situ* chert nodules spatially associated with knapping waste scatter	site n. 1011 (ws4)
Sina	low; small nodules	–	–

Tab. 1 Table showing the findings related to chert mining activities in the explored valleys, in relation to chert availability and mean dimension and morphology of the raw material blocks observed during the survey.

the sides of the valley entrance. Gali Kahni valleys revealed a Middle Palaeolithic to Neolithic long-term occupation at site 1022 (Conati Barbaro et al. 2019) – the Qale Ba'dreh rock-shelter – where an eroded anthropic deposit yielded back evidence of knapping activities using local materials (along with 2 obsidian bladelets).

Finally, Sina valley did not restitute any mining evidence. Indeed, the valley is the only one among the explored ones featuring arboreal vegetation and still active perennial springs and is characterised by the presence of a large sub-horizontal rocky panel, found under a wide rock-shelter, featuring abstract petroglyphs. The site is under study.

Four out of the explored valleys, restituted mining evidence related to chert knapping workshops to produce large blades, namely: Gali Haftijar, Old Sharya, Shik Hidir and SK2. Chert mining evidence relates to two different excavation strategies: open-air quarries in which limestone strata were directly excavated in order to isolate and extract

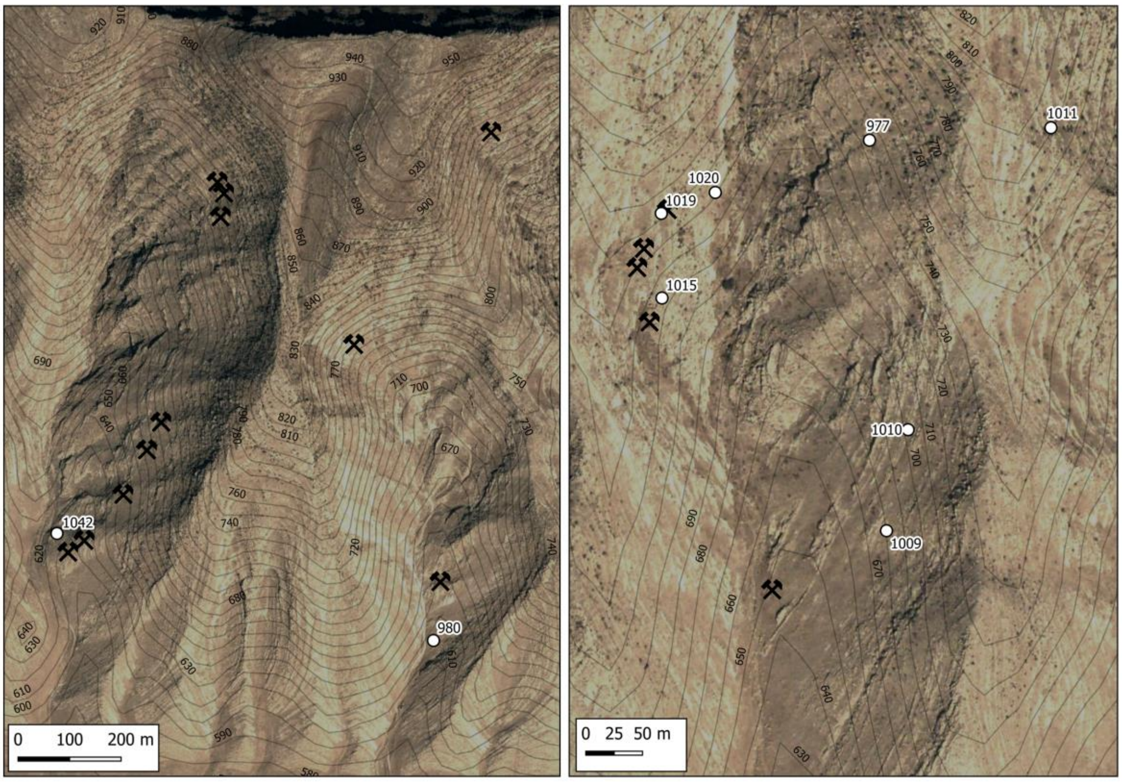


Fig. 4 Location of the mining sites and the knapping workshops in the central valleys of the Jebel Zawa. On the left, site n. 1042 is in the Gali Haftijar Valley, while site n. 980 within the Old Sharya valley. On the right, the 6 knapping workshops identified in the Shik Hidir valley are represented, while site n. 1011 lies on the ridge between the former valley and the adjacent one, renamed SK2 valley.

nodules, and natural karstic cavities which were exploited by following the inclination of the strata containing the nodules. Given the frequent occurrences of both types of evidence, very intensive chert exploitation occurred in the Jebel Zawa.

Mining of open-air chert nodules is very well documented in the Jebel Zawa. As the raw material is clearly visible and easy to approach, it seems likely that this kind of excavation was regularly performed. The exploitation of vertical limestone faces has left distinguishable digging traces on the rock surface. Niches of various size in the limestone walls attest the nodules' removal: their dimensions might correspond to the size of individual nodules or multiple extractions. The horizontal excavation of nodules located on strata interfaces is also documented. However, given the high erosion of the cliffs, it was not always possible to identify the anthropic left trace. Weathering of exposed nodules has been also observed and, in many cases, caused the complete removal of the nodules due to thermal chocs, cracks and silica dissolution.

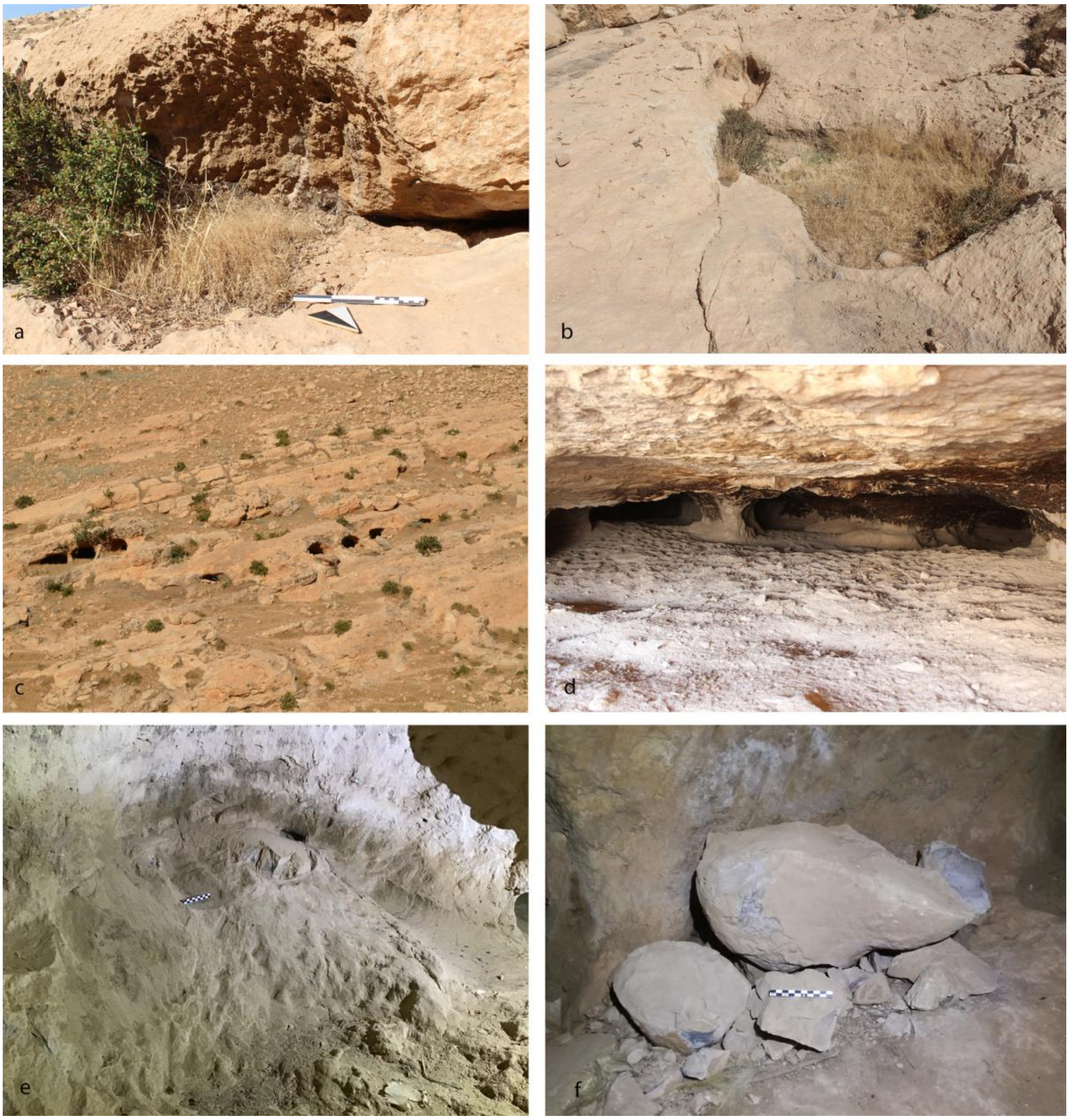


Fig. 5 Overview of the Jebel Zawa archaeological context: a) niche of nodule extraction and associated mining traces left on the limestone; b) horizontal hole on the ground, possibly related to chert nodules mining; c) panoramic view of some of the karstic cavities (site n. 1014) within the Shik Hidir valley; d) main inner chamber of site n. 1039 within the Gali Haftijar valley, from which several galleries branch off; e) lateral niche within one karstic cavity featuring mining traces to excavate a large-sized nodule and three negatives of removed blocks; f) a stack of nodules of various size from an inner chamber of site n. 1002 within the Old Sharya valley.

The Jebel Zawa karst system is characterized by small openings and rock-shelters in the limestone walls, in correspondence to a more permeable horizon consisting of massive cherty limestones interbedded with grey marls. These openings (mean length 1-1.90 m; mean height 0.80-0.90 m) are often present in clusters which create deep and convoluted galleries interconnected with each other. Karst forms are testified by traces left by flowing water on their rounded roofs and walls, and occasionally by the deposition of thick layers of white carbonates (i.e. "tufa") on the floors (Karim *pers. obs.*).

The connections between galleries are characterised by structures of the "room and pillars" type, sometimes still pronounced allowing the passage of human bodies while in other cases they are represented only by small holes. Just in fa ew cases, as the case of site 1002 in the Old Sharya valley, a complex system of galleries has been found.

This site is located at the top of the valley, at ca. 770 asl. It has two floors corresponding with two superimposed layers of galleries. The lower openings are small while the upper ones are wider and show evidence of digging traces both in the initial areas and the innermost chambers. Here, broken nodules, flakes and micro-debris have been found on the floors.

At site 981, multiple entrances clustered in a single floor enter in a single room with some lateral niches associated to digging traces, while waste blocks resulting from digging activities were placed laterally to organise the excavation activities.

Even if a high variability in shape, dimension and vertical/horizontal development of these galleries is recorded, we must assume that human modifications of the natural cavities were performed. At least is reasonable thinking that continuous extraction of nodules from a given layer could have provoked little enlargement of the cavities.

The evidence has been found in several cases. The extraction of the nodules is recorded in correspondence with a less compact layer of limestone that due to its geology (karst) and stratigraphical position within the formation, is always visible and found at the bottom of the cavities. The excavation of nodules began from the upper surface, to visually delimitate the entire extension of the block (length and width). Subsequently, it is possible that the nodule was freed from the rocky substrate by advancing frontally to check also the third dimension of the block (thickness). Moreover, as several cases may suggest, it is possible that bigger blocks were broken while still lying in the substrate, leaving the half-broken volume, featuring tool marks around, visible today in the galleries.

While it is not the aim of this paragraph to discuss in detail the extraction techniques, it is worth mentioning that no digging tools have been found within these galleries. This could be preliminarily related to several factors including the preservation of these contexts, human (the cavities are used as occasional shelters by the shepherds) and animal frequentations and gradual erosion through time. Excavation traces, however, have been recorded, and show a large variability which will be the object of future field campaigns and investigations.

2.3. The knapping workshops

Waste products of knapping activities are widely scattered along the valleys. The distribution, in most of the cases, is not of great significance and has been affected by rapid erosional and natural transport processes which created cumulus of archaeological materials deposited on plane surfaces often corresponding with natural terraces overlooking the wadis. Moreover, knapped artefacts are often found within detrital fans deposited at the foothills of the cliffs. This prevented us to identify more *in-situ* archaeological contexts. Significative artefacts (e.g. cores, blades, crests) have been also found in the wadis confirming the former observation. Nevertheless, eight major lithic clusters were identified during the 2016-2017 surveys (workshops 1-8) which have been interpreted as knapping workshops to produce large blades.

Site	Valley	Elevation (a.s.l.)	Position
977 (ws1)	Shik Hidir	715	under a rocky wall, close to chert outcrops
1009 (ws2)	Shik Hidir	696	right side of the valley
1010 (ws3)	Shik Hidir	689	right side of the valley
1011 (ws4)	SK2	800	ridge across Shik Hidir and SK2 valleys, associated to chert outcrops
1015 (ws5)	Shik Hidir	734	20 mt far from extraction sites n.1016 (niche) and 1017 (karstic galleries)
1019 (ws6)	Shik Hidir	753	close to a cavity with tool marks
1020 (ws7)	Shik Hidir	744	beneath a rock wall with chert outcrops
1042 (ws8)	Gali Haftiyar	622	large open space close to the valley bottom
980 (ws9)	Old Sharya	610	left bank of the wadis flowing at the valley entrance

Tab. 2 Overview of the knapping workshops identified according to their code-label, valleys, altitude, and spatial features.

Fig. 6 The knapping workshops evidence: a) panoramic view of site n. 977 (ws 1) within the Shik Hidir valley (the white arrows indicate respectively the location of the rock-shelter, under which a major concentration of artefacts was found, and the limit of the lowermost terrace upon which the artefacts were spread out); b) view of site n. 1011 (ws 4) within the SK2 valley; c) view of site n. 1019; d) colluvial deposit containing minor concentrations of artefacts located at the wadi level, under the ws 2-3 within the Shik Hidir valley.

The Shik Hidir valley yielded the largest amount of documentation regarding these knapping sites. They are distributed on wide flat areas throughout the valley and placed at different altitudes. Site 977 (ws 1) was the first context to be identified during the 2016 field campaign and features the largest number and highest density of artefacts recovered within the valley's workshops. It is located on a previously flat terrace, nowadays highly eroded and sloped, under a rocky wall and in the proximity of chert exposures. The preservation of the deposit containing the artefacts has been affected by erosion and minor concentrations of materials have been also found on the terraces below. However, little flaps of archaeological deposit are still preserved in correspondence with the rock-shelter.

Sites 1009 and 1010 (wss 2-3) lie on the right side of the valley and are located just above a system of galleries which opens at the wadis level. Although they have been recorded as two distinct materials 'concentrations, it is worth noting they are in close spatial relation. Site

1011 (ws 4) lies in the proximity of the ridge of the mountain where the Shik Hidir valley meets the SK2 one. This latter is quite different from the former. Its cliffs are characterised by a high slope and the wadi bed is very deep and covered by vegetation. These features may suggest that some water sources could be active on a seasonal basis to date. For these reasons, the valley's flanks were exceedingly difficult to explore and nowadays was easier to access from the neighbouring valley, even if it is uncertain whether the outcrops were reached in this way or not.

However, ws 4 represents the only one secure knapping evidence located at high altitude (ca 800 m asl). Other minor concentrations have been found in Gali Haftijar as well as in the former valley. The lithic scatters are spatially associated with chert exposures and the concentration of materials is spread out even on the lower terraces, as observed in most of these sites. It is worth noting that no occurrence of karst galleries was detected in the area. Unfortunately, the lack of diagnostic materials does not allow to reconduct these latter proofs within the cultural and chronological phenomenon under discussion, although they represent, without any doubt, evidence of raw material supplies and *in-situ* processing of the blocks.

Sites 1020 (ws7), 1015 (ws 5) and 1019 (ws 6) are located on the left side of the Shik Hidir valley. Variations of their absolute quote are recorded in the range of 20 m asl; in fact, the sites are located on the same morphological terrace, in the nearby of a series of raw material extraction sites, namely n. 1017 (a group of interconnected karstic cavities) and n. 1016 (a niche featuring tool marks).

To conclude, site 1042 (ws 8) is the only one knapping context recorded in the Gali Haftijar valley, the westernmost among the explored ones. Despite what was expected, a large area of lithic scatters was recorded at the entrance of the valley, on a flat terrace covered by alluvial sediments and rocky debris. In fact, the geomorphological setting of the valley is different from the rest. The valley is quite large and wide, its cliffs are sloped, and the Pila Spi Fm was found to be less affected by karst over a large area, corresponding with the left side of the valley, where a massive erosion of the ridge is recorded. However, the right side has been highly affected by karst and the typical cavelets are only distributed over a single geological layer.

Going through the inner core of the valley, where several cavelets clusters are recorded, the access to these sites is placed on the top of a rocky wall. A large part of the terrace is eroded, due to landslides (well-cemented remnants of preexisting terrigenous layers were noted along the external wall of the cavelets entrances), and no traces of knapping activities were recorded.

These are certainly some of the reasons explaining the incompleteness of the data available for most of the valleys. If we are not able to give an evaluation regarding the whole possibilities beyond the choices where to perform such knapping workshops, we cannot either hypothesize – in most of the cases – the real extension of these sites and related issues. Site 977 (ws 1) covers, by far, the largest surface of material scattering even if the finds lie in secondary position over large part. However, it represents a unique cluster.

The question arises for some of the other sites within the Shik Hidir valley where no clear separation between clusters exist. The problem is not easy to deal with, given the low rate of preservation of the archaeological deposits. Anyway, it is important to highlight that the degree of weathering of the materials is not always homogeneous. Thus, the possibility that natural factors (erosion, transport, and secondary deposition) and human later occupations (modern herding activities) contributed to the final setting of some sites, in terms of artefact density and scattering, should be considered.

The techno-typological features of the artefacts from these sites, however, strengthen the idea that these sites formed as coherent assemblages originated from knapping activities.

Finally, during the 2018 field campaign, a large and well-preserved lithic workshop was identified, namely site 980 (ws 9), and systematic investigations have been carried out, including test excavations whose results will be discussed in the next paragraphs (§. 3 and followings).

2.3.1. Surface collection strategy

The artefact clusters consist of several hundreds of pieces which testify the *in-situ* reduction of nodules to produce large blades. In most cases unworked nodules, rough-outs, and cores with large-blade removals have been recorded, spatially associated with the by-products of several knapping stages, such as tablets, crested or neo-crested items, and cortical and non-cortical flakes. Furthermore, blades coming from full-production stages of core exploitation are exceedingly rare and often represented only by some fragments.

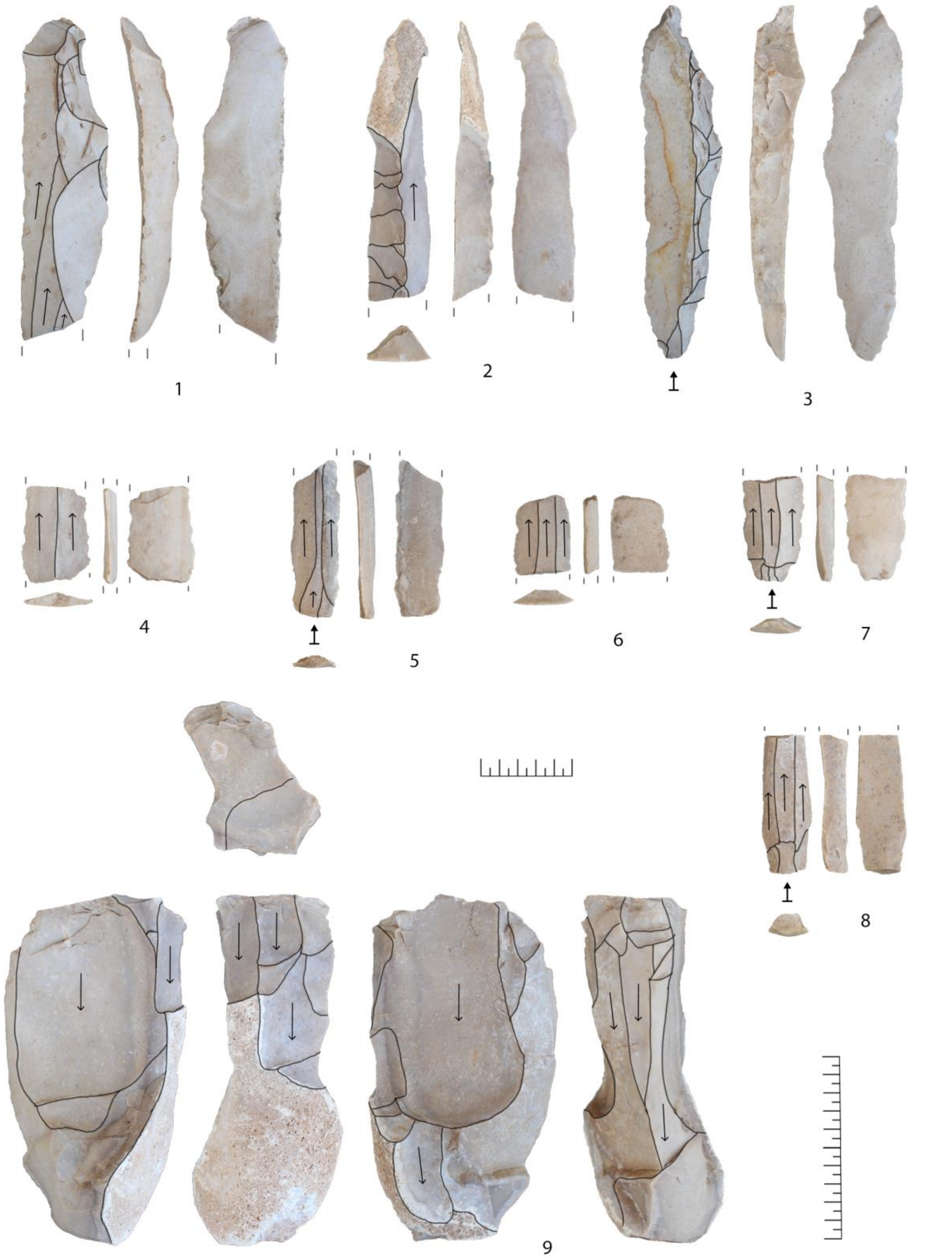


Fig. 7 Lithic artefacts from site 977 (ws 1). Neocrested blades (1-3); blades and large blade fragments detached at a full *débitage* stage (4-5, 7-8); large blade knapping accident (reflection) (6); overexploited large blade core (9).

In order to study the sites, a first description of the context was performed during the field activities. The entire site and its finds have been photographed while lying in their actual depositional context and only the diagnostic materials, useful to make comparative analyses between sites, were collected. Finally, a percentage of collected materials was estimated per each site. The strategy was chosen based on coordination and safety – in relation to the objective difficulty of moving in the unstable Jebel environment – and the future opportunity of returning to the sites to carry out detailed field investigations.

2.3.2. Lithic materials analysis

Following the outlined strategy, a total of 263 items have been collected from these contexts. The artefacts consist of cores, flakes, laminar flakes, and blades – including technical items – indicative of the knapping processes which were performed in such sites. Simple flakes, cortical items and chunks have been not collected.

Although, they are numerically not representative of the intensity of the production nor of the artefact's density, the collected items yielded back truly relevant information about the technologies and the goals of the production, useful for a general interpretation of these sites. Site 977 is the biggest among the workshops and gave the highest number of diagnostic artefacts. Sites 1009 and 1010 also restituted a sizeable number of artefacts. Within these latter, despite featuring a high number of materials, the difference between collected and non-collected items is high, indicating that simple and non-informative flakes had a higher numeric incidence respect site 977. The other sites have similar trends, but a lower number of diagnostic artefacts, indicating that the sites were smaller in size, or much more eroded.

All the collected materials exhibit similar homogeneous patinas covering their surface. The alteration is heavy, masking the original colour and the structure of the chert raw material. The development of the patina indicates that the materials were long time exposed to weathering agents. The existence of cracks and impacts on the surfaces, of post-depositional origin, indicates also that the materials moved from their primary depositional position according to the erosion of the burying deposits and were subjected to human/animal trampling. This phenomenon is particularly evident on the laminar items and elongated blanks. About 90% of the blades and laminar flakes are fragmented, even if the degree of patination observed on the fractures does not seems to indicate significative differences. A major cause explaining the evidence might be reconducted to the highly variable local climatic conditions on a seasonal basis, featuring arid summers alternated to humid and cold winters (Azooz and Talal 2015).

site	collected	cores	flakes	laminar flakes	blades	tot.
977 (ws 1)	40%	2	68	53	23	146
1009 (ws 2)	20%	6	2	4	7	19
1010 (ws 3)	20%	7	20	29	8	64
1011 (ws 4)	40%	1	2	-	4	7
1015 (ws 5)	40%	1	-	1	4	6
1019 (ws 6)	40%	4	-	3	-	7
1020 (ws 7)	40%	1	-	-	4	5
1042 (ws 8)	20%	2	4	2	1	9
tot.	-	24	96	92	51	263

Tab. 3 Percentage of collected artefacts and composition of the assemblages from the knapping sites identified.

The technological analysis of the lithic materials allowed to identify a major technical process aimed at the production of blades and large blades. The presence of discarded blocks, blade cores, rough-outs and technical items suggests that the knapping activities were performed *on-site*, after the extraction of the nodules from the nearby mining contexts.
Blades and large blades fragments are the most represented blank category. However, only a small part of the sample shows characteristics indicating their belonging to a full *débitage* stage of the production. Laminar blanks with trapezoidal or triangular sections, very regular previous removals on the dorsal surface and parallel edges are present in each site (apart from site 1042) (Fig. 7, n.4-6-7; Fig. 8, n.3; Fig. 9, n.4; Fig. 10, n. 2-3; Fig. 12, n.3). The lack of proximal portions in most of the blades prevents from an accurate diagnosis about their knapping techniques, due to the impossibility of reading their technical stigmas, while their relatively low amount concerning the whole production of blades prevents from detailed considerations, which, however, have been integrated with the analysis of the morphology of the previous removals attested on cores and technical items. However, the techno-morphological attributes of some of the blades (Fig. 7; n. 4-8) from site 977 indicate that several knapping techniques might have coexisted in these sites. The regularity of the blades is evident, as well as that of the ridges on their dorsal surfaces.

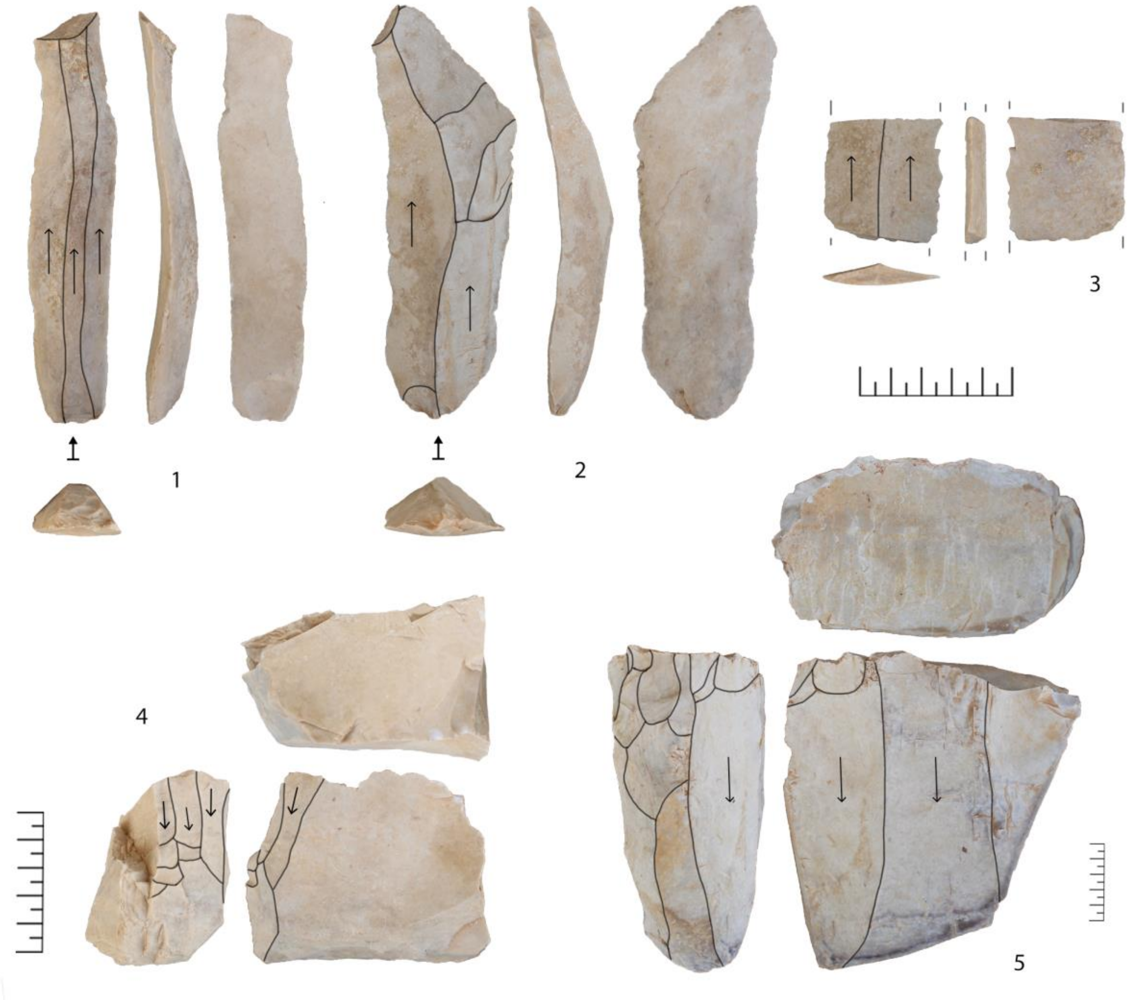


Fig. 8 Lithic artefacts from site 1009 (ws 2). Large complete blade (1); large irregular and complete blade (2); large blade mesial fragment (3); blade core fragment with few laminar removals (4); blade core (5).

These features might be consistent with the adoption of the pressure technique, even if the analysis of the technical stigmas on the proximal portions of some items (Fig. 7; n. 5-6-7) leave some doubts. The association of large and non-prepared platforms with flat bulbs (Fig. 14, a), sometimes featuring bulbar scars or detached bulbs (Fig. 14, c-f), is not properly indicative of the adoption of the pressure and might be related also to the indirect percussion (or punch technique) (Briois et al. 2006).

Further observations regard the size of the blades. While it is not possible to reconstruct their real length, given the high state of fragmentation, it is worth noting that several modules are attested: larger blades (max. width of 45 mm), indicating the extraction of long blades (Fig. 7, n.4, 6-7; Fig. 8, n.3), and narrow ones (min. width of 17 mm) that might also suggest the intentional production of smaller ones (Fig. 7, n.5, 8; Fig. 12, n.3).

Fig. 9 Lithic artefacts from site 1010 (ws 3). Large complete blade with triangular section (1); neocrested blade (2); large blade mesial fragment (core maintenance blade) (3); large blade proximal fragment (4); blade core with a knapping accident (5); large blade core reduced through the pressure technique (6).

This circumstance is evident in all the other sites. Given the nature of the evidence, it is not possible to investigate the relations between these two sizes categories which might also correspond to the employment of several technical modes (*sensu* Pelegrin 1988, 2012b) of applying the pressure within a single core reduction process or reflecting the employment of different knapping techniques in specific reduction sequences.

Only two complete blades (Fig. 8, n. 1; Fig. 9, n.1) are attested. The item from site 1009 (length 138 mm; width 27 mm; thickness 7 mm) features a trapezoidal section delineated by regular previous removals on the dorsal surface and parallel edges. A clear curvature of the profile is recorded in the mesial portion of the blade, as well as in the distal part of the dorsal surface due to the morphology of the previously removed series of blades. The bulb is removed, and the butt is orthogonal (forming an angle of 90-95 degrees with the ventral surface), of linear morphology and associated to overhang adjustment through tiny flakes removals.

The second item (length 127 mm; width 24 mm; thickness 10 mm), comes from site 1010, and share, with the former one, some of the morpho-technical attributes but features a triangular section. The proximal portion is well-preserved and shows a large faceted platform associated with a clearly visible crack located nearby the fracture initiation point. The fracture is marked also by ventral fissures and originates a developed bulb.

The features displayed by the two items, despite exhibiting regular previous ridges, are not consistent with the pressure technique. In addition, both the terminations are irregular and slightly twisted, indicating the employment of a percussion technique. Thus, it could be hypothesized the adoption of the indirect percussion, using a metal-tipped point as the case of the blade from site 1010 (Briois et al. 2006).

Additional clues about the articulation of the knapping processes are provided by the analysis of the technical blades. The items collected represent various stages of production. The neo-crested blades from site 977 (Fig. 7, n. 1-3) indicate that the core was managed during the blade extraction process. One item (n.1), despite fragmentary, suggests the production of exceptionally large blades and, at the same time, the reconfiguration of the core lateral convexities functional to the continuation of the blade extraction process. This was also observed in other sites (Fig. 10, n.1; Fig. 12, n. 2). Crest preparation on flat (or natural) surfaces is also attested (Fig. 7, n. 2-3; Fig. 9, n. 2). Other wider blades seem to be related to the shaping of core volume (Fig. 8, n. 2; Fig. 11, n. 1; Fig. 12, n. 1) or to its maintenance after knapping accidents (Fig. 9, n. 3).

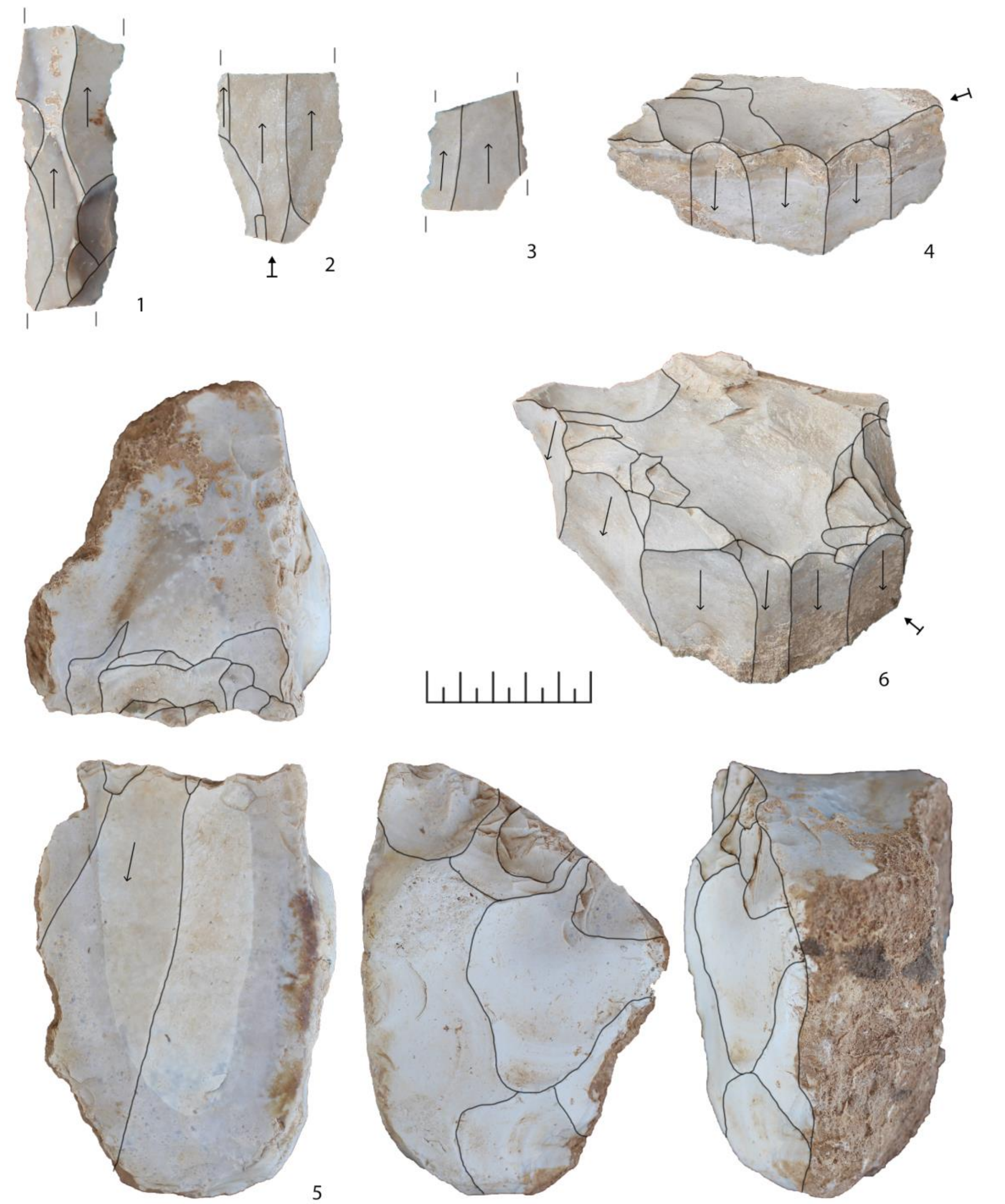


Fig. 10 Lithic artefacts from site 1011 (ws 4). Neocrested blade mesial fragment (1); large blade proximal fragment (2); large blade mesial fragment (3); tablettes (4, 6); blade core (5).

Core analysis allowed to clarify some of the issues encountered, and to understand the strategies and technical solutions adopted during the extraction of the blades. The first

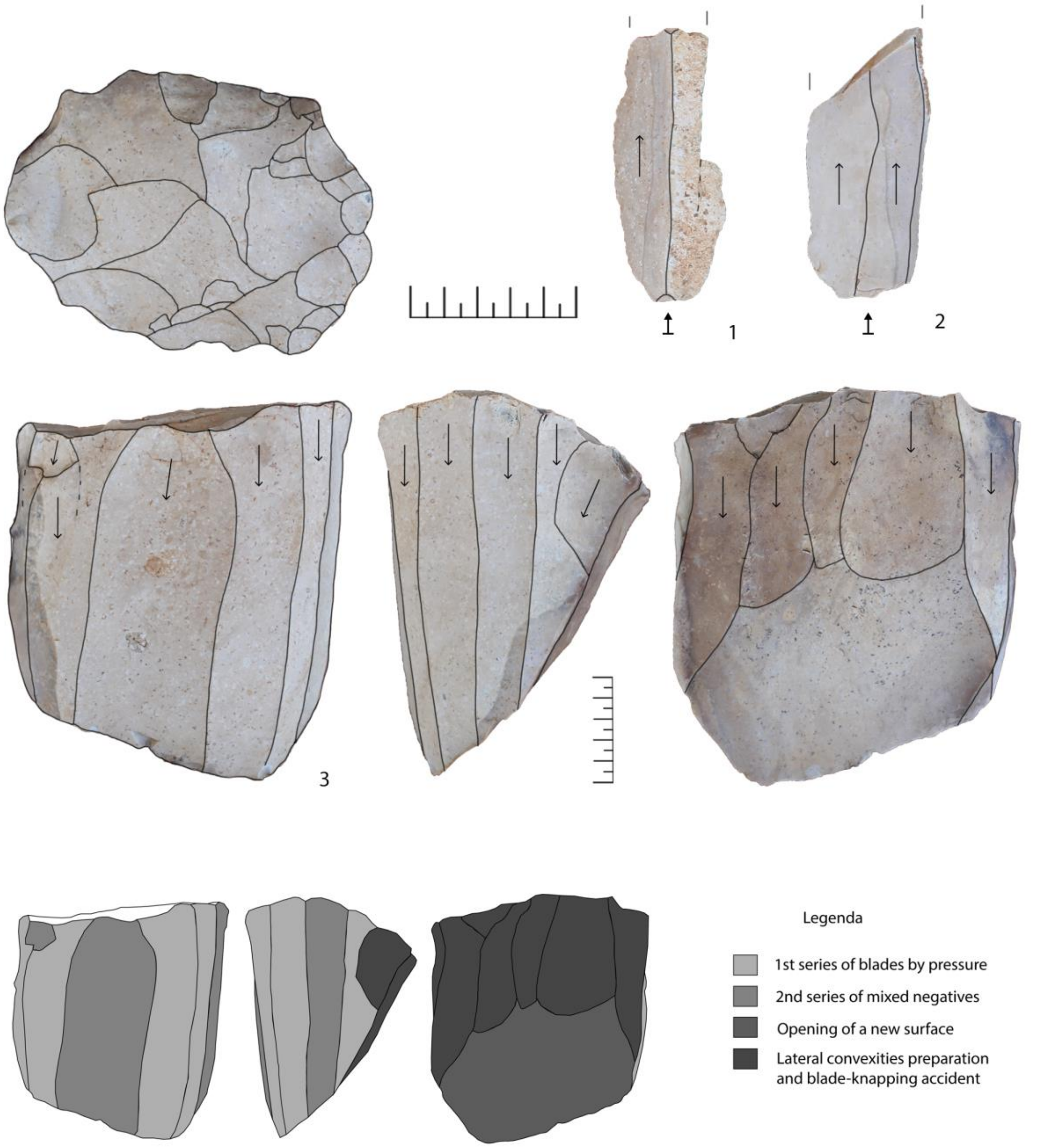


Fig. 11 Lithic artefacts from sites 1015 (ws 5) and 1019 (ws 6). Semi-cortical blade proximal fragment (1); large blade proximal fragment (2); large blade core reduced through the pressure technique (3). At the bottom, a diacritic analysis of the core exploitation strategy is reported.

feature to highlight is the reduced size compared to most the laminar blanks. If we analyse the succession of the blade removals and the degree of platform preparation, it is possible to affirm that most of the specimens represent the terminal stage of core exploitation.

The specimen from site 977 (Fig. 7, n. 9) preserves only a few removals related to the removals of blades, while the remnant surfaces exhibit several knapping accidents, not only due to wrong evaluations made by the knapper but also due to some internal fracture.

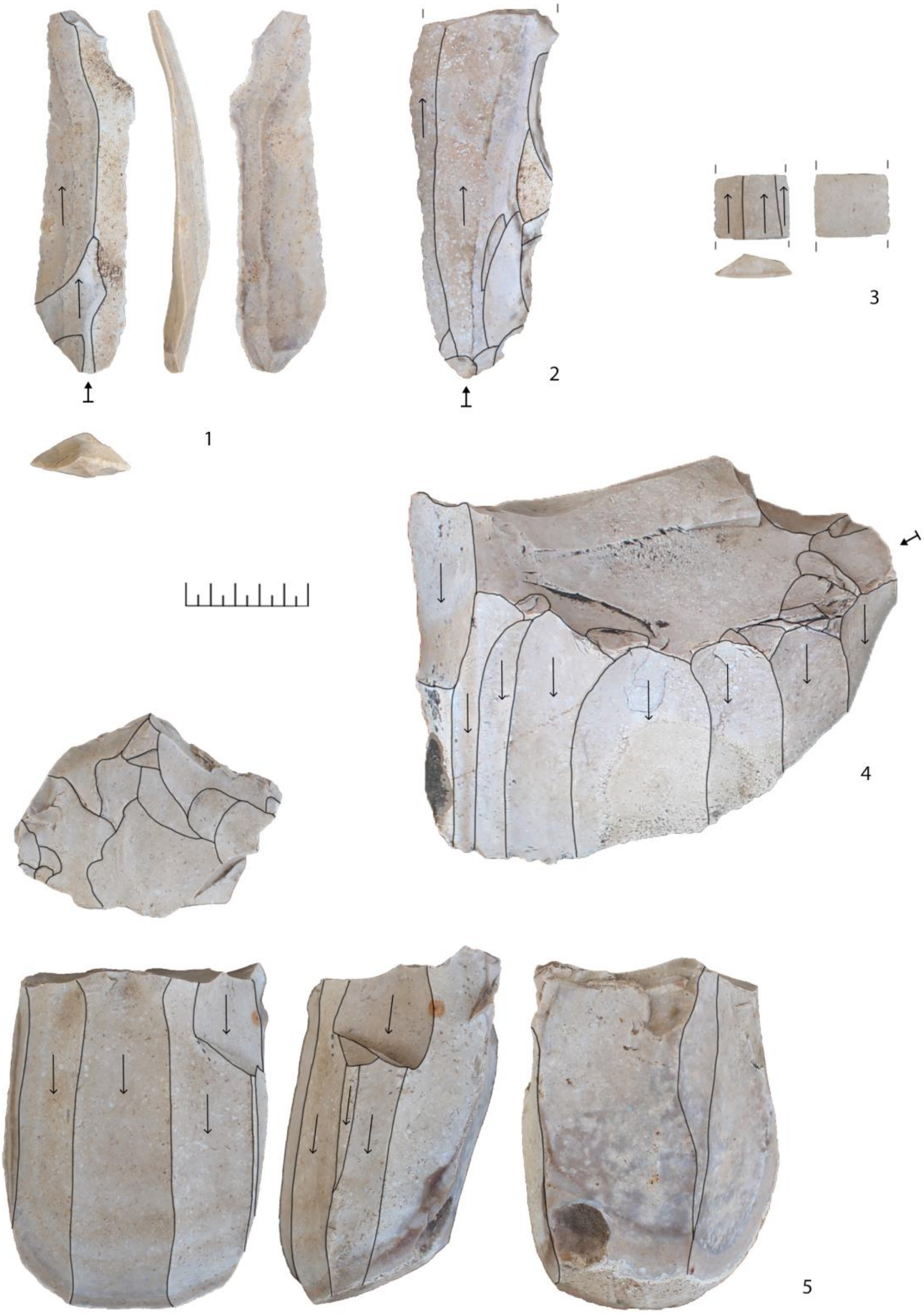


Fig. 12 Lithic artefacts from site 1020 (ws 7) and site 1042 (ws 8). Complete semi-cortical blade (1); neocrested blade proximal fragment (2); blade with trapezoidal section mesial fragment (3); tablette of a large blade core (4); blade core (5).

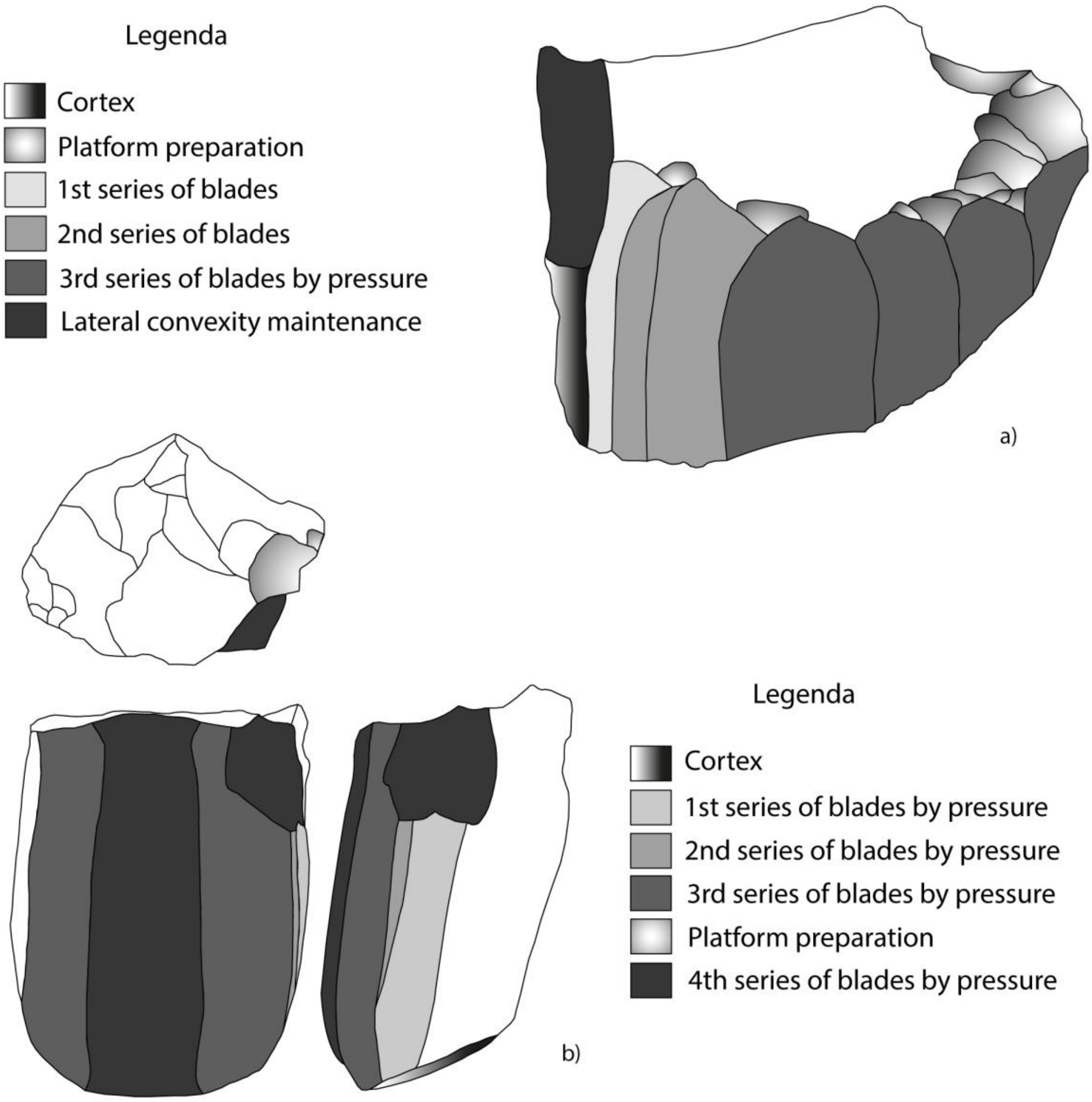


Fig. 13 Diacritic analysis of blade production strategies as evidenced from the large tablette from site 1042 (a) and the core from site 1020 (b).

The smaller core from site 1009 (Fig. 8, n. 5) lost all its previous attributes after a huge repreparation of its volume (unfortunately the platform is heavily altered) and was abandoned due to the failed extraction of a blade from the flank. This could be also the case of the core from site 1011 (Fig. 10, n. 5).

The larger core (Fig. 9, n. 6) is well preserved and show very regular blade removals (last removal length 131 mm; width 30 mm). The platform is flat, obtained by a single large flake

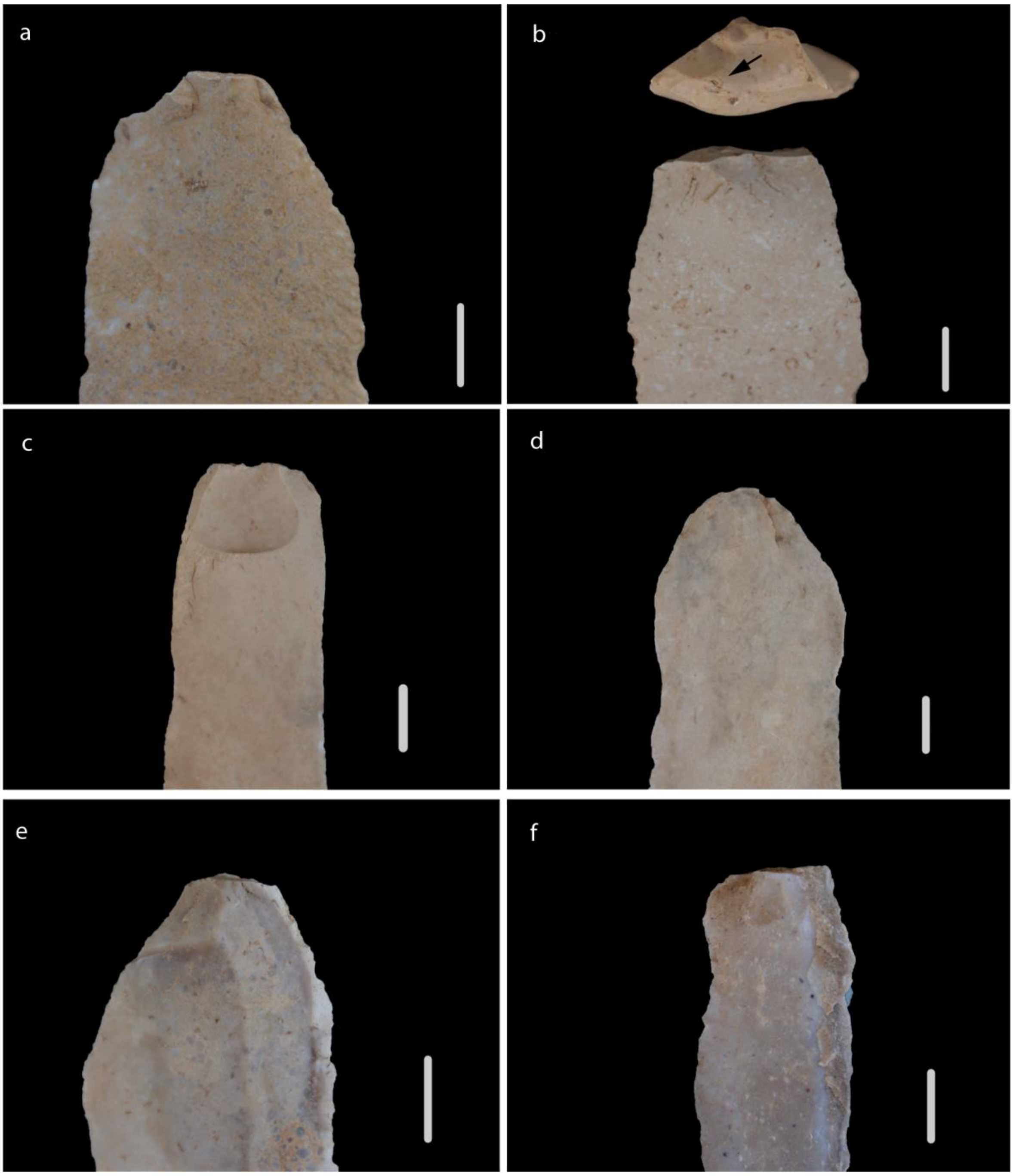


Fig. 14 Detail of the technical stigmas observed on the proximal portions of some blades. Slightly lipped and small flat platform associated to a flat bulb (a); large faceted platform showing a circular crack and a well-pronounced bulb on the ventral face (b); linear platform associated to a detached bulb (c); small flat platform associated to a developed bulb (d); small flat platform associated to ventral fissures and developed bulb (e); large flat platform associated to a flat bulb with bulbar scar (f). Scale bar = 1 cm.

removal and the blade negatives are very regular and organised following an adjacent rhythm of *débitage*. The last removal is placed on the flank, but the knapper did not complete the series. Finally, the core was abandoned after two consecutive attempts of extracting a neocrest from the flank, to refresh the lateral convexity and to continue the exploitation of the reduced frontal volume available.

The core exhibits a well-prepared flat back. The flat morphologies of the backside and distal portion could indicate it was inserted into a specific blockage mechanism during the knapping process (see Pelegrin 1984b). Considering all the features, it is possible to propose the adoption of the pressure technique.

A similar case is recorded within the site 1019 (Fig. 11, n. 3). The first stage of the sequence is testified on the main surface of the core were three series of blades were extracted. The first one, testify the extraction of blades by pressure following an adjacent rhythm of *débitage* from a dihedral prepared platform. The second series started with the removal of one blade by pressure (preserved length 100 mm; width 21 mm), but the knapper concluded the series extracting one large and less regular blade, wider than the previous ones (preserved length 100 mm; width 39 mm), and finally failing the last blade removal. Since a clear difference in the regularity of the removals is highlighted, of the growing width of the removal from the fracture initiation point, the interaction of different techniques on the core during the extraction of blades is hypothesized (see experimental observations of Pelegrin 2012). The knapper, switched to another technique – the indirect percussion is proposed – to complete the series without compromising the configuration of the core.

After the failed strike, the third series is settled on the backside of the core. A huge removal allowed to open a new *débitage* surface, modifying the shape of the core (from sub-conical to “pseudo” pyramidal), and thus reducing the general size of the core. A new series of removals allowed to regularize the surface and, at the same time, originated the ridges upon which a new blade is extracted without success. This would be the knapping accident that compromised the exploitation of the core and provoked its abandonment.

The last core to be discussed comes from site 1020 (Fig. 12, n.5). It exhibits sub-conical shape, with the bottom face being cortical. Two series of blades are extracted by using the pressure technique. The removals are very regular, with a flat termination. The bulb negative, pronounced just under the pressure point, is visible on the first blade (length 12 mm; width 32 mm) related to the second series detached. The second blade of the series is placed laterally respect the core main surface and its extraction was not successful. The general impression regarding the specimen is that, at the stage before its discard, it was much bigger. The attempts to also exploit the flank of the core might be related to the needs to optimise the productivity of the core during this late stage.

Related to the exploitation of the cores, the *tablettes* are a technical solution widespread in all the sites analyzed. When adopted, they testify a reduction in the size of the cores, but, at the same time, they are useful elements to understand the methods of platform preparation, the *débitage* techniques employed and the rhythms of blade extraction.

Three specimens are presented. The first two come from site 1001 (Fig. 10, n. 4, 6), while the third one comes from site 1042 (Fig. 12, n. 4). The item in fig. 10 (n.4) displays a single series of regular blades detached from a prepared platform (last removal width 18 mm). Pertaining to the second and third removals, is a dihedral preparation of the blade extraction point. Indeed, the *tablette* (n.6) is related to a large core. It exhibits 6 removals organised in two series following an intercalated rhythm of *débitage.* The negatives related to the first series are quite regular, while the later ones feature a less regular development (last removal width 30 mm). This fact finds comparisons with what observed on the core from site 1019 were the interaction of two different techniques during the same stage of the reduction is hypothesized.

The *tablette* from site 1042 is related to a large core. It features very regular and wide blade removals, pertaining to two series of blades detached following an adjacent rhythm. The platform is prepared by faceting and each blade is extracted by applying the force on dihedral ridges. Given the regularity of all the removals and width of the last blade extracted (35 mm), the employment of the lever pressure system, to detach long blades, is proposed.

2.3.3. What complexity and organization of the process?

The analysis of the lithic artefacts, coming from the surface assemblages, allowed to address some relevant questions concerning the interpretation of the whole archaeological evidence. It is unknown, at the present stage of the research, how intensive was the exploitation of the whole mining district of the Jebel Zawa. Not all the valleys have been explored, while the investigated ones restituted clues regarding the organisation of the knapping activities. Furthermore, it is possible to date the evidence on a techno-typological basis, to the Late Chalcolithic and the Early Bronze age (thus covering about two millennia of occupation), but it is not possible to narrow the chronological range of such occupations due to the objective difficulties in dating mining contexts and lack of specific cultural markers.

Anyway, some considerations about the position of the sites and the testified activities are needed. Most of the contexts are in the Shik Hidir valley and are placed throughout its extension, in the proximity of the raw materials outcrops.

The search for suitable and wide spaces, where performing post-block-extraction activities, is constant in all sites. Following this view, it is not surprising that site 1042 is placed at the entrance of the Gali Haftijar valley, where the large terrace represents the only suitable space onto easily moving despite being far several dozens of meters from the first actual raw materials exposures. Tested blocks and discarded nodules are often present within the sites and waste materials indicate *in-situ* knapping activities.

The technological analysis of selected categories of artefacts revealed that similarities in assemblage composition and technical processes are attested. First, the nodule was preformed and then knapped to extract blades, which is a constant in all the sites. Several sub-phases of the process, connected to the management of the core volume, are represented (e.g. maintenance of the laminar surface, platform, and lateral convexities).

The blades, constituting the goal of the production, are only little attested and the analyzed items highlight the employment of several knapping techniques that allow producing blades with various morpho-technical features. The pressure technique seems to be the technique employed during the full *débitage* stage of the production, but, as seen on several cores and *tablettes*, an interaction between techniques is testified.

It seems premature providing a punctual diagnosis about the several modes of applying the pressure. What is clear is that the blades exhibit different modules that might correspond to several size categories. In the light of the evidence, the lever pressure system to produce large blades could be hypothesized on the base of the wideness of certain removals on the cores but seems to be evanescent. Cores are often overexploited and have lost their original shape and size as being adapted to different technical choices during the blade knapping process. All the items have been abandoned due to knapping errors. This fact gives a preliminary idea about the intensity of the production on the single-core but the nature of the archaeological evidence does not permit to go over the data.

The state of preservation of these sites is not optimal. No clear clues are available about the modalities of site formation, about their real extension and the intensity of the production. Thus, for these sites, it is not known if they formed as palimpsests or single episodes of knapping or if the amount of waste materials was managed through specific modalities (i.e. waste pits or piles).

The last issue regards the destination of the products of such activities. It is worth mentioning that in these sites no evidence of other activities, apart from knapping, or residues of distinct categories of artefacts (i.e. pottery) or structures have been found. No retouch is testified on the edges of the produced blanks. It appears clear that at least most of the blades were exported, to be distributed over the region (see chapter 7), and the waste materials were left on the ground.

3. Site 980: a Canaanean blade specialised workshop

To better explore these issues and contextualise the phenomenon of Jebel Zawa blade-knapping workshops within the social and economic organization of LC and EBA settlement of the area, site 980 (ws 9) was in-depth investigated and the results will be shown and interpreted in the following paragraphs.

3.1. Site position and the context

The site was identified at the end of the 2016 field campaign, in concomitance with the discovery of the chert mines of the Old Sharya valley which allowed to identify the Jebel Zawa as a mining district. The context was initially recorded as a small concentration of non-diagnostic artefacts. Few lithic scatters were collected on the left bank of the wadi, on a small earthy terrace which opens in front of a natural cave excavated into a rough conglomerate, this latter originated during the Pleistocene epoch (Karim *pers. obs.*). Any anthropic activity was found inside the cave, apart from modern frequentations.

Site 980 is placed about 150 mt far from the valley's entrance. On the left bank of the wadi, few meters north, the first chert layers of the Pila Spi Fm begin to be visible and are associated with the cluster of karstic cavities of site 981.

Some words are necessary to explain the dynamics which allowed to identify the site as a knapping workshop. These are connected to recent anthropic activities that have altered the original setting of the valley.

First, the construction of a dirt road caused the levelling and filling of the actual wadi bottom. Colluvial sediments have been also cut and piled up the valley's flanks. Secondly, limestone quarrying activities, conducted by mechanical means, partly damaged site 981 and the right flank of the valley in correspondence of site 980.

In 2017, the reactivation of the quarry produced a huge quantity of detritus and piles of waste limestone found grouped at the foothills of the quarry. Before the beginning of the 2018 campaign, a wide erosive action – due to high-energy water transport of sediments from top of the Jebel – changed the morphology of this stretch of the valley.

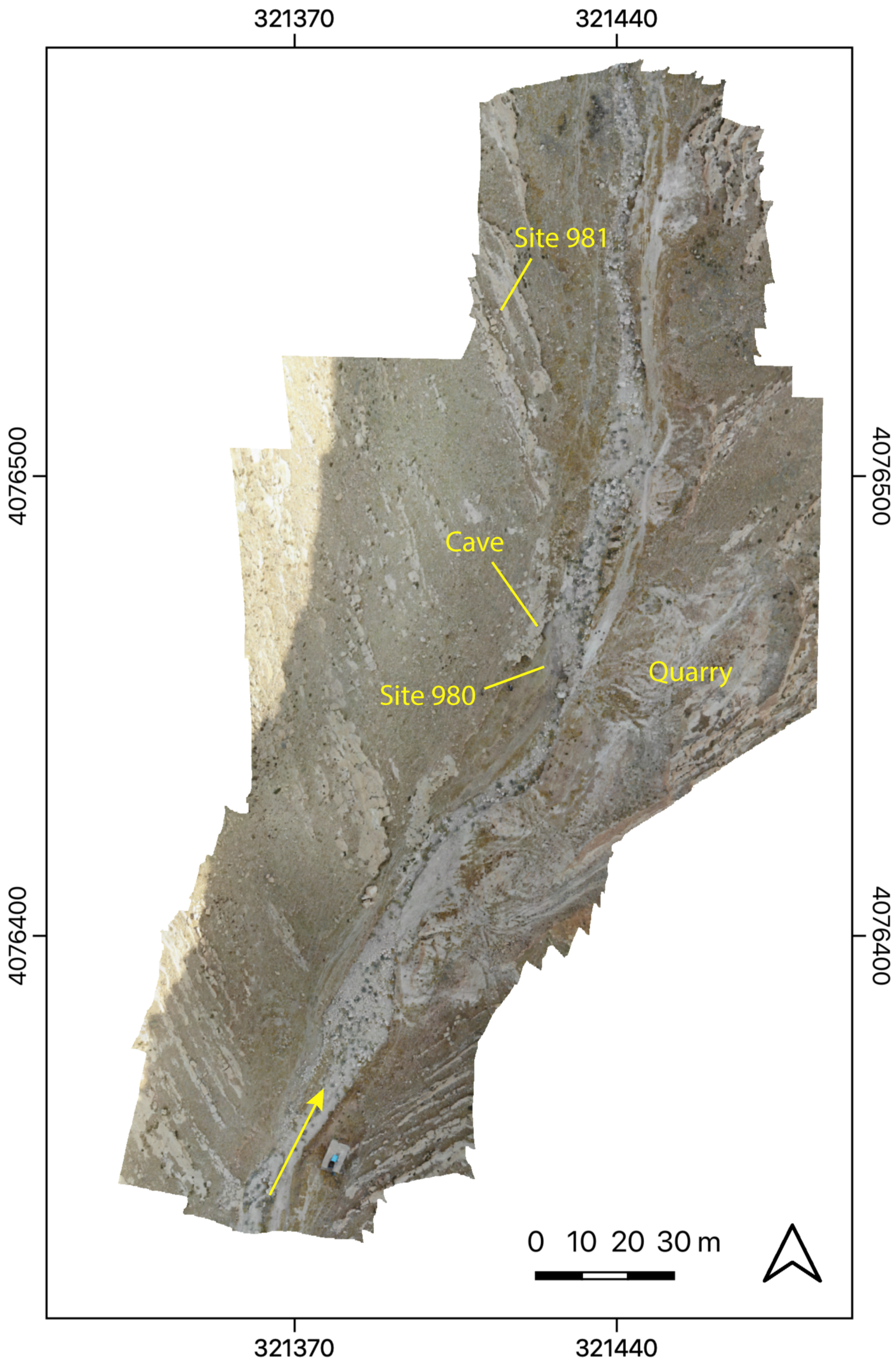


Fig. 15 Aerial view of the initial stretch of Old Sharya valley showing the position of site 980, 981 and other features quoted in the text. The arrow indicates the way of access to the valley.

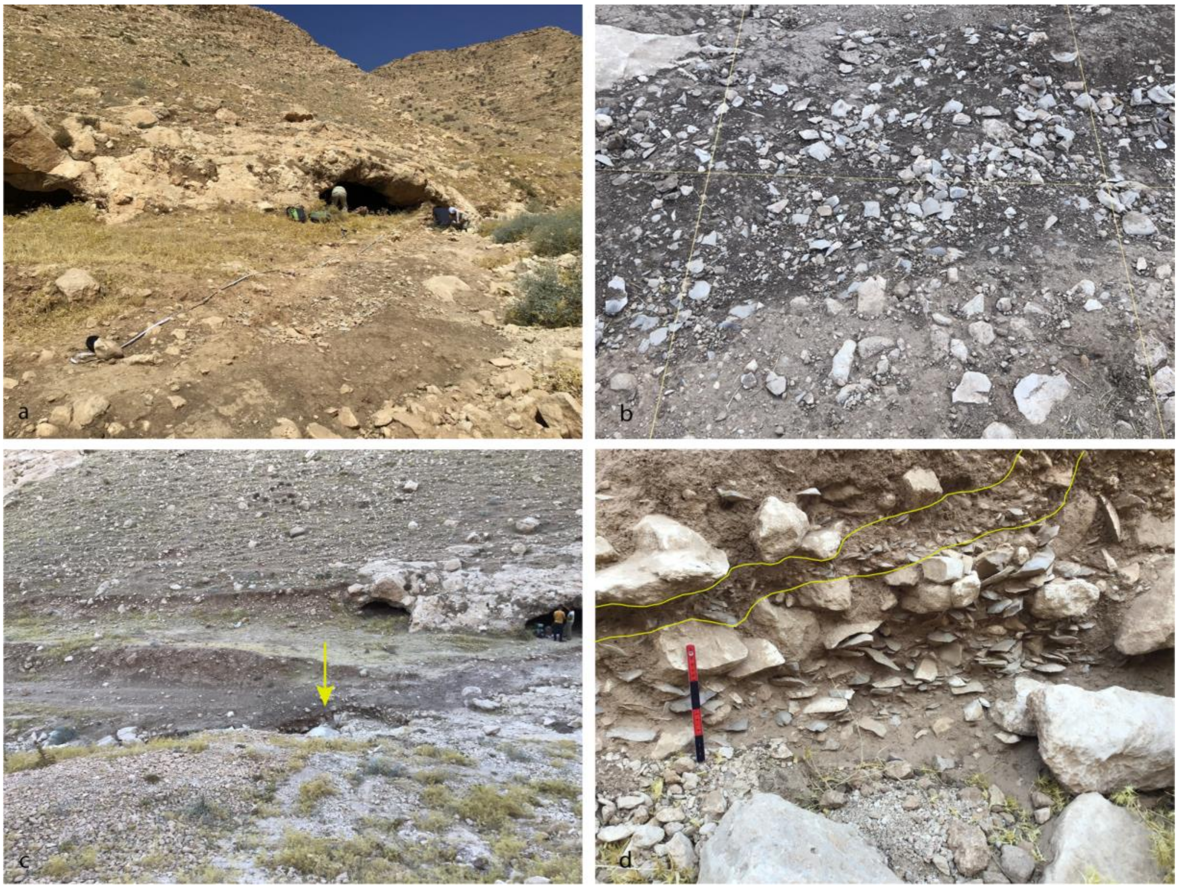


Fig. 16 Site 980. Overview of the terrace from south showing the openings of the cave and the scattering of lithic materials (a); detail of the major concentration recorded in squares A12-B12 (b); panoramic view of the site and location of the section containing the artefacts, as indicated by the arrow (c); section containing the lithic materials found in the cut of the wadi (d).

The wadi bottom was found to be highly cut, featuring coarse sediments and blocks of limestone of various dimensions. In the proximity of the site, its course was characterised by significative differences in altitude. Since the wadi bed was partly filled by quarry's detritus, the erosion involved the terrace unearthing the archaeological materials from their depositional context.

The lithic artefacts constituted a single large cluster of materials spread out thorough the border of the terrace. Along the natural cut of the terrace, an exposed section allowed to certify the presence of an anthropic deposit which developed some meters south recording a difference downwards of about 1 mt, reflecting the ancient morphology of the ancient terrace and wadi bed. In this point, a section about 60 cm high was exposed, showing an impressive concentration of lithic materials, most of them of big dimensions.

To investigate the site, an intensive collection of all the exposed materials has been performed. Subsequently, a test excavation was carried out to check the consistency of the deposit, to analyse its formation processes and to in-depth study the unearthed artefacts.

3.2. Surface collection

An N-S oriented and 3x13 mt area was delimitated on the terrace, covering the extension of the surface scatters. Then, the area was subdivided into squares of 1 m². Surface scraping was performed to collect the materials in each square.

The section located along the southern corner of the site, where the erosion originated differences in altitude, was cleaned and documented. Here, a large blade core was found

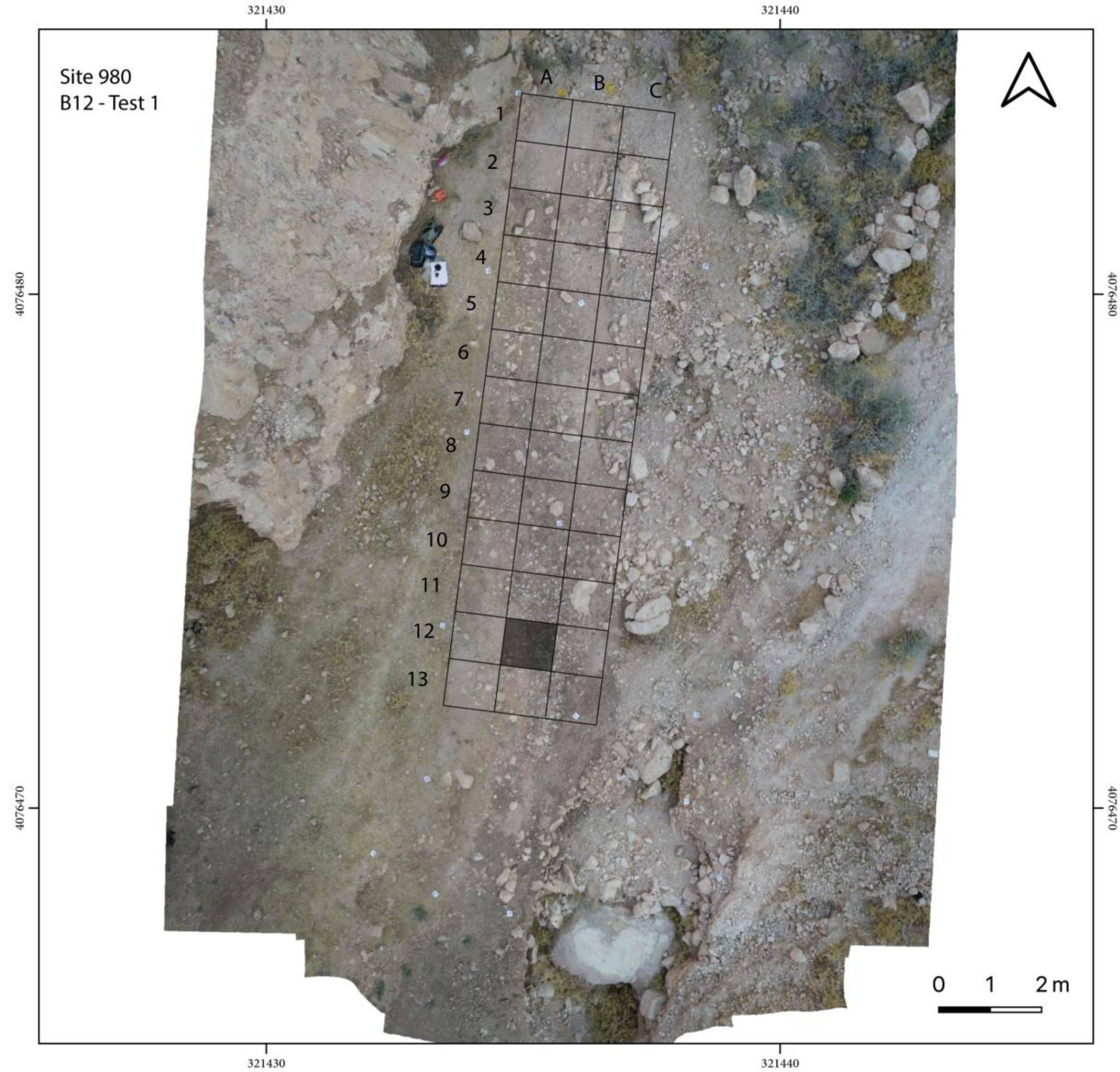


Fig. 17 Aerial view of site 980. Representation of the grid adopted to investigate the site and location of the excavation test area.

inside the sediment at the bottom. Few artefacts were found to be concreted onto a large limestone boulder fixed in-between the sections previously cut by the wadi erosion.

3.2.1. Artefacts density

The lithic artefacts were spread along the eastern border of the terrace where a dark soil layer was identified. Here, the weathering action eroded a covering layer of colluvial origin (clearly visible during the 2016-2017 field campaigns), featuring light-brown incoherent sediments and angular stones of small and medium dimensions.

The collection units (CU) corresponding to the northern part of the collection area (CA) (A1-2, B1, C1) were the most affected by erosion and did not contain materials.

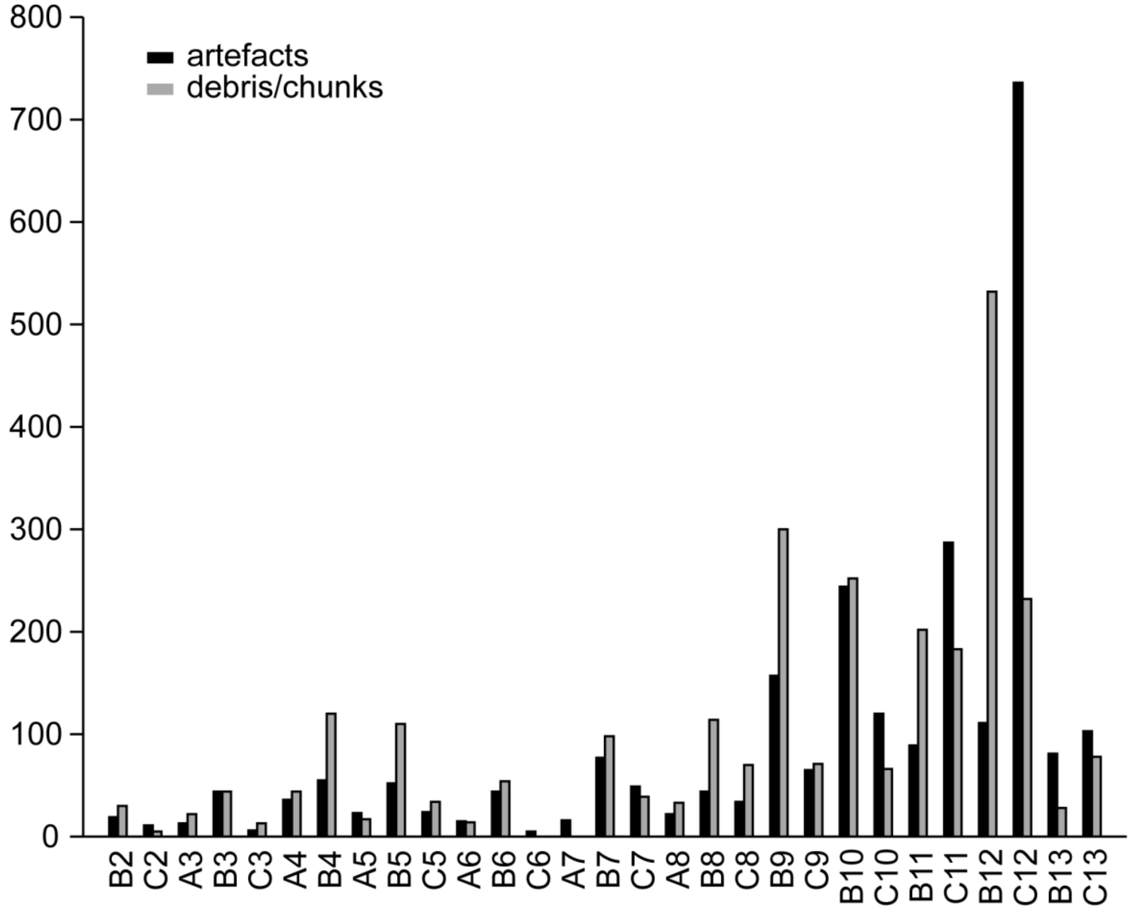


Fig. 18 Artefacts ‘count within the collection units.

Along the western edge of the CA, squares A9-13 were also devoid of materials as they were all covered by the colluvial sediment. On the contrary, the other CUs (grid columns B and partly C) featured an increasing number of artefacts from north to south.

The collected items have been divided, according to their significance, in artefacts and debris/chunks (e.g. flakes less than 2 cm in size and non-orientable/weathered artefacts). Despite being high, the number of items found in the first CUs is not comparable with the count of artefacts belonging to the remnant ones. In addition, debris/chunks from the first CUs exceed the number of artefacts, while in the others their ratio is found variable.

The CUs from B9 onwards, show a gradual increase in materials. A major density is recorded between CUs B10 and C12, this latter featuring the highest number of pieces (n. 968). Two hypotheses could be taken into consideration to explain the evidence; the validity of one does not exclude the other. First, it is possible to assume that the erosional rate was not homogeneous within the whole terrace, due to variations in wadi's transport energy related to the natural morphology of the stretch of the valley as well as to recent human activities that modified it. Secondly, it is reasonable asserting that the northern part of the CA, could represent a peripheral area of the site respect the major cluster of artefacts (CUs B10-C12).

The investigation of the terrace highlighted, thus, the presence of an archaeological deposit, whose real extension is unknown at the present stage. Further insights are provided by the section identified in the wadi's recent cut, located out of the southern edge of the CA. Here, the deposition of the huge mass of artefacts appears to be due to several natural events.

The lowermost layer (Fig. 16, d), about 40 cm of thickness, features clay sediment containing artefacts of large dimensions associated with stones, all sharing the same horizontal orientation. Along the northern edge of the section, the disposition of the artefacts is chaotic, and the stones are obliquely arranged as transported downwards by a high-energy action of the wadi. Follows a small layer, of about 10 cm of thickness, of the same terrigenous matrix but featuring exclusively by small artefacts, horizontally arranged. The northward inclination of the layer could be due to the same natural factors, occurred with less energy, that caused the deposition of the earlier accumulation. Above the series, a thick deposition of less coherent clay sediment containing sporadic lithic artefacts, without specific orientation, and stones of small dimension.

The exposed stratigraphy strongly contributes to the understanding of the agents that caused the final setting of the area and the preservation of the archaeological deposit. Three main natural events, with different transport energy, caused the erosion of the anthropic deposit, originally configurated as a pile of waste materials. At the least two erosive events washed downwards a significant amount of materials, while a third one eroded the terrace surface and unearthed the artefacts after the deposition of a colluvial layer.

The gradual erosion and redeposition of this particular man-made “structure” can explain also the scattering of the artefacts on the terrace and finds evidence from the observations carried out on the artefact’s patination degree recovered in the excavation (see paragraphs 3.2.2 and 3.3.1).

3.2.2. The surface assemblage

The state of preservation of the collected materials is generally low. As the other contexts found in the Jebel Zawa, the artefacts from the surface are all weathered. However, the degree of alteration is not homogenous as recorded elsewhere. At macroscopic scale, most of the materials show complete development of the patina, thus obliterating the naked-eye features of the chert raw material. The development of a reddish/orange non-homogenous patina stands for the most advanced degree of alteration. Other artefacts show gradual surface transformations, which make the macro-structure and colour of the raw material yet readable. A small percentage of artefacts are little weathered. All the artefacts exhibit varying amounts of black surface deposits (manganese or lichens).
In addition to these features, about the 70% of the collected artefacts exhibit a calcareous concretion, difficult to remove completely, that covers one face of the artefacts. Furthermore, it is important to highlight that the artefacts suffered a high rate of fragmentation which affected mostly the laminar blanks. The damage also involved the edges and ridges of the artefacts, especially to those on an advanced stage of weathering. Finally, some artefacts bear heavy patina, edge damage and rounding due to natural transport. This complexity is explicative of the variety of post-depositional processes that affected the site (see paragraph 3.3.1).
A total of 4908 artefacts have been collected from the surface. These are characterised for the largest part by flakes (n. 4688) and blades (n. 214). Just one retouched tool, a scraper, has been found and, finally, 5 cores close the inventory. Considering their small number, a further core collected from the section exposed in the wadi cut will be also considered in the analysis, since it was rolled out from the sediments.
The composition of surface assemblage from the site finds strict comparisons with the other workshops identified. Most of the products can be referred to preliminary knapping operations which led to the shaping of the cores from raw blocks and the preparation of the volume exploited to produce blades. Indeed, the observations carried out on the variability and the morpho-technical attributes of the blades from these workshops, find validation through the analysis of the artefacts from the site.

Technological categories		n.
	scrapers	1
tools		**1**
	non-cortical blades	179
	semi-cortical blades	38
	cortical blades	10
	surf. maint. blades	12
	neocrested blades	2
	crested blades	13
blades		**214**
	platform maint. flakes	88
	tablettes	12
	surf. maint. flakes	5
	laminar flakes	163
	flakes	2335
	debris/chunks	2085
flakes		**4688**
	flake cores	3
	blade cores	2
cores		**5**
Total		**4908**

Tab. 4 Site 980, surface collection. Count per technological categories of the lithic inventory.

The blades characteristics are shown in fig. 19. The whole inventory can be referred to non-full *débitage* stages of the production, as they do not satisfy the principle of regularity, apart from a few items which unfortunately are lacking their proximal portion (9-11).

The entire blade production is unidirectional, and the variability of the modules is highlighted, supplying information about the size categories of the products. Larger blades, with triangular section (n. 2, 6, 7, 13) and trapezoidal ones (n.1, 3), even up to 40 mm of width (n.7), are present as well as smaller ones (n. 4-5, 8-12).

Despite the preservation problems above reported, which affected the site, several proximal fragments are present within the assemblage. The analysis of their butts shown several ways of preparing the extraction point. Orthogonal and small faceted platforms are often associated with pronounced bulb, sometimes marked by bulbar scar. In some cases (Fig. 19, n. 3, 7), the preparation of the platform give rise to a more pronounced central ridge.

According to Pelegrin's experimentations, such configuration would be functional as

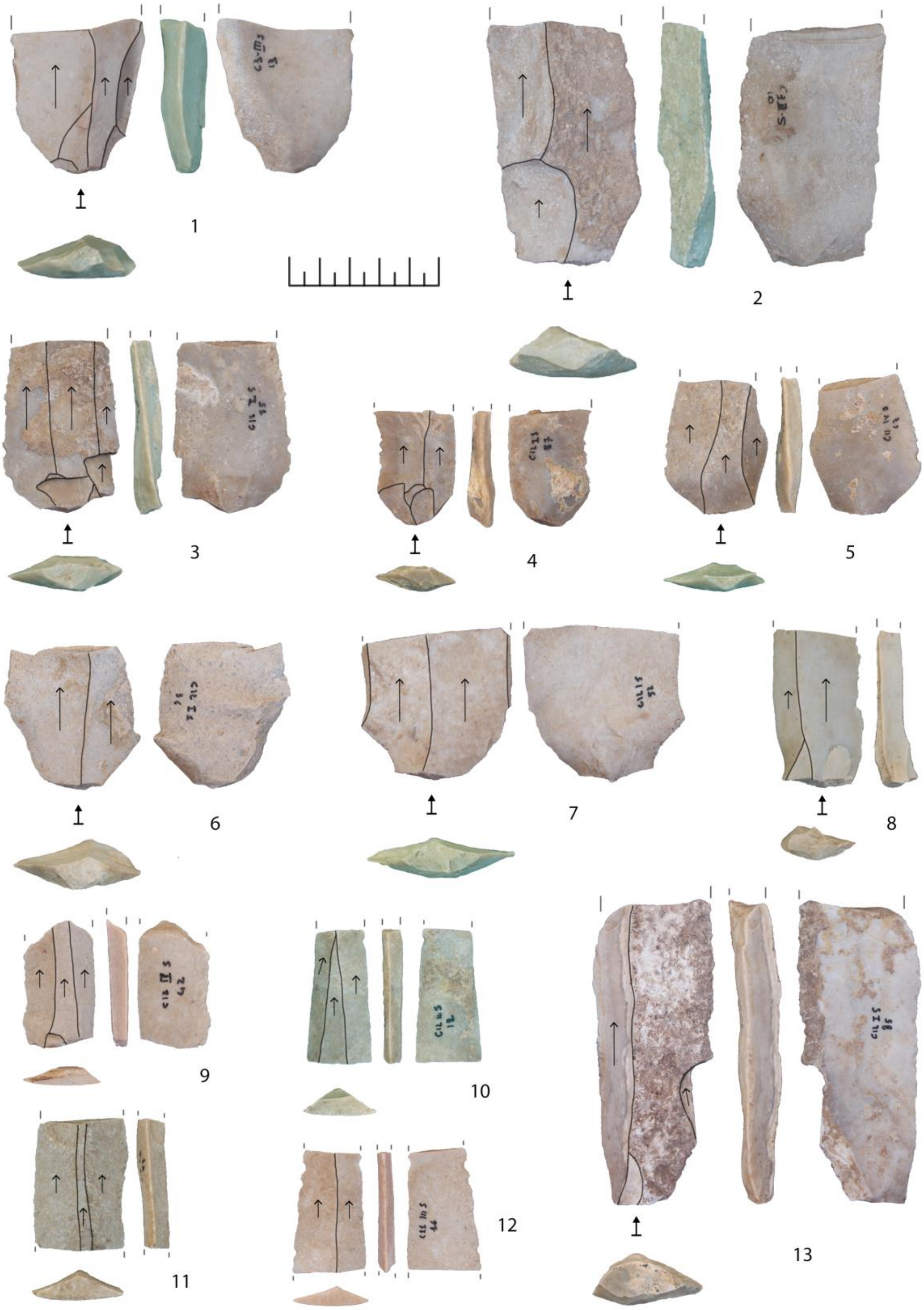


Fig. 19 Site 980, surface collection. Blade proximal fragments (1-6, 8), large blade proximal fragment (8), blade mesial fragments (9-12), semi-cortical blade proximal fragment (13).

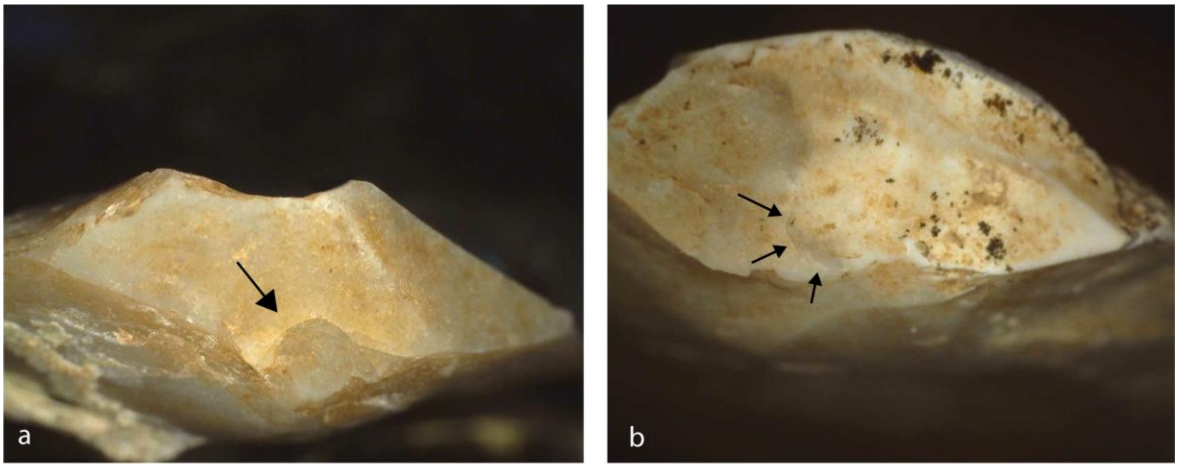


Fig. 20 Circular crack on a small and flat non-prepared butt of a regular blade (a); partial crack on a flat large butt of a thick and semi-cortical blade (photos collected by using a portable USB-microscope, at 30x of magnification).

pressure point during the *débitage* of large blades carried out through the employment of a copper tipped pressure stick, since the obtained convexity would allow a favourable contact between the platform and the pointed tool used (Pelegrin 2012b). Following yet the author, he also reports that such preparation finds confirmation of the technique only if associated with cracks indicating a strong contact between a hard material (e.g. copper) and the ridge.

Based on these observations, no cracks have been found on such butt types. The circumstance would not exclude a priori the adoption of the technique, as these kinds of technological traces do not originate in each removal[4] (Pelegrin 2012b).

Small, faceted, or non-prepared and flat platforms are also attested (Fig. 19, n. 4-5). In the case of non-prepared ones, it is important to highlight the presence of a circular crack of 2,4 mm in diameter on one item (Fig. 19, n.4). This mark (Fig. 20, a) is placed in peripheral position respect the whole area of the butt (width 9 mm; thickness 5 mm). It is associated with lateral secondary fractures, ventral fissures, and a pronounced bulb, observed on its ventral face. However, the morphology of the blade does not match completely with the criteria highlighted by Pelegrin (2012) for the identification of the pressure technique. Long and regular items can be produced also by the adoption of the indirect percussion, using a copper tipped punch, and the butts of such products might even exhibit cracks like those produced by pressure (Briois et al. 2006; Pelegrin 2012a).

[4] The knapping experiments by Pelegrin (1988; 2012b) have been carried out using fine-grained translucent or semi-translucent chert varieties. These parameters are rather variable in the cherts from the Jebel Zawa mines (see Chapter 5).

Fig. 21 Site 980, surface collection. Large laminar flake fragment (1); complete blade (2); surface maintenance blade fragment (4); surface maintenance blade distal fragment (4); tablette (5); surface maintenance flake fragment (6).

Fig. 22 Site 980, surface collection. Large blade cores: CU C6 (1), wadi section (2).

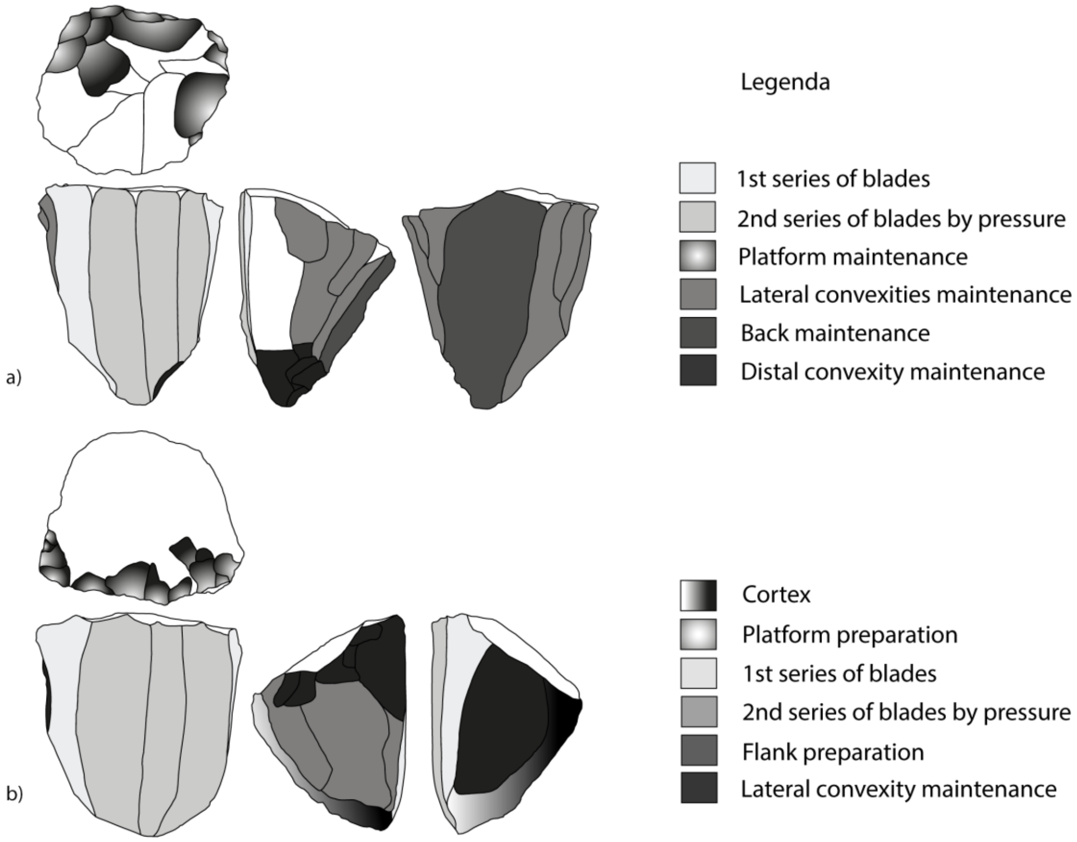


Fig. 23 Diacritic analysis of blade production strategies as shown from the cores in the earlier figure.

Supporting this latter assumption, a thick blade, semi-cortical, was identified to bear a partial crack (Fig. 20, b) located in central and peripheral position respect the area of the butt which is quite large and flat (width 15 mm; thickness 7 mm). Given the almost rectilinear profile of the blade, it is reasonable to exclude a priori the employment of the hard stone direct percussion – the other technique able to leave cracks on the butts (Damlien 2005; Pelegrin 2000; Roussel et al. 2009) – as well as the direct percussion using a soft/organic hammer which often does not produce marks (Damlien 2005; Driscoll and García-Rojas 2014; Pelegrin 2000; Pelegrin and Inizan 2013). Therefore, the adoption of the indirect percussion using a metal-tipped punch to produce this kind of blades still is a valid hypothesis to consider for the preforming/preparation and maintenance stages.

Within the surface record, elements suggesting core maintenance strategies are attested too. They are all related to the production of blades. Large cortical and semi-cortical blades are well present. They feature large and thick non-prepared butts, bearing often large "ring" cracks (*sensu* Damlien 2005) indicating the adoption of the hard-stone direct percussion. Three large but fragmentary items, showing laminar removals on their dorsal surfaces, are related to the maintenance of the extraction surface of cores (Fig. 21, n. 3-4, 6). One item shows 4 convergent earlier removals and may come from a sub-conical core featuring a pointed base (Fig. 21, n.4). On the contrary, a second item, slightly curved and plunged, suggests a different core shape – sub-conical with a flat base – aimed at producing blades featuring flat distal ends. Finally, a *tablette* (Fig. 21, n.5) shows 4 blade removals from dihedral prepared platforms (last removal width 21 mm).

Among the 5 collected cores, 3 items are unidirectional flake cores exploited to produce ad-hoc tools. Of the two laminar cores, only one will be discussed for its technical features in this section (Fig. 22, n.1), as the second one was reused as a hammer and does not allow to carry out detailed observations (Fig. 23). Additional insights and comparisons will be made on the core collected in the wadi ‘section (Fig. 22, n.2). Both the items are organized following similar volumetric conceptions. They show regular blade removals on the laminar surface, highlighting frontal exploitation and adjacent trapezoidal rhythms of *débitage*, which makes reasonable the hypothesis of the adoption of the pressure technique (Fig. 23). However, it is important to underline some differences which are significant to highlight an internal variability within the framework of the adoption of the technique.

The core from the CA (CU-C6) features two series of very regular blades detached from a flat platform, delineated by wide removals. The proximal area of the blade negatives is reduced in size, marked by the development of a pronounced bulb. The terminations are characterised by waves spanning from mesial to distal areas of the blades. These aspects are visible on the last blade removed from the core (length 135 mm; width 25 mm) as well as on the one belonging to an earlier series of removals (Fig. 23, a).

Subsequently, the core volume has been restructured to obtain the guide ridges upon which, starting from the back of the core, setting up new lateral and distal convexities to continue the extraction of the blades. These operations led to the evolution of the core towards a sub-conical shape with a pointed base. Once these were completed, the core was abandoned due to an error, localised on its flank, that compromised the entire process of maintenance (Fig. 23, a).

The second core differs from the former in several technical details (Fig. 23, b). First, it is important to note the completely different configuration of the platform. In this case, it is more inclined, if compared with the first core, and delineated by a single large and oblique removal. Secondly, it was prepared through small flake removals to originate dihedral ridges upon which the force has been applied.

The extraction surface features two series of blades, of which the latter removal (length 120 mm; width 35 mm) shows very regular and parallel edges and a flat, slightly plunged termination. The flanks have been managed through the removal of large cortical flakes using the hard-stone direct percussion. The second series of removals were aimed at the preparation of a neocrest on its right flank. The project was abandoned after failing two consecutive strikes on the same surface.[5]

Fig. 23 Site 980, surface collection. Large blade core reused as a hammer, collected in CU A5.

Finally, it is interesting to briefly discuss the large blade core found in the CU A5. The analysis of its surfaces suggests the hypothesis that the object was reused as a hard-stone hammer during the direct percussion. The convex areas (overhang, flanks, and distal portion) of the object bears macro-traces (e.g. pits, Caricola et al. 2018) connected with an action of thrusting percussion (Fig. 23). The observation finds validation if compared with relative preserved, undamaged, and fresh internal areas of the laminar ridges, the absence of differences in patination degree and the lack of roundings, polishes and neocortex (*sensu* Fernandes et al. 2007) which often characterise natural pieces with similar features.

[5] The difference in patination of certain areas on the core is due to the presence of a thick hard calcareous concretion which was removed by using diluted acid as well as mechanically.

Given its size (length 89 mm; width 93 mm, thickness 92 mm), it is possible to hypothesize its use during preliminary operations of nodules opening and cortex removal. Even if the object represents an isolated find, the reuse of exhausted cores as hammerstones is a common practice in most of the late prehistoric knapping workshops, as well as in domestic contexts (Brautlecht 1993; Dobrescu 2017) and could be one of the cases towards the scarcity of cores in such sites. It is certainly surprising to find such practice in a mining context where suitable raw material blocks were abundant.

3.3. Test excavation in sq. B12

A small sounding (test 1) was performed in sq. B12 to explore the consistency of the archaeological deposit. The excavation highlighted three different layers, namely S, L1 and L2. The W section reported in figure 24, about 50 cm high, shows their stratigraphic relationship and connection with the knapping workshop:

a) layer “S” represents the covering unit, about 20 cm thick, composed by incoherent colluvial sediment of brownish colour with angular stones of small dimensions and rare lithic scatters, chaotically distributed;
b) layer “L1” is covered by the former unit and preserved for about 20 cm of thickness, increasing to about 30 cm along the SW corner of the sounding area. The unit is composed by lithic artefacts, horizontally arranged. A minor compositional feature of the unit is represented by a calcareous concretion recorded on the lower face of all the excavated artefacts;
c) layer “L2” is covered by L1 and it consists of a sterile compact soil layer. The interface between the units is yet characterised by the presence of artefacts. Such interface is well recognisable along the NW corner of the square, while it is eroded in the S corner, where L1 gain further thickness.

These stratigraphic units have been excavated through regular cuts of 10 cm each one, to record the depth of the artefacts and analyse potential changes within the composition and weathering processes of the artefact ‘assemblages. The covering unit “S” has been removed in two cuts (S.I, S.II), while the massive L1 was excavated adopting three cuts (L1.I, L1.II, L1.III). The interface of L2 was removed per few centimetres until the unearthing of its sterile volume. Once the removal of the L1.II was completed, no differences in absolute quotes were recorded with the neighbouring square C12, where the surface scraping highlighted the continuation of L1. This fact suggests that recent wadi erosion removed a significant part of the archaeological deposit for an estimated thickness of about 30 cm.

Fig. 24 Site 980. Test excavation 1 stratigraphical sequence as shown in the west section of CU B12 (a); upper view of the L1.I interface after the removal of the S layer (b).

3.3.1. Composition of the assemblage

The whole inventory of artefacts from B12 test excavation is represented by waste products of blade-knapping activities. A total of 4538 artefacts have been recovered (Tab. 5). The "S" unit yielded back 721 artefacts, while the L1 unit 3630. Finally, L2 restituted 187 artefacts. Flakes category – including debris and chunks – represents alone the 96% of the total. The blades represent 3,9%, while only 4 tools are present (0,9%). The number of artefacts increases starting from the upper layers S.I (n.55) and S.II (n.661) while being more than double in L1.II (n. 1368). A significative decreasing in their number is recorded for L2. Moreover, a small number of undatable pottery sherds come from all the layers except L2.

As told earlier, L1 (I-III) is composed exclusively by lithic artefacts. The inventory is the completest of the series, as all the technological categories are represented (Tab. 5). A relevant number of blades is recorded (n.153) if compared with the evidence provided by S.I-II and L2.However, cores are completely absent. Concerning this latter observation, one must keep in mind the reduced size of the tested area (1x1 mt) in relation to the high number of artefacts, which, however, yielded relevant data.

All the observations carried out on the state of preservation of the surface materials (par. 3.2.2) are here valid. Significantly, the lithic materials from L1.I-III were found horizontally disposed in the unit. The upper face was found, in most of the cases, weathered.

Technological categories	Surface		L1			L2	Total	
	I	*II*	*I*	*II*	*III*	–	*n*	*%*
borers	1	–	–	–	–	–	1	–
scrapers	–	–	–	–	2	–	2	–
core-tools	–	–	–	–	–	1	1	–
tools	**1**	**–**	**–**	**–**	**2**	**1**	**4**	**0,1%**
non-cortical blades	3	–	43	20	34	3	103	–
semi-cortical blades	–	3	7	4	9	1	24	–
cortical blades	–	–	–	1	3	–	4	–
surf. maint. blades	–	–	8	1	10	1	20	–
neocrested blades	–	–	1	–	–	–	1	–
crested blades	1	5	8	1	3	2	20	–
blades	**4**	**8**	**67**	**27**	**59**	**7**	**172**	**3,9%**
platform maint. flakes	–	–	–	–	23	–	23	–
tablettes	–	–	14	13	15	–	42	–
surf. maint. flakes	–	–	3	2	1	1	7	–
laminar flakes	3	8	47	37	49	6	150	–
flakes	37	198	649	445	799	84	2212	–
debris/chunks	15	447	588	420	370	88	1928	–
flakes	**55**	**653**	**1301**	**917**	**1257**	**179**	**4362**	**96%**
subtotal	60	661	1368	944	1318	187	**4538**	**100**

Tab. 5 Site 980, square B12. Table showing total and subtotal counts of the excavated artefacts per technological categories.

The observed types of alteration include white patina (minor percentages), desilicification/recrystallization and deposition of minerals on the surfaces (yellow/orange patinae). The alteration degree is not homogeneous on the same piece. It develops gradually, highlighting several areas on the piece showing different scales of weathering. However, the pieces coming from the lower depth of L1 exhibits a higher degree of surface patination.

The lower face evidences a different behaviour. A good percentage of artefacts shows a concretion covering entirely the face. Under this latter, a well-preserved surface is often found to be present. In other cases, the concretion covers a weathered surface. The alteration increases going into the lower cuts (e.g. L1.III).

The preservation conditions of the artefacts excavated in sq. B12 L1 yielded some clues about the processes which affected the site. The horizontal orientation of the artefacts may indicate redeposition or little movement, from their original position, due to the action of water. The development of the concretion, which only affected their lower faces, can suggest a graduality in the formation of the deposit and calcareous water infills.

These observations are significative if compared with the conditions of preservation of the artefacts lying on the interface between L1 and L2 units. These only show a homogenous white patina, indicating long-time exposure to weathering agents.

3.3.2. Analysis of the knapping waste products

Simple flakes and laminar flakes are the most represented category of knapping waste products (Tab. 5). The products are related to preliminary core decortication and shaping activities which were performed *in-situ*. These items have been subdivided into two main morphological classes (A-B) (Tab. 6). Within each class, subclasses from 1 to 3 have been labelled according to the amount of cortex localised on the dorsal surface, to distinguish cortical products, from semi-cortical and non-cortical ones.

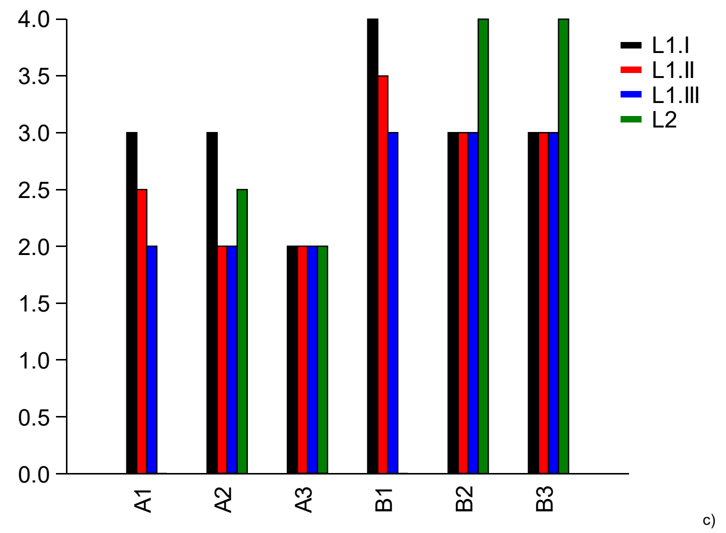
class	type
A1	cortical flakes
A2	semi-cortical flakes
A3	non-cortical flakes
B1	cortical laminar flakes
B2	semi-cortical laminar flakes
B3	non-cortical laminar flakes

Tab. 6 Morphological classes of artefacts; A= flakes, B= laminar (elonged) flakes.

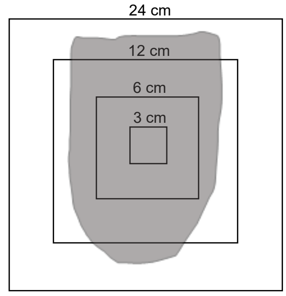
A total of 2362 items have been measured using a quadrangular grid (Fig. 25, b). Four-dimensional categories[6] have been identified and reported: from the smallest ("very small", within 3x3 cm) to the largest one ("large", equal to/more than 24x24 cm).

The histogram in figure 25a compares the median values of the artefact 'sizes according to the identified subclasses and, at the same time, subdivided per unit/cut.

[6] Flakes minor than 2x2 cm have been classified as "debris".



a)



b)

very small	1	<	3x3 cm
small	2	<	6x6 cm
medium	3	<	12x12 cm
large	4	>	24x24 cm

c)

Fig. 25 Site 980, sq. B12. Dimensions of flake and laminar flakes. Histogram comparing the median values of the artefact ‘size, according to the subclasses, per each unit/cut (a); grid used to measure the items (b); size categories adopted (c).

First, it is important to specify that the number of artefacts per each subclass is not homogeneous. The differences in counts reflect the trends reported for the flake/laminar categories in table 5, where the items coming from the L2 unit are in small number respect L1 (I-III). This is the reason lying towards the adoption of the median values, thus excluding the frequencies.

As visible in the graph (Fig. 25), the flake category is smaller in size respect the laminar items. The first class stands around small-medium sized items, while the second is settled towards large-medium sized elements. Indeed, the biggest cortical pieces, both simple and laminar flakes, belong to the high parts of the volume of unit L1.I, while a general correspondence in artefact ‘size is recorded going downwards in depth. The unit L2 revealed the largest non-cortical laminar flakes. Non-cortical flakes are equal in size at each depth.

This trend is significative if contextualised in the framework of the processes and strategies of core shaping activities. The data suggest the incidence of large laminar flakes, to shape the rough block to open multiple flat surfaces and platforms from which managing the refinement of the final core shape through the detachment of flakes (cortical, semi-cortical and non-cortical). Large cortical flake removals were also aimed at the opening of the blocks. The schematization of such activities is confirmed by the experimental data available in the literature regarding the predetermination of cores for the extraction of regular blades, where the reproduction of a series of features and concepts constitutes the geometric constraints against the knapper: the curvature of the *débitage* axe, platform angle, lateral and distal convexities, and guide ridges upon the main surface (Pelegrin 1984a).

3.3.3. Technical items

Such constraints take on greater significance once started the process of blade extraction, as it is possible that during such process the core changed its original conformation due to the loss of control above the mentioned variables, which depend on the choices made by the knapper and/or the characteristics of the raw material.

Within the assemblage from the sq. B12, several technical items attest the strategies adopted by the knapper to renew such originally planned conditions and continuing the exploitation of the core. As evidenced by the dimension and organisation of the previous removals on the dorsal surfaces of these artefacts, such items were detached from cores at various stages of the production.

Surface maintenance blades and flakes (Fig. 26, n. 3-4, 6-8) are the most represented among the items. They had the function to refresh the guide ridges on the laminar surface, due to knapping accidents (reflection, Fig. 26, n. 4, 7), or to control the curvature of the *débitage* axe after the evolution of the core shape from prismatic to sub-conical, as suggested by the convergent directions of the previous blade removals, the curved distal ends and the plunged terminations (Fig. 26, n. 4, 8).

Some cases exhibit complete cleaning of the main surface (Fig. 26, n. 3), thus necessitating a new repreparation of the lateral and distal convexities of the core, to renew the guide ridges. Related to these latter, the preparation and detachment of neocrested blades was the preferred strategy carried out at the site (Fig. 26, n. 5; also compare Fig. 9, n. 6). As shown from the core analysis (paragraph 3.2.2), the flanks of the cores were also managed through simple laminar flake/blade removals.

However, the maintenance of lateral convexities happened also by detaching blades (both cortical and non-cortical, see Tab. 5). when the extraction surface was enlarged towards the one or both the flanks (sub-conical core stage), blades were also detached to manage the core (Fig. 26, n. 9). Results of these operations were blades with regular previous negatives and parallel edges bearing asymmetric trapezoidal sections.

Platform maintenance was necessary to maintain, on the one hand, a correct orthogonal angle (around 90 degrees) between the surface and platform, on the other, to ensure an idoneous preparation of the specific point where the force was applied.

Fig. 26 Site 980, sq. B12. Technical items. Crested blade (1), large *tablette* (2), surface maintenance flake (3); surface maintenance blades (4, 6-8), blade mesial fragment with asymmetric trapezoidal section (9).

Fig. 27 site 980, sq. B12. Platform maintenance flakes.

Flakes attributable to platform faceting/dihedral preparations are attested (Tab. 5). They are not always recognisable, but, when attributable (Fig. 27), they show on the butts the ridges pertaining to the laminar exploitation, and a convex-concave cross-section (or *chapeau de gendarme* morphology, see Inizian et al. 1999).

Tablettes are also numerous (Tab. 5). They were detached to manage the inclination of the platform and to repair the core after knapping accidents (Fig. 26, n.2).

Finally, a large crested blade (length 175 mm; width 41 mm; thickness 32 mm) is finalised at initialising the blade production and shed light on the core 'size at their first stage of exploitation.

3.4. Blade production

A sample of 123 blades and blade fragments, from a total of 172 will be discussed in this section. The samples have been selected from L1 and L2 units, avoiding the items excavated in the "S" unit. The sampling was also conditioned by the overall state of preservation of the pieces, whose significative technological were found to be obscured by weathering.

Blade	L1.I		L1.II		L1.III		L2	
	n.	*%*	*n.*	*%*	*n.*	*%*	*n.*	*%*
Entire	1	2	–	–	3	7	1	17
Distal	13	25	6	26	14	33	2	33
Mesial	23	44	9	39	8	19	–	–
Proximal	15	29	8	35	17	40	3	50
Total	52	100	23	100	42	100	6	100

Tab. 7 State of preservation of a sample of 123 blades from L1 (I-III) and L2 units from sq. B12, site 980.

The sample is composed of 52 items coming from L1.I, 23 from L1.II and only 6 items from L2. As shown in table 7, complete pieces are rare within the deposit (n.5). Moreover, they are not distributed uniformly. The blade evidence is missing from L1.II, while only 3 items come from L1.III. Apart from complete pieces, fragmented artefacts (e.g. distal, mesial, proximal) are randomly distributed. Moreover, each type of fragment is equally present at each depth of the archaeological deposit (Tab. 7).

Among the fractures observed, 5 types have been identified according to their morphology and following the terminology outlined and modified from Dini et al. (2008).

Fracture type	**n.**	**%**
concave	27	23
convex	1	1
irregular	11	9
sinuous	4	3
straight	37	31
proximal/distal	80	68
concave+convex	1	1
concave+straight	14	12
irregular+straight	1	1
sinous+concave	1	1
sinous+irregular	1	1
sinous+straight	2	2
straight+straight	18	15
mesial	38	32
Total	118	100

Tab. 8 Type of fractures and relative occurrence on the fragments.

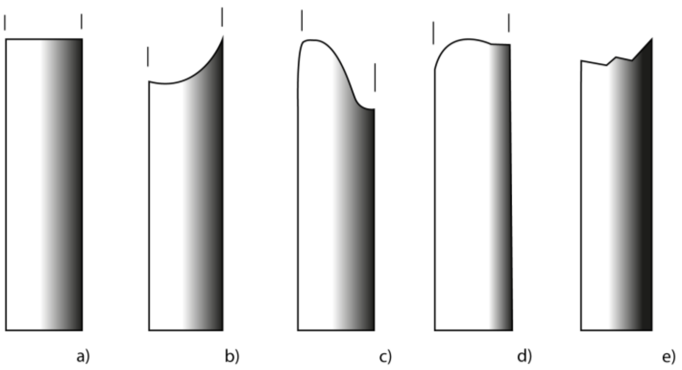


Fig. 28 Morphology of the fractures, as seen from the blade profile: straight (a), concave (b), sinuous (c), convex (d), irregular (e) (modified from Dini et al. 2008) (drawings made by the author).

Table 8 shows the occurrence of such fracture types on the blade fragments. The largest part of the objects with only one end fractured, exhibit straight (31%) and concave (23%) fractures. The other recurrent type is the irregular one (9%), while sinuous and convex types are not significative within the sample. The items with both the ends fractured – namely mesial fragments – show similar trends. Objects showing "straight-straight" fractures are the most frequent, followed by "concave-straight" ones.

As known in the literature, straight and concave fractures often originate due to high impact shocks (Fischer et al. 1984, Borgia 2006) and are often associated to intentional fragmentation techniques carried out by direct or bipolar percussion. Concave or sinuous fractures are related to flexion techniques (Inizan et al. 1999).

No impact points have been observed on the fractures characterising the blade fragments. All the straight fractures do not show diagnostic features supporting an intentional fragmentation (Anderson-Whymark 2011; Bergman et al. 1987; Inizan et al. 1999; Slavinsky et al. 2018; Vardi and Gilead 2011).

As observed in other near eastern contexts, the state of preservation of the blades represents an important variable to consider for investigating the techniques of fragmentation even when the archaeological record (glossed blade segments, residues of glue, hafting traces) supports their employment (Manclossi et al. 2016; Moscone 2019).

No doubts arise towards the efficacy of the flexion, as a valid alternative to percussion, in the intentional fragmentation of such large blades. For example, the analysis of the large blades from the southern Levant, showed a wide spectrum of strategies adopted to produce blade segments (i.e. percussion, flexion, truncation), while the items from the north-western

Mesopotamia showed differences on a regional basis (Chabot and Eid 2003; Chabot and Pelegrin 2012, Anderson et al. 2004; Edens 1999).

	proximal	**mesial**	**distal**
N of samples	43	40	35
Min (mm)	27	10	18
Max (mm)	90	67	72
Mean	48	30	42
Stand. dev	17	13	14
Median	45	27	41
25 prcntil	34	23	29
75 prcntil	56	34	54

Tab. 9 Metric values (in mm) of the length of the blade fragments coming from L1 (I-III) and L2 units.

Although all these observations would be potentially valid here, no clues supporting the standardisation of the strategies of segmentation are reported, such as the occurrence of retouch and trends in blade portions size being represented. Regarding this latter, high variability is recorded within the metrics of three fragment categories, especially inside the mesial group which does not support the *in-situ* fragmentation hypothesis (Tab. 9). Moreover, it is important to state that full production blades are completely absent in the archaeological record, supporting the idea of export of complete blades from the site.

Considered all the issues, the evidence provided by site 980 – sq. B12 seems to point out towards a natural origin of the blade fragments. This fact assumes importance once considered the depositional history of the site and the processes that altered the deposit. In such context, natural fractures can occur due to a wide range of agents, such as trampling and sediment pressure (Burroni et al. 2002; Eren et al. 2011; Kuhn and Li 2019; McPherron et al. 2014), to which certainly soil processes contributed (Stapert 1976; Thiry et al. 2014).

Finally, it is worth mentioning that knapping errors can also cause the fragmentation of the blades during their extraction (Briois et al. 2006; Roche and Tixier 1982).

Knapping errors can happen due to wrong evaluations made by the knapper (testified also on cores; see paragraphs 2.3.2 and 3.3.2), or due to the presence of internal obstacles in the raw material (e.g. inclusions, impurities) causing deviation of the force within the core (compare Fig. 7, n. 9; see Chapter 5).

Technique	L1.I		L1.II		L1.III		L2	
	n.	%	*n.*	%	*n.*	%	*n.*	%
Pressure	13	25	9	39	12	29	3	50
IP	7	13	–	–	9	21	2	33
HSDP	–	–	2	9	4	10	1	17
Undiagnosed	32	62	12	52	17	40	–	–
Total	52	100	23	100	42	100	6	100

Tab. 10 Distribution per each unit of the blade *débitage* techniques identified (IP, indirect percussion; HSDP, hard-stone direct percussion).

Despite the blades fragmentation rate emerged during the analysis, several *débitage* techniques are hypothesized: pressure, indirect percussion, and hard-stone direct percussion. The identification, as explained in earlier diagnosis (paragraphs 2.3.2 and 3.3.2), is based on the blade's techno-morphological attributes. However, a stronger diagnosis has been only possible being made for the proximal fragments, while the difficulty of analysing mesial and distal ones was objective. As stated by Chabot and Pelegrin (2012), the impossibility of carrying out diagnosis on non-proximal Canaanean blade fragments from northern Mesopotamian sites lies in the impossibility of setting the observation just on few technological details (e.g. profile, dorsal ridges, edge morphology). Considering this fact, distinguishing the pressure technique from the indirect percussion would be rather difficult without examining the technical stigmas on the proximal parts, especially from northern Mesopotamian sites where the coexistence of the pressure and indirect percussion techniques for obtaining large blades is hypothesized by several authors (Angevin 2018; Chabot and Pelegrin 2012; Van Gijn 1988)

This is the reason explaining the 62% of undiagnosed blades in L1.I, 52% from L1.II and 40% from L1.III. The number of blades produced by the pressure technique is higher than the indirect percussion produced ones. The hard-stone direct percussion was identified on several items, but it is not equally distributed.

Leaving apart the blades produced by this latter technique, as it has been identified on blades belong to core shaping and maintenance stages of the process of core reduction (see Fig. 26, n.6), in the next paragraphs will be discussed the items produced adopting the other two techniques.

Fig. 29 Site 980, sq. B12. Blade proximal fragments produced by the adoption of the indirect percussion.

3.4.1. Indirect percussion

Blades produced by the adoption of the indirect percussion (IP) are present for a total of 18 items (Tab. 10). A selection of proximal fragments is reported in figure 29. As it is possible to see, all the blades show an irregular morphology. Few items have a trapezoidal section (Fig. 29, n. 3-5), while the others exhibit triangular (Fig. 29, n. 7) and irregular ones (Fig. 29, n. 1-2, 6). The non-regularity of the previous ridges of most of the blades is associated with clear undulations visible on the ventral faces, related to a consistent thickness of the blank. Two items are interpretable as surface maintenance blades, as they show previous non-successful removals on the dorsal faces (Fig. 29, n. 2-3, 6).

blade attributes	**pressure**				**indirect percussion**			
	min	*max*	*mean*	*std. dev.*	*min*	*max*	*mean*	*std. dev.*
IPA (degrees)	75	100	89	4	90	105	95	6
EPA (degrees)	80	105	91	5	75	90	84	7
pl. width (mm)	9	27	16	4	11	23	17	4
pl. thickness (mm)	4	18	7	3	4	13	8	3
platform prep.	flat/convex/dihedral faceted				flat/convex faceted; flat unprepared			
butt stigmas	v-cracks; circular cracks				none; (ring crack?)			
bulb	flat/pronounced/detached; bulbar scar				flat/diffuse; bulbar scar			

Tab. 12 Synthesis and comparison of the attributes observed in the proximal portions of the blades produced by pressure and indirect percussion. (IPA, Internal Platform Angle; EPA, External Platform Angle).

As reported on the table above (Tab. 12), there is a significative difference between the blades interpreted as being produced by indirect percussion with the ones produced by pressure. This diversity is visible in the metric features as well as in the strategies of platform preparation and technical stigmas, observed on the proximal fragments.

For what regards the platform preparations, blades produced by IP exhibit flat or convex faceted platforms. Flat and larger non-prepared ones are also attested. Among these, one item exhibits a slight platform inclination associated with a twisted profile. On the butt of the blade, a large ring crack is visible (Fig. 31, f) which suggests being related to a considerable impact; a circumstance that makes comparable the stigma with the ones observed on the blades produced by HSDP (Fig. 31, e). Finally, the bulbs of force are generally flat – sometimes a bulbar scar occurs – or diffuse.

The internal platform angle (IPA) varies in a range of 90-105 degrees (mean value 95°) suggesting that these kinds of blades were detached from platforms forming an obtuse angle with the ventral face of the blade itself. On the contrary, the external angle (EPA) varies in an equal restricted range of 75-90 (mean value 84°), indicating an acute or nearly orthogonal angle (90°) between the core platform and the *débitage* surface.
However, the butt dimensions are found to be restricted and comparable to those for which the pressure technique has been proposed (Tab. 12). This would mean that a reduced contact surface was exploited to remove the blades, thus supporting the hypothesis of the adoption of a punch as an intermediate tool during the percussion (Briois et al. 2006).

3.4.2. Pressure technique

A selection of blades interpreted as being produced by the pressure technique is reported in figure 30. Several modules are attested: from larger, trapezoidal or triangular, to smaller trapezoidal ones. The sections are always asymmetrical. Their profile is thinner if compared with the IP blades, and the negatives of the previous removals on the dorsal surfaces highlight the presence of knapping accidents (Fig. 30, n. 2, 7, 9). In addition, the overhangs have been refreshed in some items (Fig. 30, n. 2-3, 7).
Three items are semi-cortical. Among these, a blade is an almost complete semi-cortical specimen (preserved length 131 mm; width 23 mm; thickness 12 mm), detached from the core flank (Fig. 30, n. 1). The blade presents a slight curvature originating since its mesial area. The distal end is fractured, and even if it is not possible to reconstruct the exact original length, we hypothesize the item was about 20 cm long. All these arguments support the idea that the items belonged to non-full production stages of the knapping process.
A substantial difference with the IP blades is recorded on the platforms. The present population of blades features flat, convex, or dihedral-convex preparations (faceting). Their dimensions, if compared with the IP group, are characterised by a wider range of variability (width 9-17 mm; thickness 4-18 mm), but the mean values (width 16 mm; thickness 7 mm) indicate they are small and comparable with the former population.
Conversely, the analysis of the flaking angles separates the two groups. The pressure blades population is characterised by an obtuse EPA (range 80°-105°, mean 91°) and an acute IPA (range 75°-100°, mean 89°). This trend indicates that the blades were often detached from obtuse and convex or dihedral prepared platforms. The presence of cracks, concavities, and v-shaped fractures (Fig. 31, b-d) on these butts, in correspondence of a central ridge of the platform faceting (convex or dihedral preparations), emphasizes the differences.

Fig. 30 Site 980, sq. B12. Blade proximal fragments produced by the adoption of the pressure technique.

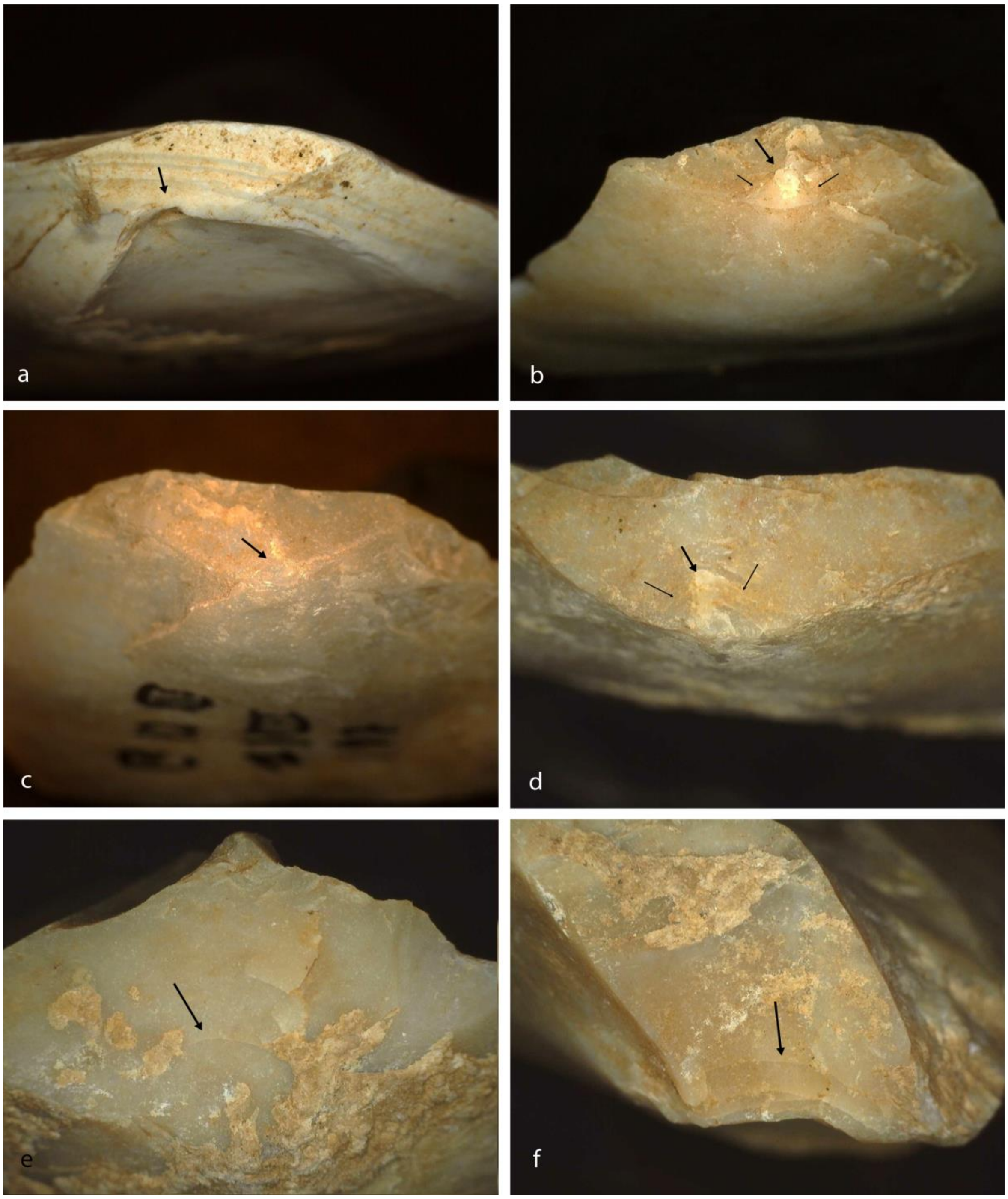


Fig. 31 Different types of technological traces observed on the butts of the blades. Circular crack on a flat and non-prepared bulb associated to a detached bulb (a); concavity (diameter 2.6 mm) located on the ridge and associated to a v-shaped crack (b); concavity (diameter 2.1 mm) located on the ridge and associated to ventral fissures (c); concavity (diameter 1.5 mm) located on the ridge and associated to v-shaped crack (d); large ring cracks on flat and non-prepared butts (e). The main arrows indicate the point of contact, while the small ones indicate the development of the fractures (photos collected by using a portable USB-microscope from 30x to 40x of magnification).

In the previous paragraphs, the technological meaning of such types of marks has been explained. The archaeological record from sq. B12 adds some details useful to trace their internal variability. The concavities located along the ridges, associated with v-shaped fractures, occur frequently on butts configurated as convex-faceted or dihedral-convex. The fractures departing from the concavities are not always present; they are related to more prominent ridges. This indicates that the fracture originating the blade, adopting a dihedral preparation, started several millimetres behind the contact point, while in flattened platforms the fractures might have started in a close range.[7]

A certain variability is also recorded within the diameter of such concavities. The experimental dataset published by Pelegrin (2012b) show that such marks can vary in a remarkably close dimensional range, spanning from 1.5-2 to 3-4 millimetres for the pressure modes 4-5. The measures collected on the blades from sq. B12 fits perfectly in this range (Fig. 31, b-d).

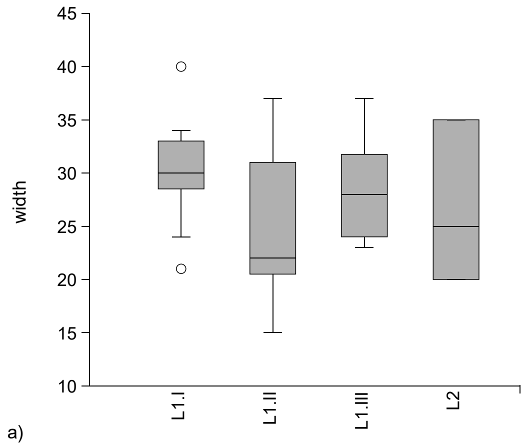
To conclude, such characteristics are diagnostic of the adoption of the pressure technique using a copper tipped stick. The presence of cracks, considered alone, is not a valid argument to carry out convincing diagnoses. Nevertheless, several criteria are satisfied based on our observations that allowed to distinguish a given group with homogenous features. Within such a group, cracks on the butts assume importance only in association with a regular morphology of the blade (edges, profile, previous removals) and with certain modes of platform preparation. Finally, it has been already shown that in absence of such criteria, the interpretation can be different and might suggest the adoption of the IP or HSDP techniques.

3.5. Identification of the pressure modes

The widths of the blades belonging to the group of items produced by the pressure technique have been plotted together to analyse and identify trends upon which base the interpretation of the modes of applying the pressure. The basic principle is related to the assumption proposed by Crabtree that *the wider the blade the bigger the force* needed to detach it (Crabtree 1969). This assumption has been explored and experimentally verified (Marchand et al. 2020; Pelegrin 1988, 2012b) (see chapter 1).

Considering the expected results, it is worth mentioning here that based on the “5 modes”

[7] These latter assumptions are based on the cases reported in literature and they have been not verified through proper experimentations (compare figures in Pelegrin 2012, paragraph 18.5). In addition, the cases here report are numerically not consistent to be statistically explored.



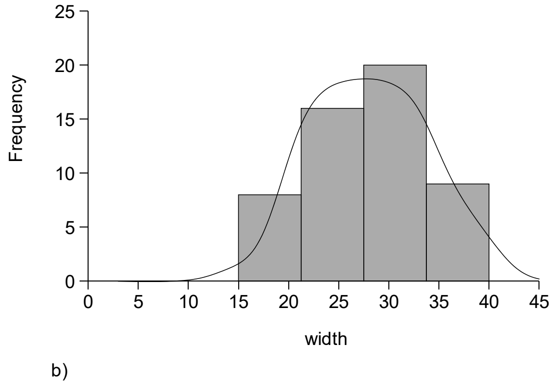


Fig. 32 site 980, sq. B12. Boxplot showing the distribution of the width values per each unit/cut (a), histogram reporting the frequencies of the width classes identified and the curve obtained through the kernel density algorithm (b).

	L1.I	**L1.II**	**L1.III**	**L2**
N of samples	13	9	12	3
Min width	21	15	23	20
Max width	40	37	37	35
Mean	30	25	29	27
Stand. dev	5	7	5	8
Median	30	22	28	25
25 prcntil	29	21	24	20
75 prcntil	33	31	32	35

Tab. 12 Summary statistics related to the plot in figure 32a.

proposed by Pelegrin (1988; 2012), long and large blades can be only produced following two ways of exerting the pressure: using long crutches in a standing position and adopting the lever pressure mechanism (see chapter 1). The two systems have strong cultural and evolutionary implications, and both are known in the Old World at the end of the prehistory. The boxplot in figure 32a, reports the distribution of the width[8] values per each unit/cut. The distribution oscillates within the different units/cuts as indicated by the median values. Anyway, the width values are comprised in a defined range (20-40 mm) with few exceptions (L1.II, min value 15 mm; L1.I, max value 40 mm).

[8] Due to the high fragmentation of such blades, the width measures have been collected on the distal ends in the case of proximal fragments, and on the proximal ends as the case of distal ones. This strategy would allow the comparison of a central width value as well as possible.

Considering all the values in a single histogram (Fig. 32b), it appears clear that the distribution is unimodal and has its peak around the classes comprised between 25-30 mm of width. Comparing the obtained data with the experimental ones, the range is diagnostic of the adoption of the lever pressure mechanism, as all the blades wider than 22 mm would not be produced by the crutch and, conversely, the lever system would be not able to produce average blades smaller than 20 mm (Pelegrin 1988; 2012b).

However, in the light of the results recently obtained by J. Vosges (2019) and J. Heredia (Pelegrin 2012; Vosges 2019), the possibilities around the adoption of the crutch system have been pushed up until 30 mm (see chapter 1).

The question arises regarding whether the production of blades by the crutch and the lever mechanism are distinguishable. Until today, several authors investigated the problem and attributed blades wider than 22 mm to lever mechanism. In the Near Eastern panorama, all the studies conducted on the archaeological collections agreed with this view (Anderson et al. 2004; Angevin 2015, 2020; Chabot 2002; Chabot and Pelegrin 2012; Manclossi et al. 2016, 2019; Shimelmitz 2009), while other scholars considered only blades wider than 30 mm as produced by the lever (Marchand 2014, 2017; Peyronel et al. 2019).

Some scholars explored the possibilities given by an experimental prototype based on a small-sized lever mechanism (Abbes 2013). Unfortunately, no experimental datasets are currently available to compare our archaeological results.

Lately, L. Manolakakis (2017), dealing with the large blade productions of Balkan's Late Chalcolithic, proposed two possibilities to explain the presence of smaller blades in the archaeological contexts characterised by pressure blades with large modules. First, the adoption of a small lever system would be favoured through a first preparation of the laminar ridges and set up of the cores by the "traditional" lever system (*sensu* Pelegrin). The second option would imply a complete reshaping of the cores and the prosecution of the *débitage* process with the crutch system, after having exhausted the possibilities given by the lever.

Both the options consider the production of blades as a continuous process of extraction of laminar blanks until the core exhaustion. For this reason, and following our results, it seems plausible reasoning on these hypotheses.

Based on the frequencies of the width intervals represented in figure 32b, we see that the most represented class is the one around 30 mm, followed by the 25 mm class. Few blades exceed this range as well as those who do not reach 20 mm. Given the graduality in width decrease, it seems appropriate at this stage of the research to propose the hypothesis of the adoption of a small lever, or a flexible lever mechanism able to constantly adapt the force, to produce most of the blades at site 980. This could be one of the reasons also explaining the abandonment of cores when out of the possibilities offered by the lever, but potentially productive by switching to the crutch. Future works will be carried out to explore the problem from an experimental perspective. Anyway, the assumption is supported by the strategies of core maintenance and reduction previously discussed, which highlighted a gradual transformation in size and shape of the cores, and, therefore, a decreasing dimension of the targeted blades. A synthesis of the entire process will be presented in the next paragraph.

3.6. Reconstruction of the chaîne opératoire

The analysis of the lithic artefacts coming from the knapping workshops of the Jebel Zawa allowed to reconstruct the *chaîne opératoires*, intended as sequences of gestures, tools involved, methods and technical strategies – and annexed *savoir-faire* – contextualised in a spatial/temporal dimension (Geneste 1988; Pelegrin et al. 1988).

The exclusive goal of these sequences was the production of blades (Fig. 32). The process started with the extraction of the nodules from the outcrops following two strategies: from open-air quarries and inside karst cavities of natural origin. Subsequently, the rough blocks were transported in specific locations were performing the knapping activities.

Based on the whole documentation and focusing on the data provided by systematic investigations carried out at site 980, three stages of the production – following the decortication phases and core preforming – have been identified.

The first stage is that of large and wide blades production from prismatic cores, consisting of a single prepared platform and a unique, frontal, *débitage* surface (Fig. 32). The evidence is provided by crests fragments, large *tablettes* showing wide and regular removals, and larger blade fragments. The production started with the detachment of long lateral crests allowing to exploit subsequently regular ridges for entering in the full *débitage* phase. During the reduction, several maintenance strategies were carried out (e.g. tablettes, platform maintenance through single flakes removal, maintenance blades) which, however, do not cause a radical transformation of core ‘shape.

The second stage is testified on most of the cores. This phase features evident core adjustments to continue the exploitation, causing their size reduction (Fig. 32). The maintenance strategies mostly consist of the detachment of blades and flakes from the flanks together with adjustments of the back of the cores.

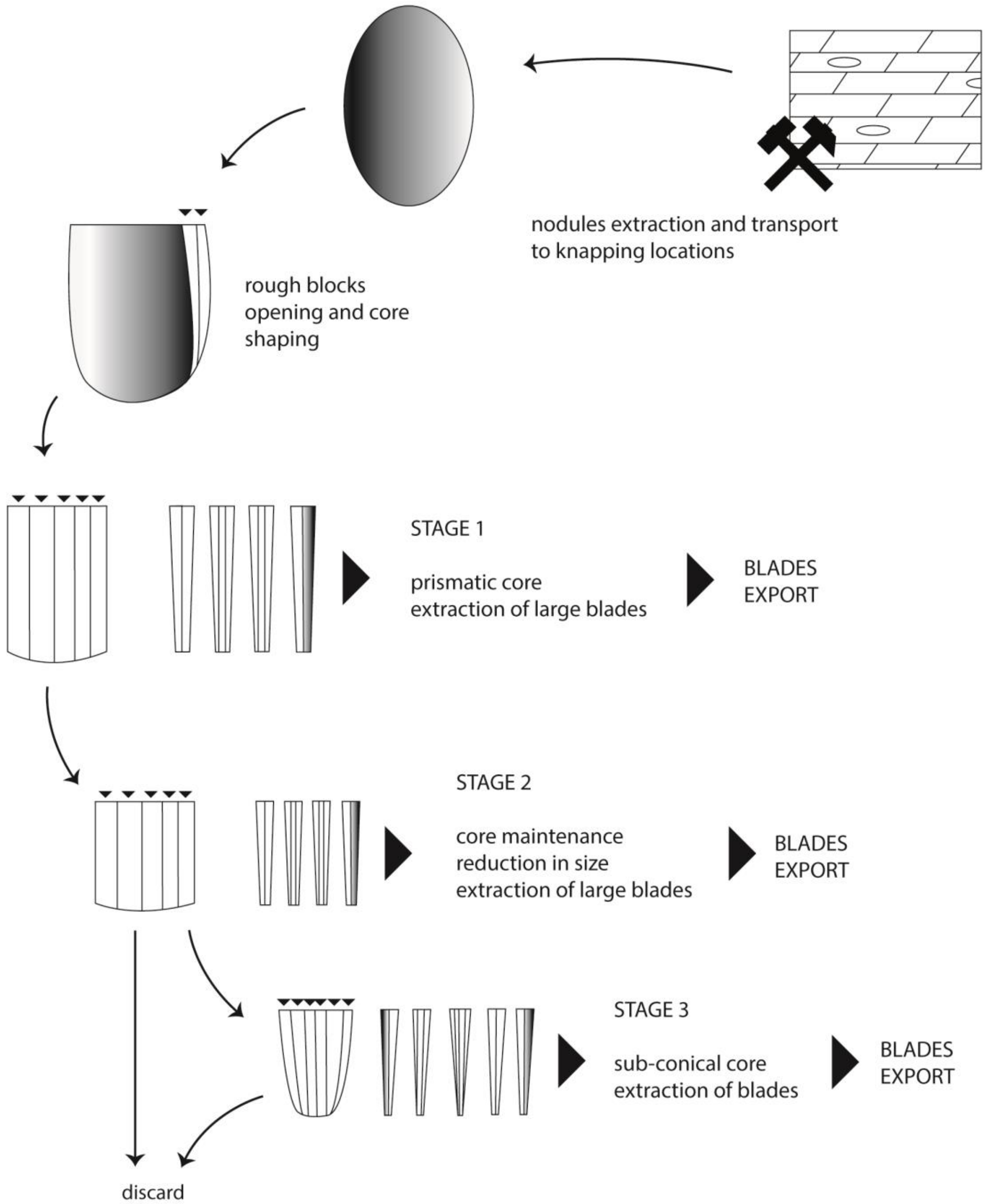


Fig. 32 Site 980, sq. B12. Proposed schematisation of the chaîne operatoire.

These latter were abandoned due to knapping errors, or issues related with compositional features of the chert blocks, when no longer exploitable in a systematic way to produce blades with specific features (size, regularity, trapezoidal sections).

The last stage marks the passage from prismatic to sub-conical core shapes, to continue the exploitation (Fig. 32). The evidence is provided by the core from CU CA6 and a series of maintenance blades featuring convergent removals of small modules, together with pointed/plunged terminations, having the function to control the curvature of the core surface. Blade fragments of reduced size also support this assumption.

The present conceptual schematisation seems to be subject to a more flexible practice, depending on nodules size/shape (see chapter 5). We cannot exclude that smaller nodules were also exploited, thus allowing to produce smaller blades without passing through intermediate stages, as the size of some crests seems to suggest.

All the collected and discussed data converge towards a relevant implication of economic nature: the targeted blades are completely absent and were exported from the workshops to be distributed or exchanged. Indeed, it has been already shown in the previous paragraphs, how the techno-morphological features of the blades composing the archaeological record allowed to reconduct them to maintenance and/or initialisation activities. In this sense, the duality between IP and pressure blades can be understood only by comparing the morphology of the removals left on the core surfaces.

3.7. Discussion

The Jebel Zawa mining district and the large blades knapping workshops constitute unique evidence in the Near Eastern archaeological panorama. No comparable sites related to the supply and on-site processing of chert blocks to produce Canaanean blades are known. Even though in certain areas suitable sources of raw materials are known (e.g. Southern Levant, Rosen 1997; Middle Euphrates Region, Hartenberger et al. 2000; Behm-Blancke 1991), systematic field researches are lacking or did not yield significative documentation.

From our perspective, it is important to highlight the factors of visibility and preservation of such contexts. Site 980 was obliterated by alluvial and colluvial sediments, while most of the other workshops of the Jebel were found to be highly eroded. Thus, the evidence is fragmentary due to several processes of transformation of the environment that occurred in the past and still active today. We should also consider the gradual changes inducted by modern communities settled at the foothills of the Jebel.[9] For these reasons, the evidence provided by the Jebel Zawa is of extreme interest to understand techno-economic dynamics related to the knapping processes dealt with in this chapter.

The analysis of the lithic artefacts evidenced a new complexity – previously hidden – including strategies of rough blocks extraction and selection, transport to the knapping locations and organization of the waste debris through *débitage* piles. The characters of this

[9] In summer 2019, site 980 was completely destroyed by the reprise of the limestone quarrying activities.

exploitation implied specific technological choices in relation with the goal of the production: long and regular blades detached using the pressure technique applied adopting a flexible mechanism (i.e. long crutches, small and/or large lever systems) allowing reducing the cores and optimising the results. Moreover, it has been shown how the interaction of different techniques (e.g. indirect percussion and hard-stone direct percussion) permitted to manage various stages of the process.

Given these premises, the sites meet all the theoretical requirements to be defined as specialised workshops, following the definition yielded by Rosen (2010). If the exclusive character of the production has been discussed, the other factor – the intensity of the production – is, in the same way, satisfied. Only within site 980 – sq. B12, about 87 kg of raw material have been discarded. The total amount is of 154 kg once considered the entire scattering of artefacts collected on the surface. The proportion is impressive when considering, on one hand, the average weight of the cores (1,250 kg), and secondly, that large part of the site was not excavated.

Specialisation and intensity of the production characterise these workshops. However, it is important to highlight another factor emerged from this work: the specialised character of this particular production. Despite some differences between the workshops have been recorded, clues regarding the adoption the pressure technique have been identified in each context. The maintenance of core volume represented a crucial moment which was ruled out following rigid schemes. Only when their volumetric structure was no longer sustainable, the cores were abandoned. The mechanisation and standardisation of the processes of production of Canaanean blades is not a new fact and has been already highlighted by several scholars (Chabot and Pelegrin 2012; Manclossi et al. 2019).

Once delineated all the factors contributing to the definition of these contexts, we necessarily need to enlarge the discussion to the cultural meaning of this phenomenon within the archaeological background of the Near Eastern archaeology.

The adoption of metal tools involved in the production of such blades indicates that these sites belonged to the Late Chalcolithic and/or Early Bronze ages chrono-cultural horizons. No comparisons based on the length of such artefacts are possible due to the absence of full production blades and the fragmentary preservation of the artefacts. These comparisons are rarely possible given the wide transformations of such blades in their contexts of distribution and use (Anderson et al. 2004; Anderson and Chabot 2004; Chabot and Eid 2003; Inizan and Anderson 1994; Manclossi and Rosen 2015; Van Gijn 1988). In the whole Near Eastern panorama, only a few contexts yielded complete items, mostly related to caches within the settlements where the artefacts were stored for a delayed use (Caneva 1993; Futato 1996; Hartenberger et al. 2000; Rosen 1997).

Within the Jebel Zawa, the longest blade is a crest of about 17 cm, but some incomplete blades let us think that the longest was about 20-25 cm, which is more than the average length (10-15 cm) calculated for the Canaanean blades from Southern Levant (Rosen 2012), and comparable with the blades[10] (length 25-30 cm) coming from the Late Early Bronze age massive workshops of Titris Höyük (Hartenberger et al. 2000), located on the Middle Euphrates Region, and from Tell Arqa (Marchand 2014), in the Northern Levant.

A punctual reflection is made for the preparation of the platforms. Technological analyses conducted by Chabot and Pelegrin on several collections from 4th-3rd millennium Northern Mesopotamia sites (Hassek Höyük, Tell Gudeda, Tell Atij, Tell Kutan) highlighted relevant differences. The morphology of platforms was delineated by the preparation of a dihedral-pronounced (acute) central ridge at Hassek Höyük, Tell Gudeda and Tell Atij (Chabot 2002; Chabot and Pelegrin 2012; Pelegrin and Otte 1992), in the Middle Euphrates and Jezirah Regions. This preparation allowed to successfully exert the pressure with a metal point. At Tell Kutan, located in Western Mosul Dam Region, few dozens of kilometres away from the Jebel Zawa, the platform preparation was found to be convex-faceted or dihedral-convex (Anderson et al. 2004; Chabot and Pelegrin 2012). These modes are perfectly comparable with the evidence provided by the Jebel Zawa, indicating that at least two distinct technical traditions coexisted between the western and eastern regions of the Northern Mesopotamia, in contrast to a further view which supports a gradual “globalisation” of the phenomenon of the Canaanean blades through time (Angevin 2018).

Finally, the discovery of the Jebel Zawa confirmed the theories regarding the regionalisation of this phenomenon in the Northern Mesopotamia (Chabot and Pelegrin 2012; Nishiaki 2002; Rosen 2012), in contrast with an old assumption based on a single core area of innovation and irradiation, identified in the Mid-Upper Euphrates Region (Anderson et al. 2004; Chabot and Eid 2003; Eid 2004; Frahm 2004; Thomalsky 2017).

The geographical distribution of the blades from the Zawa workshops will be faced in the next chapters. Here, it is worth mentioning that lithic assemblages from the Mosul Dam Region indicate the presence of a Cananean blade component made out of a specific chert, of unknown origin, sharing the same characteristics with the Zawa raw material, at Tell

[10] Since no metric data are actually published, the lenght has been calculated from the plate reported in Hartenberger et al. 2000, p.1.

Kutan (Inizan et al. 2004), Tell Karrana (Brautlecht 1993), Tepe Gawra (Tobler 1950), and several minor settlements distributed along the Dam and now submerged (Thomalski 2019).

4. The Canaanean blades from the north-western Iraqi Kurdistan

1. Introduction

The chapter aims to present and discuss the Canaanean blade assemblages provided by the sites identified within the LoNAP area. The artefacts have been selected among the surface lithic inventories collected during 2012-2018 surveys. Despite the nature of the available dataset do not allow going deep into specific issues, field-data coming from the intensively surveyed settlements (i.e. pottery chronology, site position, size, and type of occupation) have been used to preliminarily assess their distribution in the territory and build research-questions to be addressed in the next chapters, and through future investigations.

The results allow tracing a first outline for the area – although susceptible of changes as soon as excavation data will be available – providing information that contribute to focus on the problem of their regional distribution in relation to the chert mining phenomenon and the lithic workshops identified within the Jebel Zawa.

Nevertheless, it is considered premature to build a precise distribution model for these objects from their geographical sources to the sites of acquisition, consumption and discard. The discussion about the Canaanean blades evidence is functional here to introduce and justify the analyses faced up in the following chapters (chapters 6-7), where their relationship with the chert source of the Jebel Zawa will be the focus of the investigation.

2. The territory and the LC/EBA occupation

The territory comprised within the LoNAP area, due to its geomorphology, offers ideal environmental conditions for settling; the occurrence of water sources, land for cultivation, sources of raw materials (i.e. wood, stones, clay) and mountains for transhumance, must have represented attractive factors for human occupation (Conati Barbaro et al. 2019). The region is crossed by wadis and significant permanent watercourses flowing westwards. In the specific, favourable conditions for carrying out agricultural practises are reported for the region between the Ba'dreh and Bardarash villages – namely the Navkur Plain – which is crossed by a dense network of permanent watercourses (e.g. Al-Khazir and Gomel rivers, and their tributaries) whose rate of flow greatly increases during the wet season (Morandi Bonacossi 2016).

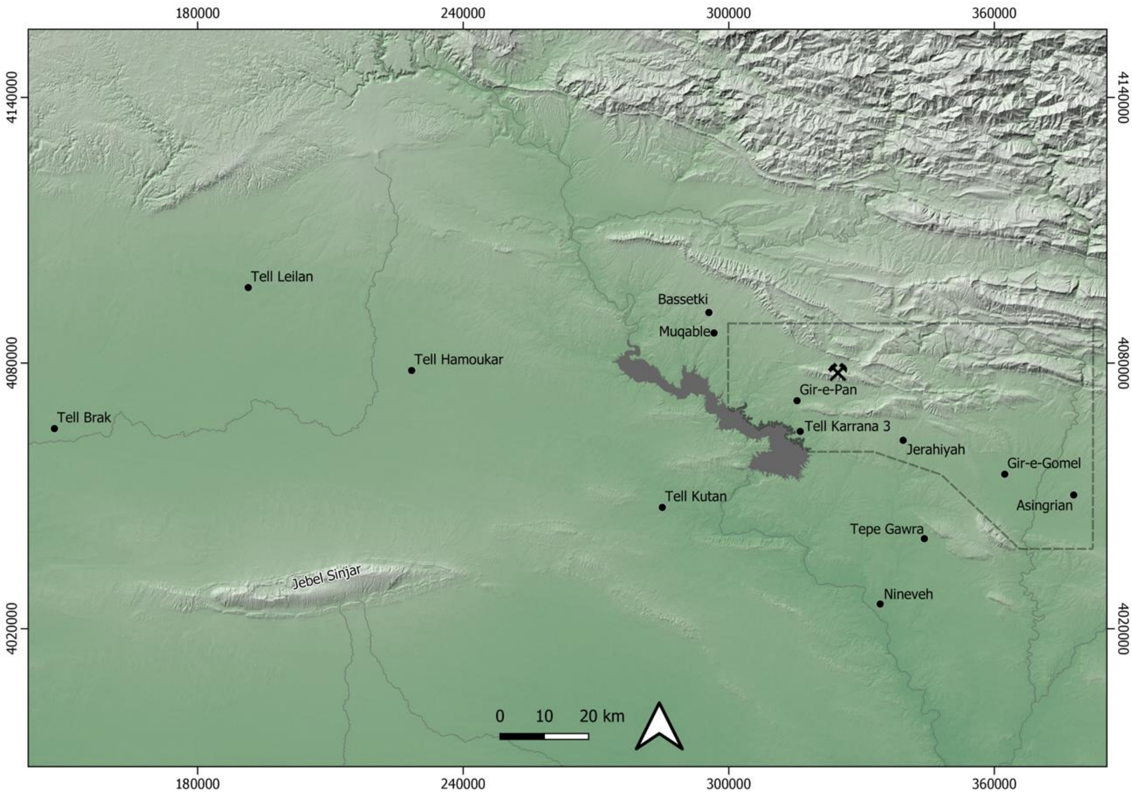


Fig. 1 Map of the North-eastern Mesopotamia and the sites quoted in the text. The extension of the LoNAP area is also reported, together with the sites of interest.

Apart from the documentation provided by the sites of Tepe Gawra (Speiser 1935; Tobler 1950; Rothman 2002) and Kuyunjik (Campbell Thompson and Mallowan 1933; Gut 1995), the well-known Assyrian Nineveh, both located few kilometres south in the Ninawa Governorate (Fig. 1), the 5th to 3rd millennia BC settlement in the region east of the Tigris was unknown until 2012. During the ‘80s, the Mosul Dam Salvatage Operation (Killick and Black 1985) carried out surveys and excavations along the course of Tigris River, renewing the interest for the area and identifying several sites (Simi and Sconzo 2020) which confirmed the presence of local and original developments in the trajectories of urbanisation within the Northern Mesopotamia (Iamoni 2014). The Late Chalcolithic (LC) and Early Bronze age (EBA) site of Tell Karrana 3 (Fig. 1) is an example of the documentation produced by this rescue archaeological research (Wilhelm and Zaccagnini 1993). The projects developed in the neighbouring Jezirah and Sinjar areas demonstrated that during the LC the processes leading to the formation of urban landscapes were active and gave rise to large settlements with hierarchised patterns of small settlements around them (Fig. 1), such as Tell Brak (130 ha) and Hamoukar (300 ha) (Wilkinson and Tucker 1995; Oates et al. 2007; Al Quntar et al. 2012).

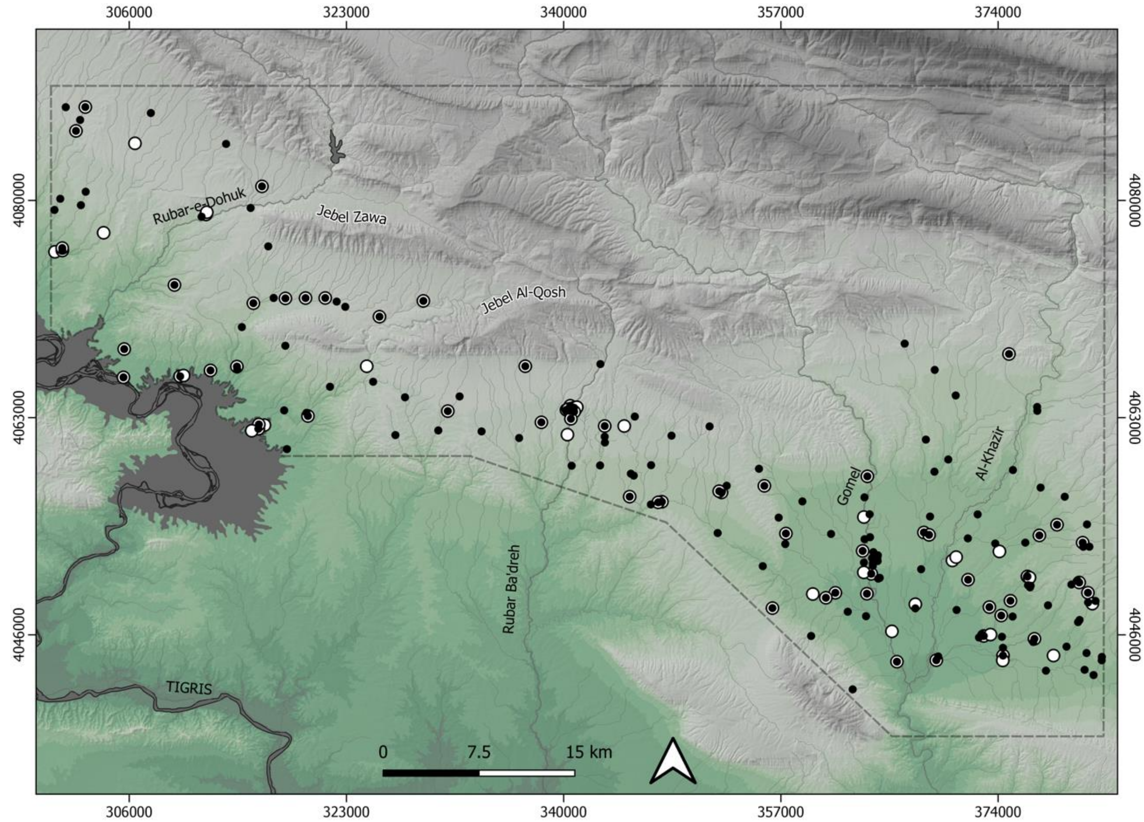


Fig. 2 LoNAP sites dating to the Late Chalcolithic and Early Bronze age periods. The black dots are related to LC sites, while the white ones indicate EBA occupation. Dots superimposition indicates continuity in site occupation from the former to the later period.

Field-research carried out in the LoNAP area, from 2012 to 2018, demonstrated that the number of sites quickly grew at the end of the Pottery Neolithic and the beginning of the Early Chalcolithic (end of the 7th and 6th millennium BC), to became homogeneously distributed over the territory during the LC period (5th – 4th millennia BC) (Conati Barbaro et al. 2019; Morandi Bonacossi and Iamoni 2015). The evidence has been interpreted as a reflection of a demographic growth, widely attested and documented during this period in the northwestern Mesopotamian regions (Conati Barbaro et al. 2019).

The research also showed that the highest number of LC sites are localised in the Navkur Plain (Conati Barbaro et al. 2019) (Fig. 2). However, survey data and pottery assemblages composing the surface collections from the sites indicate that the whole area was only marginally involved in the processes of urbanisation which took place in the Mid-Upper Euphrates and Jezirah regions. Indeed, the sites are comprised in the range between less than a hectare and 4-5 ha. None of these sites, belong to the class of the "giant" tells which are known from the adjacent

Iraqi and Syrian Jezirah and were entirely inhabited during the periods here considered (Morandi Bonacossi 2016).

In addition, pottery analyses from the sites support the assumption of very limited contacts with the Uruk World and point out through the presence of regional developments in pottery traditions (Conati Barbaro et al. 2019), emphasized during the stages 3-5 of the LC (2^{nd} half of the 4^{th} millennium BC), indicating that the Tigris River might have represented a sort of natural border for the population living in the area (Gavagnin et al. 2016).

The subsequent Early Bronze age period (Fig. 2) is characterised – at broader scale – by the development of the Ninevite 5 culture (1^{st} half of the 3^{rd} millennium BC) that represents a phase of widespread reduction in regional occupation (Rova 2013). The urban development of the sites resumed towards the second half of the 3^{rd} millennium BC when contacts with the southern Mesopotamian elites were established in the Syrian area (Rova 2013).

The Ninevite 5 settlement in the LoNAP area is marked by a drastic decrease in the number of settled sites as compared to the LC 3-5, and a parallel reduction in the aggregate surface area occupied (Conati Barbaro et al. 2019). Unlike the strong processes of landscape urbanisation that took place in the adjoining regions of Upper Mesopotamia, the Tigris region has recorded the emergence of a ruralised landscape distinguished by a pervasive and dense system of small- and mid-sized rural sites. As mentioned above, the vicinity of the area to Nineveh might have been responsible for the lack of competing urban centres in the region, and might instead have promoted the development of a weakly hierarchical network of agricultural villages and small towns as an incentive of its economic growth (Morandi Bonacossi and Iamoni 2015).

3. Sites selected

A total of 24 sites have been selected for having provided evidence of Canaanean blades within their material culture assemblages (Tab. 1). These sites can be divided according to their location into four clusters (Fig. 3) from north-west to south-east: the Dohuk Plain (sites 941, 108), the Mosul Dam area (sites 776, 1085, 121, 122), the Sharya valley (sites 821, 48, 49), the Ba'dreh area (sites 43, 697, 698, 151, 888) and the Navkur Plain (sites 29, 87, 89, 185, 285, 329, 341, 356, 739).

All the sites are multi-layered settlements with superimposed building phases often spanning from pre-Halaf cultural horizons until the Islamic period. However, it is interesting to note, according to the picture traced by Morandi Bonacossi and Iamoni (2015), that most of the considered sites are not new foundations dating to the LC period (Fig. 4).

site	chronology	ha tot.	area	n. of artefacts
29	LC/EBA	14	Navkur Plain	2
43	LC/EBA	2,9	Ba'dreh Plain	4
48	LC/EBA	0,73	Sharya Plain	35
49	LC/EBA	3,7	Sharya Plain	4
87	LC/EBA	3,3	Navkur Plain	2
89	LC	7,11	Navkur Plain	1
108	LC	6,17	Dohuk Plain	3
121	LC	1,54	Mosul Dam	1
122	LC	0,58	Mosul Dam	1
151	LC	7,66	Ba'dreh Plain	1
185	LC/EBA	4,31	Navkur Plain	1
285	LC/EBA	7,5	Navkur Plain	3
329	LC	2,81	Navkur Plain	1
341	LC/EBA	1,15	Navkur Plain	1
356	LC/EBA	12,71	Navkur Plain	1
697	LC/EBA	0,9	Ba'dreh Plain	5
698	EBA	0,94	Ba'dreh Plain	1
724	LC	2,64	Ba'dreh Plain	5
739	EBA	2,76	Navkur Plain	2
776	LC/EBA	1,79	Mosul Dam	16
821	LC/EBA	1,5	Sharya Plain	21
888	LC/EBA	1,83	Ba'dreh Plain	6
941	LC/EBA	6,7	Dohuk Plain	3
1085	LC/EBA	1,24	Mosul Dam	54

Tab. 1 Sites considered in this work, according to their total extension, location, pottery chronology and number of Canaanean blades analysed.

A large part of them exhibits an ancient occupation dating back to the Pottery Neolithic and have been also repeatedly occupied until recent periods (Fig. 4, a), even if none of them grew as a large centre (Fig. 4, b).

Fig. 3 Overview of the landscapes characterising the different areas. View from the top of the Jebel Zawa of the Sharya valley and the Wadi Bandawai overpassing the Jebel Al-Qosh on the left and the Chya-i-Dekan on the right (a), panoramic view along the vector Sharya-Faideh-Tigris River as seen from the top of the Jebel Zawa (b), view of site 776 located in the border of the Mosul Lake (c), view of the Dohuk Plain landscape from site 941 (d), view of the Ba'dreh Plain with the Jebel Al-Qosh in the background (e); view of the Gomel River at the height of Gir-e-Gomel with the Jebel Maqlub in the background (f).

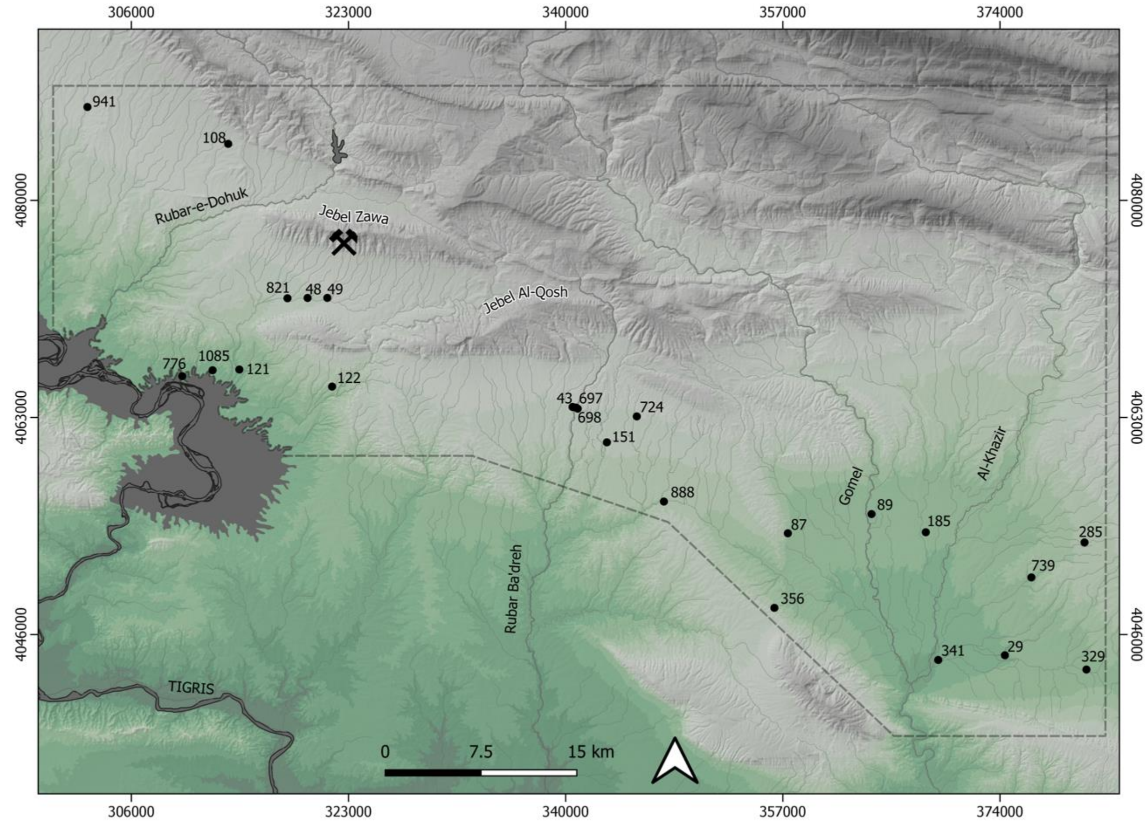
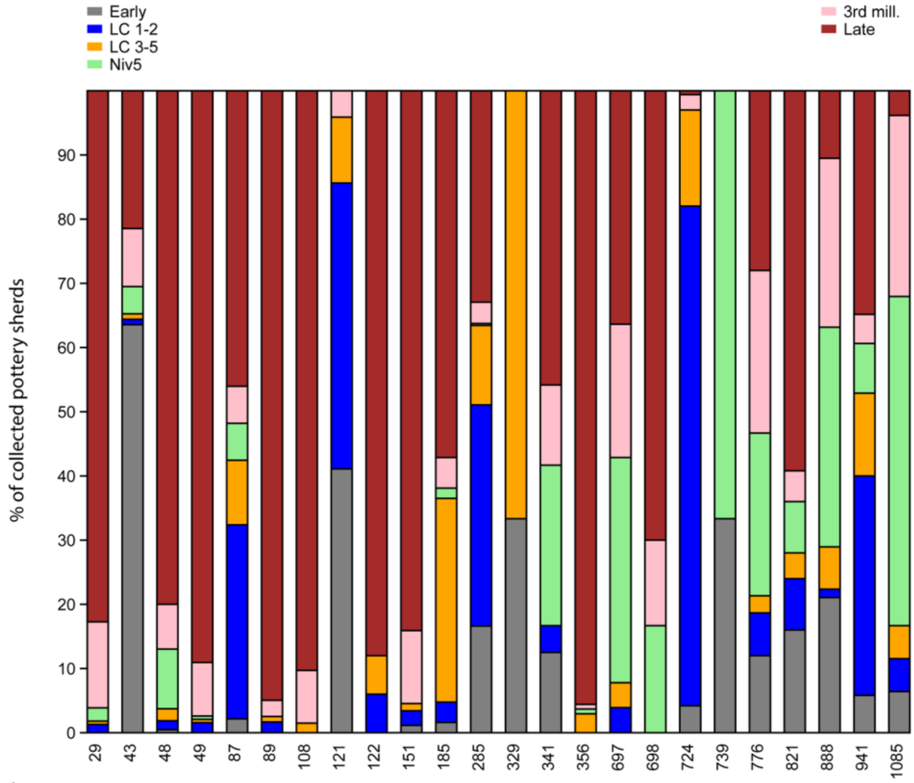


Fig. 4 Location of the studied sites within the LoNAP area. The position of the Jebel Zawa chert mines is reported.

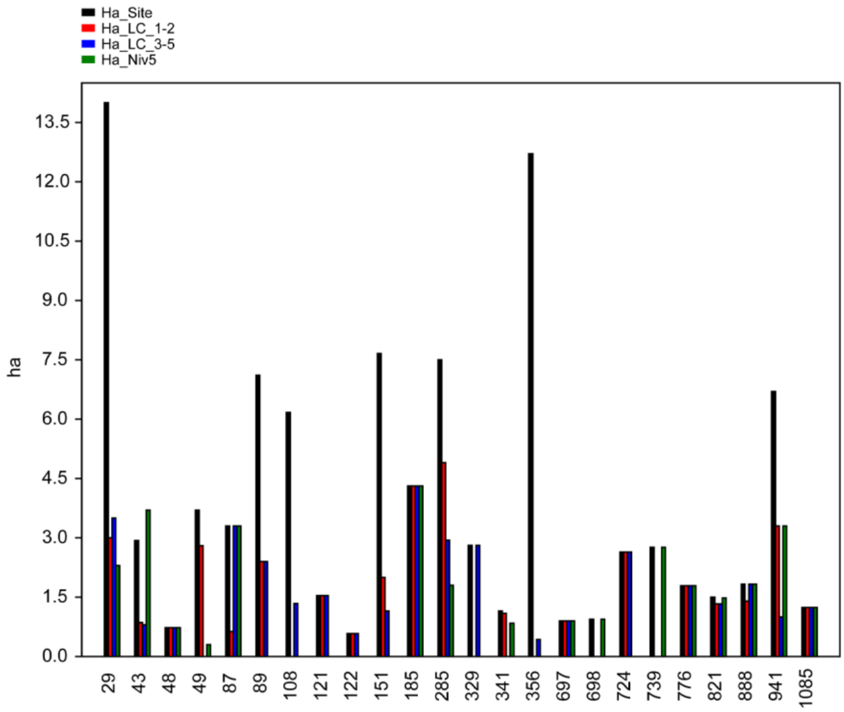
Only two sites (29, 356) exceed the 10 ha in size and are respectively located in the Ba'dreh and Navkur areas, even if the occupied areas during the periods here considered are very reduced. The rest of the sites show great variability, featuring mean extensions of about 1.5 ha, and depicting a picture where occupations of less than 1 ha coexisted with small settlements of about 3-4 ha. These features permit to define the sample of sites here considered as small rural settlements. Their position in association with alluvial, humid zones and fluvial terraces is indicative of a primary economy based on the availability of water to carry out agricultural practices. The LC period is attested in all the sites but one. The occupation in many cases extends into the following Ninevite 5 period. However, 7 among the sites do not show continuity with the EBA. The selected of sites, thus, reflect the patterns of occupation observed for the whole inventory of discovered sites in the area.

4. The lithic materials

The analysis of the pottery distribution allowed to identify the different phases of occupation and their expected location within the sites, and to reconstruct the single histories of settlement



a)



b)

Fig. 5 General information about the LoNAP sites. Number of collected pottery sheds according to the different periods, expressed in percentual: early (prehistoric), Late Chalcolithic 1-2, Late Chalcolithic 3-5, Ninevite 5, generic 3rd mill. BC, late (from the Middle Bronze age onwards) BC (a); sites total extension in hectares, compared with the size of the pottery scattering according to the periods under investigation (b).

evolution through time. The lithic materials have been thus selected to be studied only if associated with a consistent amount of diagnostic pottery sherds within the collection areas.

As table 2 shows, the number of samples per site is quite variable for several reasons. First, it should be considered that prehistoric and protohistoric occupations may suffer lower visibility than later ones within tell sites, due to the superimposition of the structures through time (Morandi Bonacossi and Iamoni 2015). This is particularly evident in the case of site 48 which was no longer systematically occupied after the 3rd millennium BC and thus restituted a significant amount of lithic materials. Conversely, sites 29 and 356 – the largest among the sample – respectively supplied only 1 item each one.

Few different situations have been encountered at sites 776 and 1085. The settlements are located on the current shore of the Mosul Lake and are periodically affected by erosion due to water lever oscillations. In such an environment, the visibility is enhanced by water washing action and erosion. In the specific, site 1085 is a Ninevite 5 settlement with an earlier LC phase of occupation which has been identified thanks to the low stand of the Mosul Lake waters during summer 2018. Here, the large amount of Canaanean blades have been collected *in situ* (Conati Barbaro *pers. comm.*).

A total of 174 artefacts have been analysed. In table 2, all the Canaanean blades studied have been reported according to their collection sites. In addition, technical elements (e.g. crested blades, surface maintenance blades, core rejuvenation flakes) connected with their production stages have been also reported when available within the lithic collections. However, they are very rare and attested in only 2 sites (48, 739).

Large blade cores are completely absent, and this would not constitute an element of surprise. However, their presence within the sites cannot be a priori excluded. Almost all the samples are represented by blade fragments on which further clues regarding their use-life can be observed. In fact, blade segments exhibiting macroscopic gloss (Inizan and Anderson 1994; Anderson et al. 2004) on one or both the edges are the most represented category, along with segments showing different types of edge retouch, independently from the presence of glossed edges. In addition, on some particularly well-preserved artefacts, it was possible to observe residues of bitumen used as glue, indicating that some of these objects were hafted in composite tools.

The proximal fragments are scarsely represented and concentrated in specific sites. The mesial fragments, indeed, constitute the largest part of the evidence. Distal fragments are little represented and might have suffered recognition problems by the surveyors.

site	technical items	proximal fragments	mesial fragments	distal fragments	glossed segments	retouched segments	total
29		1	1				2
43			2		1	1	4
48	12	9	7	3	2	2	35
49		1	3				4
87						1	1
89			1				1
108					2	1	3
121					1		1
122			1				1
151			1				1
185					1		1
285			1		2		3
329					1		1
341						1	1
356					1		1
697			3		2		5
698						1	1
724					3	2	5
739	1					1	2
776			3	1	4	8	16
821		4	8	2	4	3	21
888		1	3		2		6
941		1	2				3
1085		6		2	27	19	54
			total				172

Tab. 2 Artefacts categories represented within the analysed sample, according to their collection sites.

Differently from the Jebel Zawa workshops, where full production blades are absent, the evidence provided by settlements reveals that targeted blades circulated within the settlements and were processed in several ways by their owners.

4.1. Mosul dam

The area located along the shore of the artificial Mosul Lake (also known as Mosul Dam)

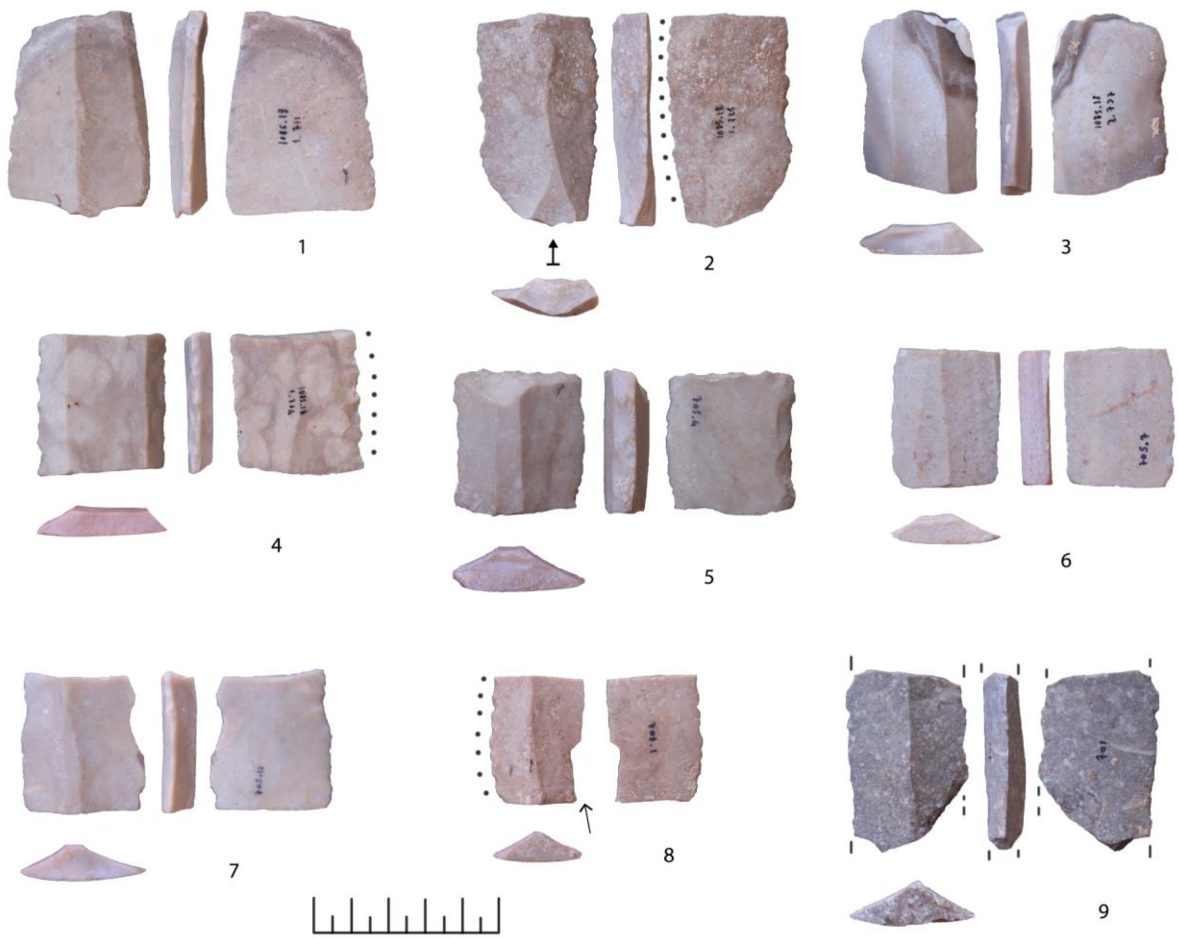


Fig. 6 Canaanean blades from the Mosul Dam area. The items n. 1-4 are from site 1085, n. 5-7 from site 776, n. 8 from site 122, n. 9 from site 121. Mesial fragments (1, 6, 7, 9), glossed segments (2, 4), retouched segment (5), glossed segment and burin spall removal on the opposite edge (8).

is characterised by the high terraces of Tigris River, cut by modern wadis. The sites are positioned along small peninsulae that nowadays constitute the only non-submerged portions of the territory. Site 1085 and 776 restitued a large part of the evidence. The occupation of both the sites is dated to the LC/EBA.

The artefacts from the two contexts are comparable both for the represented chert raw materials at macroscopic scale (e.g. greyish shades, shaded, mottled and banded types), and the size of the blades (Fig. 6). Glossed segments are present, and the occurrence of retouch associated with glossed edges has been also observed.

Moreover, the proximal fragments from site 1085 allow a strict comparison with the blade-knapping workshops of the Jebel Zawa for the morphology of the butts, which are dihedral-faceted or convex-faceted. Few items show also the occurrence of dihedral-acute butts.

Site 121 is very small (1,54 ha) and located in the nearby of the well-known site of Tell Karrana 3 and features a LC occupation. Only one blade mesial fragment with trapezoidal section and convergent previous removals is attested (Fig. 6, n. 8). On the left edge, a heavy gloss is visible, opposed to a non-retouched edge from which a burin spall has been removed.
Site 122 is an LC site located more inland but connected with the Lake through a wadi. As for the previous site, the record is limited to 1 artifact which is a blade mesial fragment of a dark grey coloured chert, showing a large trapezoidal section (Fig. 6, n. 9).

4.2. Navkur Plain

The Navkur Plain represents the northernmost fertile Mesoptamian plain showing a settlement pattern related to favourable environmental conditions (Simi 2020). It is characterised by high productive soils, allowing both extensive and intensive cultivations of cereals, enhanced also by groundwaters flowing, springs, and a high rainfall rate which contribute to the availability of water (Morandi Bonacossi et al. 2018).
The area is worthy of interest for the dense number of settlements observed around a key site, namely Gir-e-Gomel, which became the largest centre of the whole region during the mid-late 3rd millennium BC and the subsequent Middle Bronze age, reaching a total of 35 ha considering both the extensions of the Upper and Lower Towns (Morandi Bonacossi et al. 2018). The emergence of a dense rural landscape, with small-sized villages scattered throughout the plain, occurred only in concomitance of the maximum extension of the site (Simi 2020).
The first strong development of the settlements in the Gomel area took place in the LC with also a distinctive grow of the total settled area within Gir-e-Gomel (Simi 2020). The step trench excavation at the site (Operation 3), carried out in the western area of the lower mound, provided elements to place the earliest occupation of Gir-e-Gomel at the end of the 5th- 4th millennia BC (LC 1-2 and 3-5 phases) when the area was equipped with a pottery workshop. The presence of such facilities is a common feature in the Upper Mesopotamian LC sites, used to explain the growing social complexity and the emergence of specialised labour during the period (Morandi Bonacossi et al. 2018).
The sites here considered can be contextualised within such a framework. As an example, the evidence provided by site 285 (also known as Asingrian), a small settlement of about 7.5 ha, is representative of complex extra-regional relationships that occurred with the neighbouring regions, and the long-distance connections with the southern Mesopotamia.

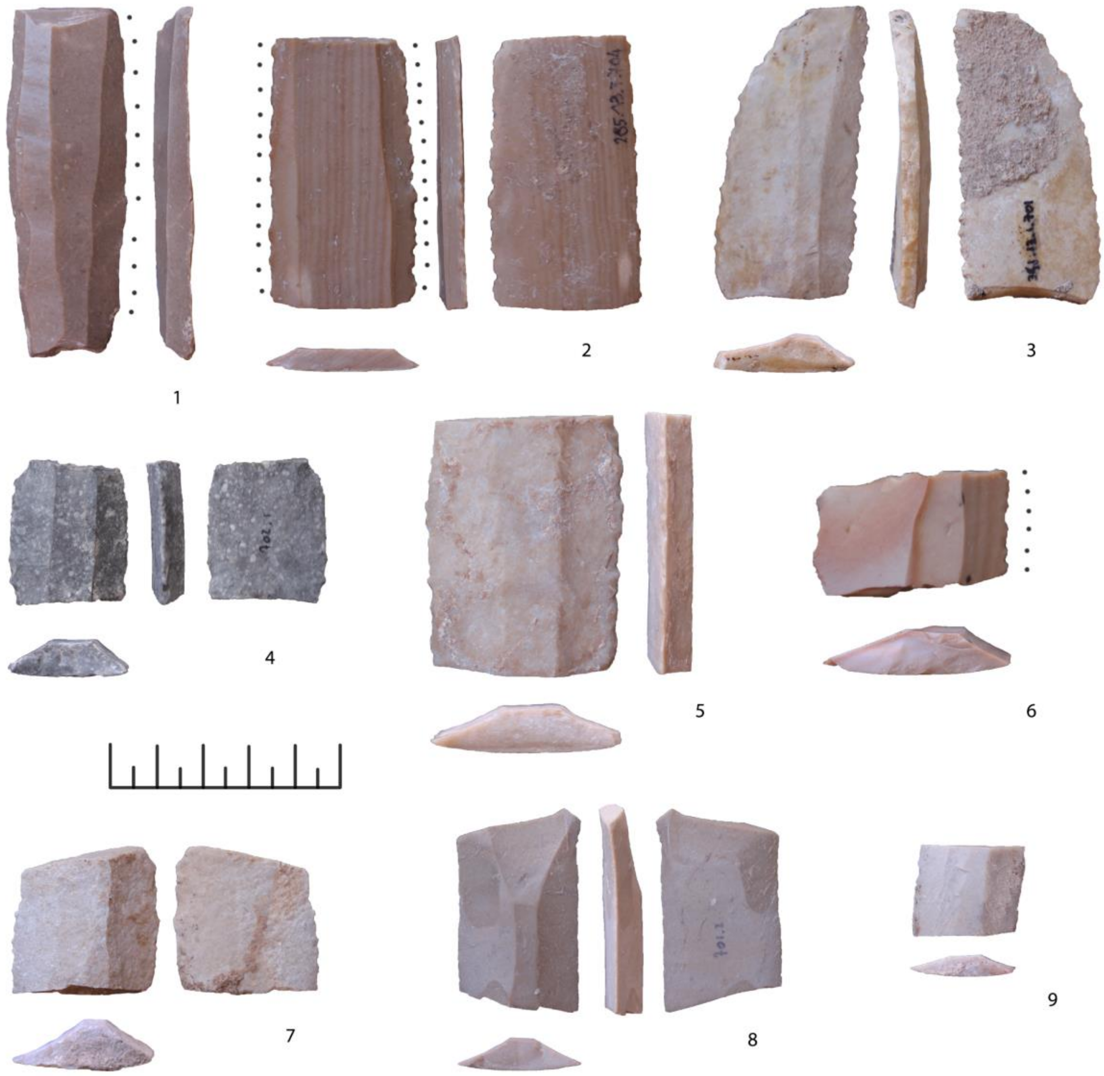


Fig. 7 Canaanean blades from the Navkur Plain. The items n. 1-2 are from site 285, n. 3 from site 341, n. 4 from site 356, n. 5 from site 379, n. 6 from site 185, n. 7 from site 89, n. 8 from site 87, n. 9 from site 29. Glossed segments (1-2, 6); retouched segments (3, 5); mesial fragments (4, 7-9).

The presence of pottery of Uruk style at the site within the surface collections represents an absolute rarity in the area. The two items of Canaanean blades from the site here presented[1] (Fig. 7, n.1-2), if compared with the Mosul Dam blade collections, introduce some elements of diversity for what regards the chert raw material used (laminated and spotted types; brownish and reddish shades).

[1] The site of Asingrian has been the subject of excavations during the 2019 field-campaign by M. Iamoni of the Udine University. Thus, soon it will be possible to analyse the huge collections of lithic artefacts from the site (M. Iamoni *pers. comm.*) as well as the lithic materials unhearthed at Gir-e-Gomel during the 2017 campaign.

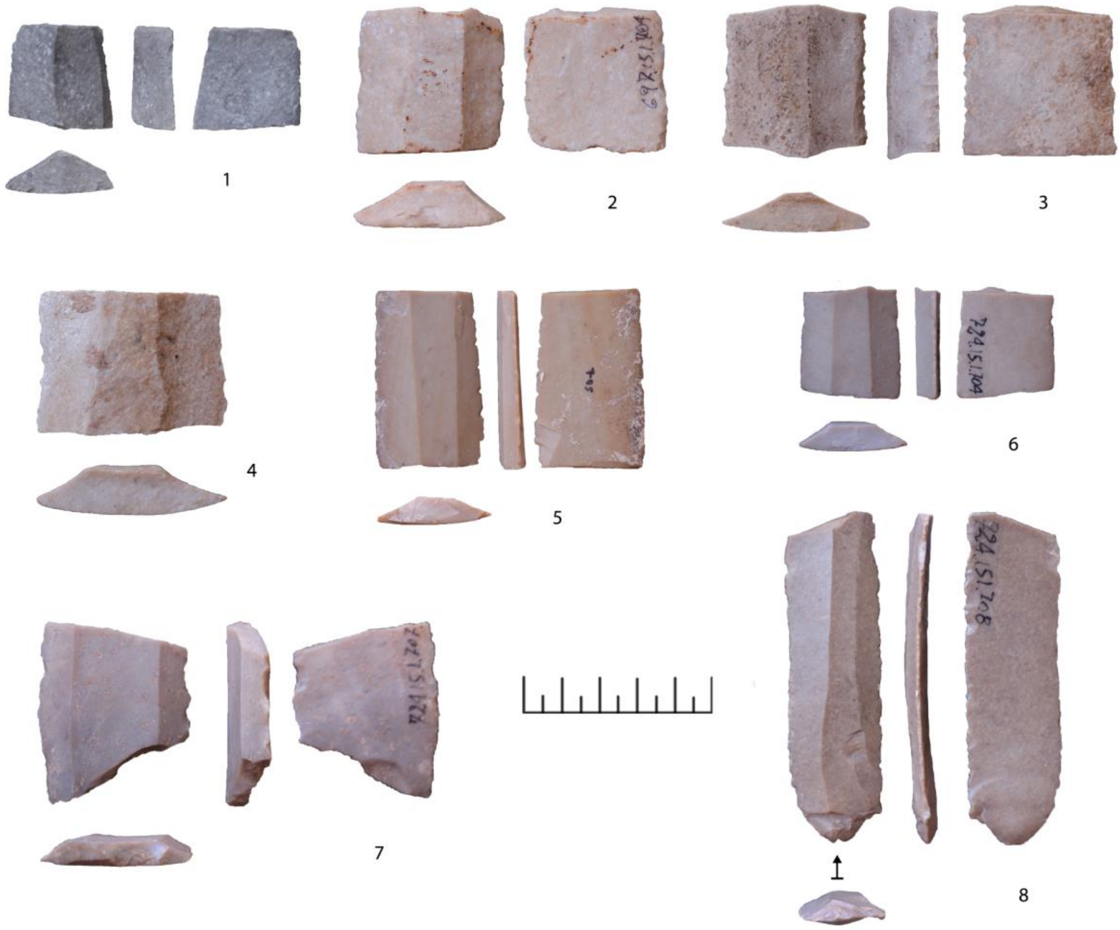


Fig. 8 Canaanean blades from the Ba'dreh Plain. The item n. 1 is from site 151, n. 2 from site 697, n. 3 from site 43, n. 4 from site 698, n. 5 from site 888, n. 6-8 from site 724. Mesial fragments (1-2, 4, 6), retouched segments (3, 5, 7), proximal fragment (8).

Chert raw material variabilility can also be observed at site 185 (Fig. 7, n. 6) and site 87 (Fig. 5, n. 8). Conversely, chert raw materials attested in the Mosul Dam area are present at site 341 (Fig. 5, n. 3), site 379 (Fig. 5, n. 5), site 89 (Fig. 5, n. 7) and site 29 (Fig. 5, n. 9).

4.3. Ba'Dreh Plain

The Ba'dreh Plain is the area extending at the foothills of the Jebel Al-Qosh and forms the northern part of the Great Nineveh Plains, historically known for being the place of the large artificial canals built by the Assyrian kings and devoted to the transport of water from the Zagros foothills to their capital Nineveh (Morandi Bonacossi 2018).

Unfortunately, the Canaanean blades record is limited to few artefacts, due to strong continuity in the occupation of the sites through time. In addition, the site of Jerahiyah, which is the main site of the area, did not provide Canaanean blades evidence, but only a small concentration of undatable lithic materials located in the Lower Town area.

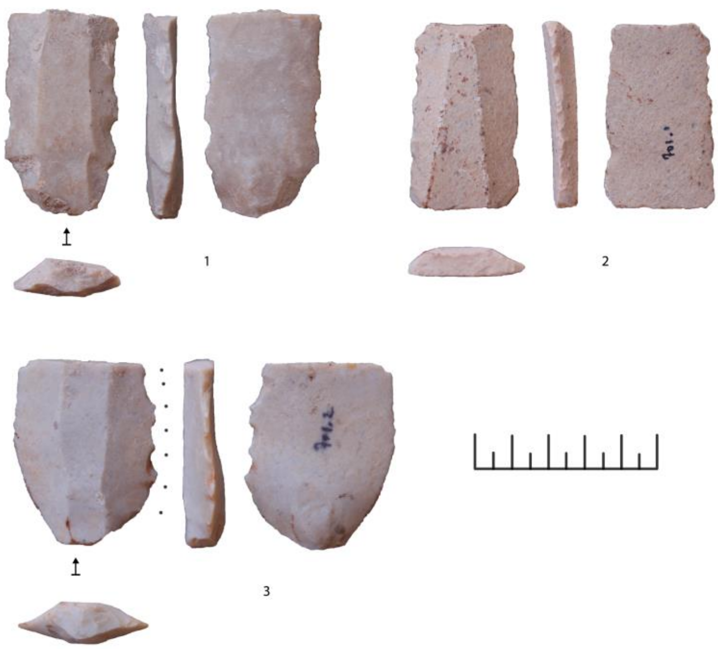


Fig. 9 Canaanean blades from the Dohuk Plain. The item n. 1 is from site 739, n. 2-3 from site 108. Retouched segments (1-2); Glossed segment (3).

The sites are positioned along the course of the Rubar Ba'dreh and form a dense cluster, among which Jerahiyah is the largest one (8.5 ha in size) (Morandi Bonacossi and Iamoni 2015).
As observed in the Navkur Plain, of which the area represents a direct geomorphological prosecution, the analysis of the Canaanean blades revealed that a similar duality between a recurrent type of chert raw material of greyish shades and different others is here also recorded. An element of divergence is attested for the types represented (e.g. homogeneous varieties), which differ from the former area (Fig. 8, n. 5-6, 8).
It is worth to mention that site 724, restituted also a blade proximal fragment of smaller size if compared to the others. From a technological point of view, the blade also differs for the morphology of the butt, which is flat and punctiform (Fig. 8, n. 8).

4.4. Dohuk Plain

The Dohuk Plain extends into the valley characterised by the presence of the homonymous city and the territory comprised between the course of the Tigris River and the mountains that separate the plain from the city of Zako.

Contrary to what the LoNAP evidence may suggest (Fig. 2), the area is not marginally involved in the processes evidenced in the previous paragraphs. The investigations carried out in the neighbouring area by the EHAS Project (Eastern Habur Archaeological Survey), led by the Tübingen University, evidenced complex socio-cultural dynamics dating between the LC and EBA periods. The excavations carried out at Muqable[2] (Fig. 1), revealed that the site was mainly occupied during the late 5th and 4th millennia BC (Pfälzner and Qasim 2017a; Pfälzner et al. 2017). However, during the EBA, the settlement seems to lose its importance in favour of a new emerging site of about 50 ha – namely Bassetki – which was structured with a city wall during the Late Ninevite 5 period (2800-2650 BC) (Pfälzner and Qasim 2017b; Pfälzner et al. 2018).
The sites here considered (sites n. 941 and 108) can be connected to these dynamics. Site 108 is an LC settlement (about 1.5 ha in size), while site 941 (about 3.5 ha) exhibits continuity from the previous period to the EBA. The Canaanean blades here recorded, despite being very few pieces, highlight similarities from a macroscopic point of view with the chert varieties of the Mosul Dam. In addition, the proximal fragments reported (Fig. 9) are very well comparable with the technology employed at the Jebel Zawa blade-knapping workshops (e.g. convex-faceted butt preparations).

4.5. Sharya valley

The Sharya valley represents the flat area located at the southern foothills of the Jebel Zawa and gets the name from the homonymous village of Sharya[3] (Fig. 11). The piedmont area features detrital and residual soils and features no settlements apart from sporadic late presences and modern small house aggregates exploiting the groundwaters of the subsurface karst system. Conversely, the ancient settlements are located on the opposite side of the valley, aligned along the course of a small seasonal river which conveys the waters flowing from the Jebel and discharges them into the Tigris River.
Among the sites here considered, site 821 is a flat mound of 1.5 ha occupied during LC and the EBA. Site 48 is a small mound of about 0.73 ha and features the same patterns of occupation.

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[2] We refer to Muqable I-VI and III evidence. The whole area consists of a cluster of eight archaeological sites in close proximity to each other (Muqable I to VIII) and occupied from the Halaf period onwards. Muqable I is a small settlement of about 1 ha in size and togheter with Muqable VI might have been formed a unique settlement of medium dimensions. Muqable III is a new LC foundation site of 2.5 ha and attests the transition to the EBA. The site was also occupied during later periods (Pfälzner et al. 2017; Sconzo 2019).
[3] Sharya is also the name of the small yazidian settlement of "Sharya Khadim" (or Old Sharya) located at the entrance of the homonimous valley of the Jebel Zawa and built on the ruins of the ancient kurdish village.

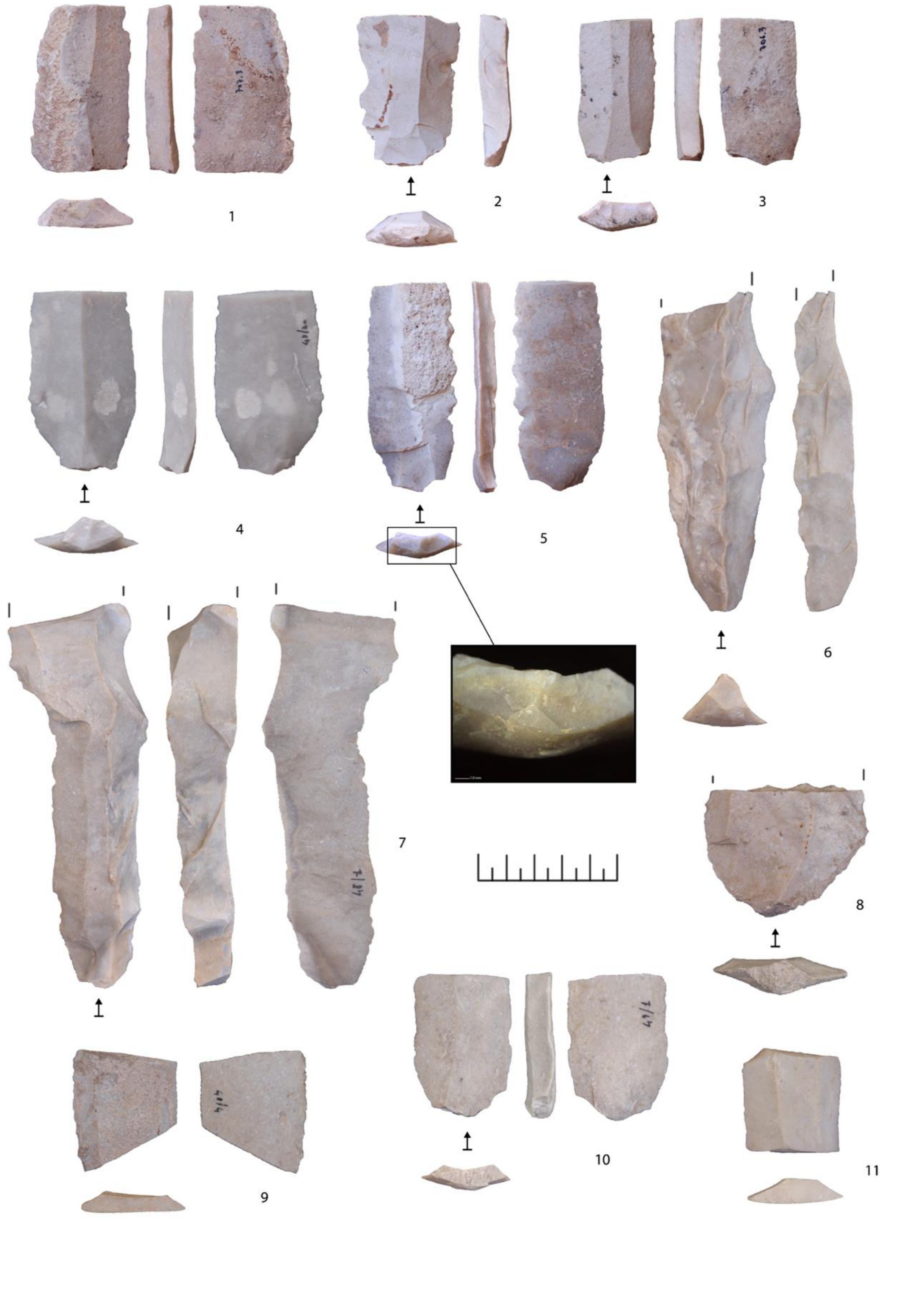


Fig. 10 Canaanean blades and technical items from the Sharya valley. The items n. 1-2 are from site 821, n. 3-9 from site 48, n. 10-11 from site 49. Proximal fragments (2, 4, 8, 10), proximal fragment bearing bitumen residues (3); proximal fragment and a detail of the butt showing a v-shaped crack in correspondence of the main ridge (5); crested blade proximal fragment (6); surface maintenance blade (7); mesial fragments (9-11).

Site 49 is placed alongside the previous settlement and it is slightly bigger, reaching a size of about 3 ha. These contexts assume importance once considering the assemblages they provided. From a raw material point of view, the cherts types represented very well comparable with the Jebel Zawa evidence, from a macroscopic point of view (Fig. 8). The comparison is strengthened from a technological view, for the reasons reported below.

Site 48 yielded back a good number of proximal fragments that allow the observation of the technical stigmas on the butts. As figure 10 shows, convex-faceted (Fig. 10, n. 3-4) and dihedral-acute butts are present (Fig. 10, n. 5). On this latter, a v-shaped crack located on the ridge is evident and constitutes a valid argument to claim the adoption of the pressure technique using a copper point, in relation with the extreme regularity of the blade. In addition, 1 item is a very large blade proximal fragment of 45 mm of width (Fig. 10, n. 9), supporting the hypothesis of being produced using the lever pressure system.

The present features have been also observed at sites 49 and 821. What differentiates the latter site is the presence of a large number of technical items (Fig. 10, n. 6-7) connected with the production of large blades and indicating that some stages of their knapping process were carried out on-site, implying a transport of the cores from the mines to the settlement. The evidence from the site indicates that not only such blades were produced within the settlement, but they were also used (see tab. 2).

5. Discussion

The 5th to 3rd millennia BC exploitation of Jebel Zawa chert outcrops emerged at the periphery of two socio-political entities: the territory of Ninive, which was the only one large centre of the northern Tigris macro-region, and the giant tell-sites of the Jezirah region, both raised during the Late Chalcolithic as urban centres in relation to a sudden demographic increase.

Within the LoNAP area, under the impulse of such developments, the number of sites increased at the end of the 5th millennium BC. However, none of the settlements reached relevant dimensions and economic supremacy over the regional territory. It is thus plausible that several small sites were well distributed on the territory, sharing an original and local material culture (Morandi Bonacossi and Iamoni 2015). Further details are provided by the excavations at Gir-e-Gomel, located in the Navkur Plain. These investigations highlighted that the area of the site was regularly settled since the LC and coexisted with several sites scattered through the plain (Morandi Bonacossi et al. 2018).

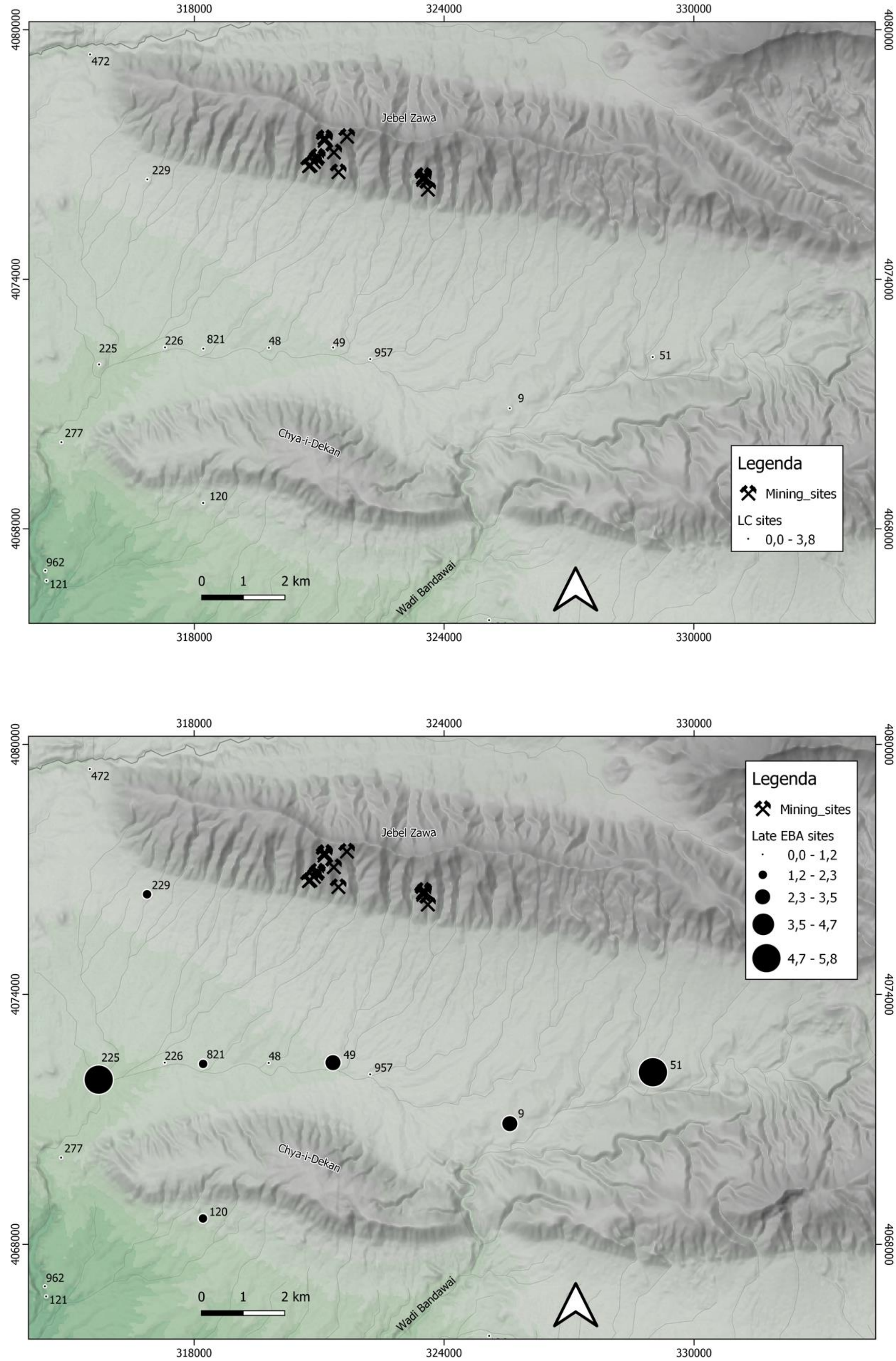


Fig. 11 The Sharya valley and the evolution of the size of the settlements through time. The LC settlements (upper) and late EBA settlements (bottom).

The Early Bronze age transition has been marked by a decrease in the number of sites and the ruralisation of the landscape (Conati Barbaro et al. 2019; Simi 2020). Most of the sites were abandoned, while others continued to be inhabited during the period and only a few sites were newly occupied. This trend has been observed for other known sites of the area, such as Tell Karrana 3 as well as the LoNAP sites along the course of the Tigris River, and the site of Muqable in the Dohuk Plain (Wilhelm and Zaccagini 1993; Pfäzner et al. 2018).
The integration of the Canaanean blades within the lithic toolkits started at the very beginnings of the LC period. They are distributed in most of the regional sites and their demand was not influenced by the socio-political changes that occurred at the end of the 4th millennium BC. Although the present documentation does not allow to understand what the effects of such changes at micro-scale have been, it is possible to assert that Canaanean blades are attested both in sites with an LC and EBA occupation. This coexistence can be considered a reliable indicator of their prolonged demand through time.
However, the continuity in site occupation, evidenced by the surface distribution of LC and EBA pottery sherds in settlements, prevented us to refine the chronology of these finds in several cases. Therefore, a larger chronological interval to which attribute the lithic evidence has been considered. These limitations do not allow identifying possible changes in their distribution and capturing technological developments through space (e.g. variations between sites or micro-areas) and time (phases or sub-phases of site occupation).
On the other hand, the analysis of the Jebel Zawa knapping-workshops revealed the homogeneous features of their productions both in the goals and in the technical background owned by the knappers, highlighting their specialised character (see chapter 3). This phenomenon seems to be reflected also most of the artefacts collected from the sites, where elements allowing the comparison have been identified.
From a technological point of view, the predominance of convex-faceted butts associated to regular trapezoidal modules constitutes an indication of the adoption of the pressure technique and element of comparison between sites where proximal blade fragments are available. At site 48, the employment of a copper tip has been noted on a single fragment in association with technical elements suggesting *in situ* knapping activities (Fig. 8).
By observing the settlement patterns within the Sharya valley (Fig. 11), it is possible to add further issues to the present discussion. The Canaanean blades assemblages collected at sites 48, 49 and 821 suggest that these sites were connected with the Jebel Zawa workshops. In the specific, site 48 indicates that blade-knapping activities were not limited in the nearby of the mining valleys but were also carried out in small settlements located in the adjacent valley

where these artefacts were also used and discarded. The continuity in the occupation of the contexts, from the LC to the EBA, led to the hypothesis that a more articulated system of mining areas, specialised lithic workshops and connected settlements might have existed and functioned over the long period, constituting an element of originality (Conati Barbaro and Moscone 2020).

Looking at the broader picture of the valley occupation, all the sites are very small settlements during the LC and some of them experienced a further contraction during the Ninevite 5 period. Conversely, at the late EBA two sites placed along the routes of access to valley grew up until 5 ha (Fig. 11); the site of Gir-e-Pan (site 225) might have controlled the south-western access to the valley along the vector Tigris-Faideh-Sharya, while site 9 could have been involved in similar dynamics along the other access – the Wadi Bandawai – which represents the south-eastern route towards north across the Jebel Al-Qosh and the Chya-i-Dekan.

What might have been the relationships between smaller and larger sites in the Sharya Valley during the Early Bronze age is not easy to speculate. The position and arrangement of the sites in relation to the mines suggest that a larger system could have existed over the long period. However, it is only possible to hypothesise such relationships, in the absence of in-depth investigations. In addition, it is possible to affirm that other sites of the region were involved in the productive processes – at least blades detachment from cores – such as a crested blade from site 739, located in the Navkur Plain, and some semi-cortical blades at site 1085 from the Mosul Dam area, might suggest.

In this view, the evidence provided by the archaeological researches carried out in the neighbouring areas can be considered. In the Great Zab Plain, which represents the direct continuation of the Navkur Plain towards the east, a context of production of large blades[4], S212, has been identified behind the plain in a raised position and close to the mountains. The lithic workshop seems to be linked to a settlement dating to the Ninevite 5 period. Unfortunately, only very little information is published from the moment.

The evidence from Tell Karrana (Brautlecht 1993) suggests that even in the Mosul Dam area, cores could have circulated together with finished blades and that their extractions could occasionally have been conducted on the settlements. This observation finds comparisons with Tepe Gawra, where during the phases IX (LC2, 4200-3850 BC) and VIII (LC3, 3850-3700 BC) some large blade cores were found (Tobler 1950).

[4] Thanks to Prof. Kolinski, director of the UGZAR (Upper Great Zab Archaeological Reconnaissance) Project of the University of Poznań (Poland), I had the possibility to inspect the collected materials, confirming similarities with the Jebel Zawa blade cores technological features.

Further south, Tell Kutan, dated to the Ninevite V period, offers detailed insights to understand the lithic raw material economy carried out at the site (Initan and Anderson et al. 1994). Flake production to obtain *ad-hoc* tools was carried out on small siliceous pebbles locally available in the secondary exposures of the Tigris River (cp. chapter 6), while the segments of Canaanean blades were all imported (Anderson et al. 1994). The type of raw material was found to be very similar to that used in Tell Karrana 3 (Anderson et al. 1994).

A different situation is attested at the site of Tell Leilan, located on the middle course of the Khabur River, where a well-known Early to Late Uruk sequence was excavated. Here the dichotomy between *ad-hoc* productions, made out on local pebbles, and Canaanean blades on imported chert types is also recorded. These latter would seem to be more similar, as types, to those represented in the settlements of the middle course of the Euphrates River (Van Gijn 1988, Chabot and Pelegrin 2012).

To conclude the discussion, the imperative will be answering the following questions in the chapters 6-7: is it possible to distinguish a local lithotype within the archaeological record that correlates with the chert evidence of the Jebel Zawa? How this cchert type was distributed within the LoNAP territory? What are the markers that allow the distinction between the local type and non-locally available types imported from extra-regional sources?

5. Tell Helawa

1. MAIPE expedition

The MAIPE (Italian Archaeological Expedition in the Erbil Plain) Project, headed by the University of Milan, started in 2013 to investigate a small area of c. 25 km^2 in the south-western part of the Erbil Plain (Erbil Governorate, Kurdistan Region of Iraq), where two main settlements, namely Helawa and Aliawa are located with a distance of 2.5 km from each other (Fig. 1). They correspond to sites n. 272 (Helawa) and n. 246 (Aliawa) identified by the EPAS Project (Erbil Plain Archaeological Survey) run by the Harvard University. The area investigated by MAIPE is bordered to the south by the Awena Dagh hills stretching from north-west to south-east, which mark the separation from the Makhmour Plain (Fig. 1). Helawa site is located on the course of a secondary branch of the Chai Kurdara river course, one of the southern tributaries of the Upper Zab, which forms the Erbil drainage system (Fig. 1).

2. The site

Helawa is located on the right bank of a nowadays seasonal stream, flowing from the Awena Dagh hills towards the main southern branch of the Chai Kurdara, that curves around the southern and south-western slope of the mound (Fig. 2).

The multi-period settlement has an irregular ellipsoidal shape that includes a higher mound, reaching a maximum elevation of 22 m above the surrounding plain (332 m asl), with a steep slope to the south and south-west, and two gently sloping extensions to the north and east (minimum altitude 310 m asl) (Peyronel et al. 2019). The maximum extension of the area is c. 10 ha and the high mound covers c. 2 ha.

The morphology of the site (Fig. 2) suggests that the conical high mound was formed by the progressive superimposition of structural levels from the earliest occupation onwards (Vacca et al. 2020). The top of the site is almost flat, and traces of a modern ditch are visible at the southern and south-western edges and connected to a ramp on the south-eastern mound. The southern and south-western sides, which are bordered by the watercourse, are characterised by a steep slope in the upper and middle parts, becoming gentler towards the bottom. The northern side, on the other hand, slopes gradually toward the modern road running east to west. A small secondary mound of about 90 m wide, which rises to c. 7.5 m above the surrounding plain is situated in the south-eastern part of the site (Peyronel et al. 2019).

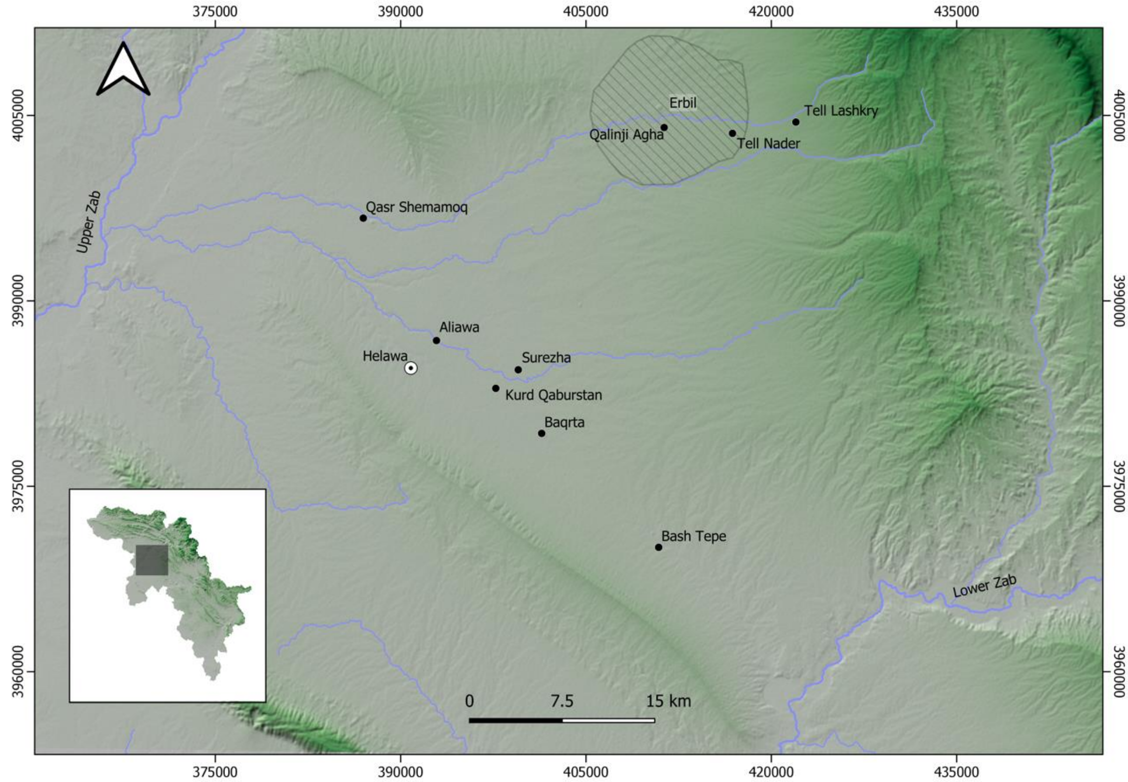


Fig. 1 Map of the Erbil Plain showing the location of the site and main settlements known.

However, the steepness of the southern side of the mound was the result of human building activity (e.g. terracing, levelling, and filling) and natural processes of erosion. Five steps corresponding to changes in elevation have been identified on the south and west slopes (Vacca et al. 2020). It has been suggested that erosion was higher at the third major step, which cuts the mound profile abruptly, and that the steeper southern slope might be due to heavy erosion and possibly to landslides that had already begun in antiquity, as also indicated by the substantial building and terracing activities during the LC 1-2 singled out in step Trench B (Peyronel et al. 2019; Vacca et al. 2020). The site's rapid growth, during the second half of the 5th millennium BC, made the southern side of the mound unstable, compromising additional terracing and building activities, and imposing a change in the settlement organisation at the end of the LC 2. During this period, the settlement was confined to the top of the mound and extended towards north and north-east (Peyronel et al. 2019; Vacca et al. 2020).

Fig. 2 Aerial view of the site from the south (modified from Peyronel et al. 2019).

3. The excavation

Archaeological investigations at the site started since 2013, when a program of intensive survey allowed to recognise the main settlement phases through the analysis of the distribution of material culture (e.g. pottery, lithics, furnace waste) remains in relation with the morphology of the mound (Peyronel and Vacca 2015; Peyronel et al. 2016; Vacca et al. 2020). From 2016 to 2018 field campaigns, targeted excavation had started and a stratigraphic step Trench (B), two operations (B1 and D) and a test sounding (G38), lately interrupted, were dug (Fig. 3). Excavations at the site are still active and future campaigns are being defined.

3.1. Step Trench B

The stratigraphic step trench is located on the southern slope of the main high conical mound (Fig. 3). The excavation was aimed at investigating the occupation sequence of the site and providing stratigraphic and pottery sequences anchored to the absolute radiocarbon dates obtained from botanical samples collected from sealed contexts belonging to distinct phases (see par. 4.3). However, excavation data revealed the presence of well-preserved structures dating from the 7th to the 4th millennium BC (Peyronel et al. 2019).

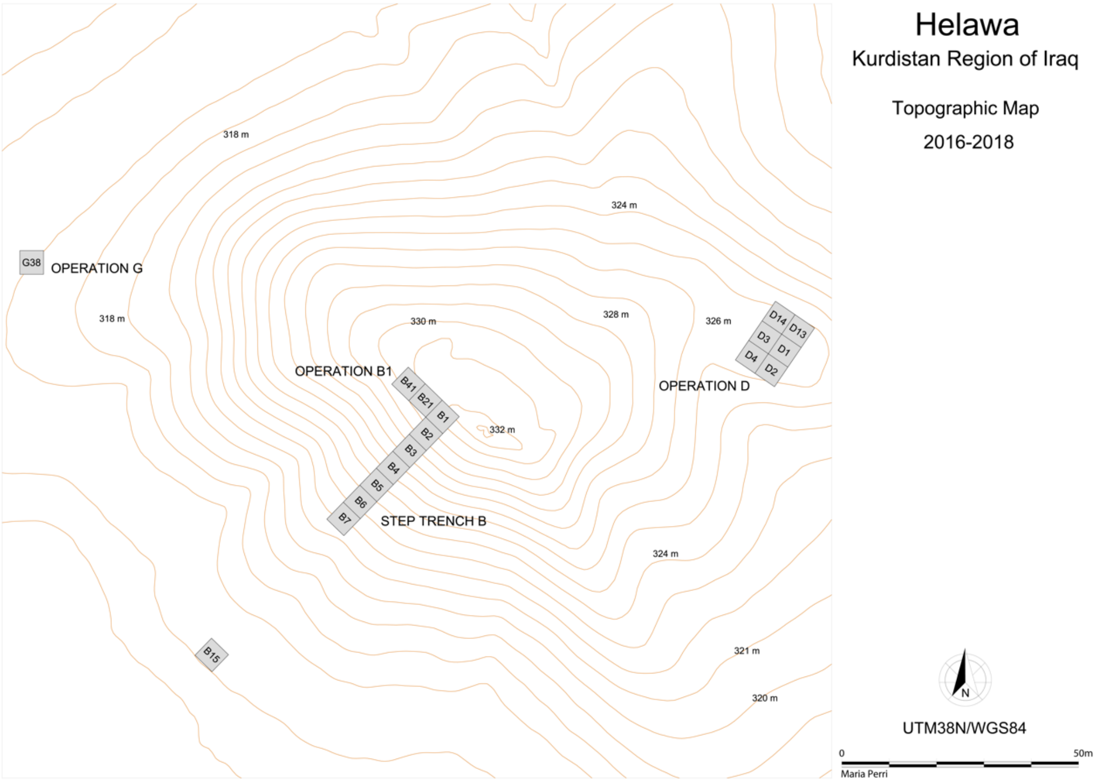


Fig. 3 Topographic map showing the excavation sectors during 2016-2018 campaigns (MAIPE ©).

The trench had a total length of 40 m north-south and was 4 m wide. It was excavated for a length of 35 m from the top edge of the mound (square B1) to its mid-slope (square B7); a further square (B15), was dug at the base of the mound. The total excavated area amounted to about 160 m^2 (Peyronel et al. 2019).

3.2. Operation B1

Operation B1 is located on the top of the mound (squares B21-B41), immediately adjacent to square B1 pertaining to the long step Trench B (Fig. 3). In 2018 the excavation area was enlarged by about 10 m westwards, to investigate the well-preserved buildings uncovered during the 2016 season in step Trench B and dated to the LC2/3 period.

3.3. Operation D

Operation D is located on a lower raised area covering c. 500-600 m^2 that lies immediately east of the high mound (Fig. 3). A large number of potsherds dating to the 2nd millennium BC, collected during the survey, indicated the presence below the surface of structures dated to the Middle to Late Bronze age. The excavations were conducted over an area of about 125 m^2.

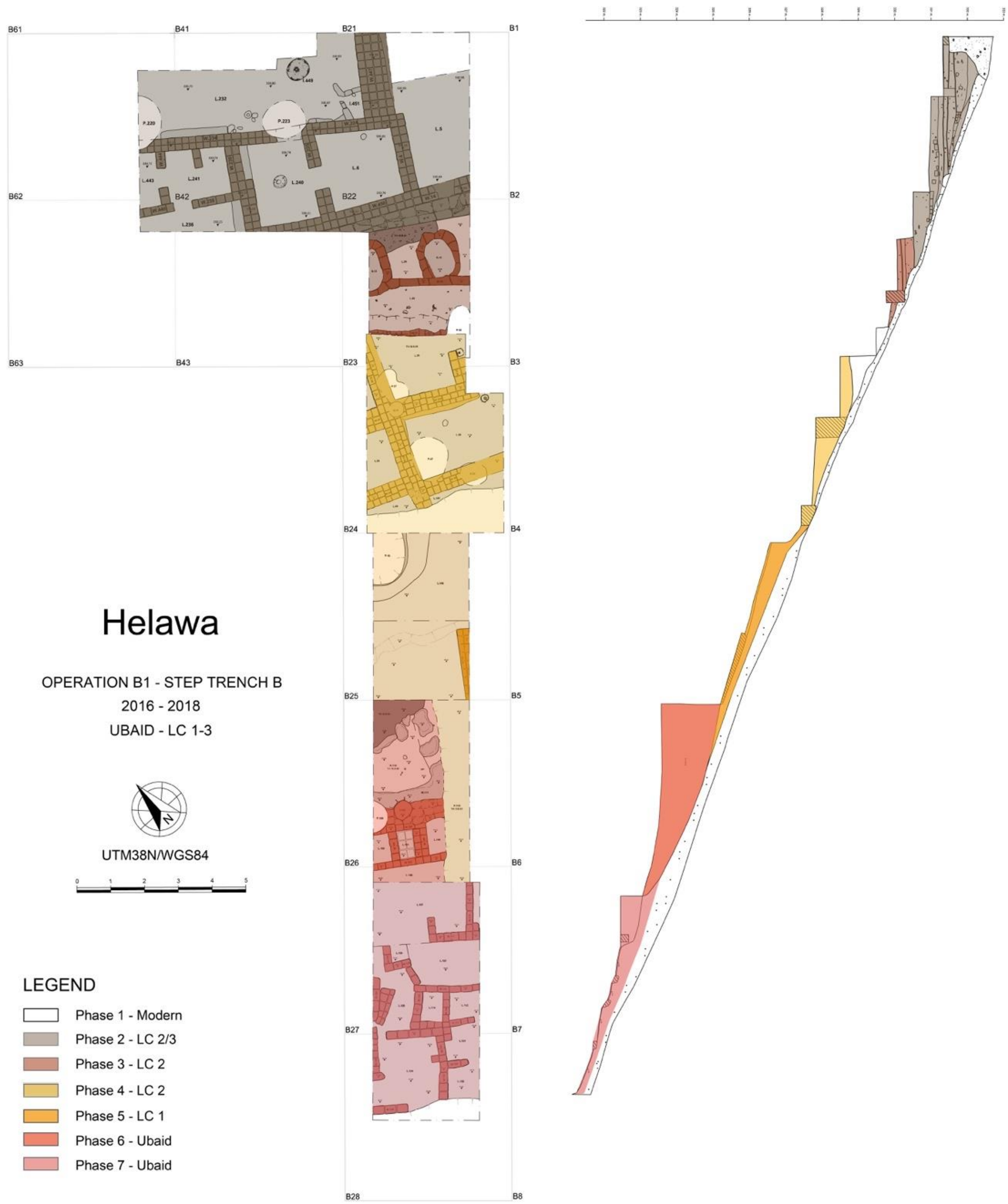


Fig. 4 View of the main phases within the step trench B and operation B1 (MAIPE ©).

4. Periodisation

The site's occupation sequence was established based on the diagnostic material collected on the surface during the survey campaigns (2013, 2015) and found during the targeted excavations carried out during the 2016-2018 fieldwork seasons (Tab. 1). The excavation has confirmed the periodisation deduced from the surface finds and has allowed a precise chrono-typology to be drawn up using the well-stratified sequence of the step Trench B (Peyronel et al. 2019).

Helawa site was settled uninterruptedly from at least the Pottery Neolithic (Helawa I) to the early Late Chalcolithic 3 period (Helawa IVC). After a period of abandonment lasting two millennia (from c. 3700 to 1800/1750 BC), the site was again occupied during the MBA II and LBA I, for less than three hundred years (between c. 1800/1750 and 1400/1350 BC). Finally, an ephemeral early Islamic settlement on the top of the mound attests its last occupation before modern times frequentations (Peyronel et al. 2019).

4.1 Early periods (7th – 6th millennia BC)

Early phases of occupation of the site are sporadically attested by surface findings relating to pottery sherds attributable to the Hassuna and Samarra traditions, suggesting that the site was already inhabited during the 7th millennium BC (Helawa I). An important occupation is attested for the 6th millennium BC, where structural remains have been found at the bottom of the step trench B (sq. B7-9) suggesting that during the Halaf period (Helawa II), a small settlement of ca. 2 ha might have existed (Peyronel et al. 2019).

4.2. Ubaid period (c. 5300-4500 BC)

The Ubaid period (Helawa III) occupation was indicated by surface finds mainly collected on the mound's southern slope; the existence of a small village covering c. 2 ha and dating to the Late Ubaid 3-4/Northern Ubaid period has been postulated based on the scatter distribution. Excavations in step Trench B, squares B5-6, brought to light two main architectural phases (Phases 6-7), consisting of a pottery production area with a large chambered kiln, built over a series of small square rooms possibly pertaining to storage activities (Fig. 4).

4.3. Late Chalcolithic (c. 4500-3600 BC)

The presence of diagnostic LC artefacts collected almost all over the mound indicates that a true settlement nucleus appeared at the beginning of the 5th millennium BC and that LC 1/2 (5th millennium BC) were periods during which the site grew substantially (Peyronel and Vacca 2015; Peyronel et al. 2019). The whole Late Chalcolithic occupation sequence is documented in step Trench B and consists of more than 10 m of superimposed structures with associated deposits (Fig. 4), built one on top of the other through extensive raising, levelling and terracing activities (Phases 2-5).

Fig. 5 View of Building 1 – step trench B/operation B1 excavated on the top of the mound (MAIPE ©).

The LC 1 (Helawa IVA, c. 4500-4200 BC) and 2 (Helawa IVB, c. 4200-3850 BC) periods are documented within the step Trench B, phases 3 to 5. Similarly to the previous Late Ubaid phase, the LC 1 contexts (Phase 5 A-B) attest a craft working area, with an obsidian-knapping workshop and layers with pottery kiln by-products, ash and burnt clay fragments, which was obliterated by an imposing residential building during the LC 2 period (Phase 4), in turn covered by a stock-piling and food storage area equipped with processing facilities and circular silos lined with mud-bricks, dating to the same LC 2 period (Phase 3 A-C) (Peyronel et al. 2019).

The overall distribution of surface material dating to the LC 2/3 transition and early LC 3 (c. 3900-3700 BC) show that the southern slope of the high mound was no longer occupied by this period, and that the settlement was centred on the top of the high mound and extended towards the north and north-east. The excavations in step Trench B, operation B1 and operation D yielded evidence that can be dated to an early LC 3 period (Helawa IVC, c. 3850-3700 BC). In step trench B and operation B1, a large tripartite building (Building 1) and structures lying to its eastern side (Building 2) ended in a conflagration that dates to the very end of the LC 2 period (Peyronel et al. 2019) (Fig. 5). After this burning event, installations and poorly preserved structures represent the last LC phase identified on the top of the mound, which is likely to be contemporary with the ephemeral structures and dumping layers brought to light in operation D (Phases 5 A-C) and might date to the early LC 3 period (Fig. 6). It seems that the LC 3 occupation at Helawa was of short duration and no diagnostic pottery of the local LC 4-5 ceramic horizon or southern Uruk-related material have been found in the surface collection nor the excavation, suggesting that the site was abandoned at some time during the LC 3.

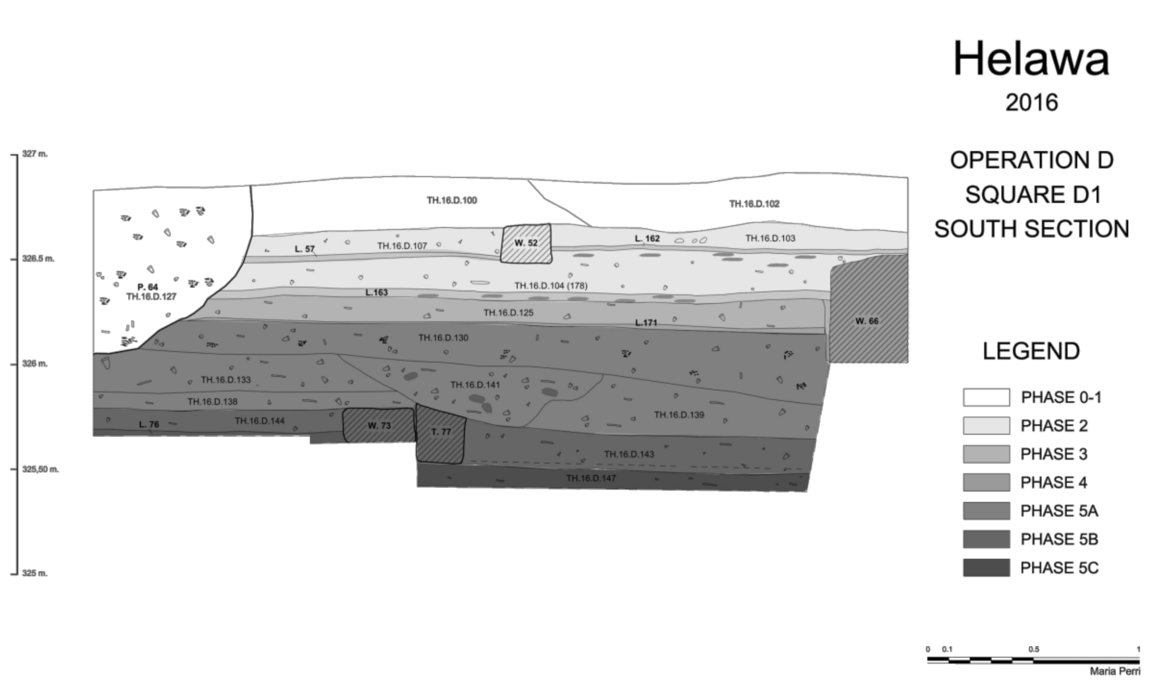


Fig. 6 Southern section of the stratigraphy unhearted in operation D and the structures related to the LC 3 period (phases 5 A-C) (MAIPE ©).

4.4. Late periods (1750 BC to modern times)

After a long break, the site was reoccupied during the Middle Bronze age (1750-1550 BC) (Helawa V) in the upper part of the mound where a preserved building was excavated. Traces of MBA occupation was also documented in operation D, where it shows continuity with structures pertaining to the LBA I horizon (c. 1550-1300 BC) (Helawa VI).

More recent phases of occupation belong to the medieval period (Early Islamic, Helawa VII). Latest occupation of the mound is dated to the modern period and is documented by activities belonging to the Ottoman period and a military trench excavated during the first Gulf War (Helawa VIII).

<table>
<tr><th>Period</th><th>Chronology</th><th>Absolute</th><th>B</th><th>B1</th><th>D</th></tr>
<tr><td>I</td><td>Pre-Halaf</td><td>7000-5900 BC</td><td></td><td></td><td></td></tr>
<tr><td>II</td><td>Halaf</td><td>5900-5300 BC</td><td>8</td><td></td><td></td></tr>
<tr><td>III</td><td>Ubaid</td><td>5300-4500 BC</td><td>6, 7</td><td></td><td></td></tr>
<tr><td>IVA</td><td>Late Chalcolithic 1</td><td>4500-4200 BC</td><td>5</td><td></td><td></td></tr>
<tr><td>IVB</td><td>Late Chalcolithic 2</td><td>4200-3850 BC</td><td>3, 4</td><td rowspan="2">3 A-B (LC 2/3)</td><td></td></tr>
<tr><td>IVC</td><td>Late Chalcolithic 3</td><td>3850-3600 BC</td><td>2</td><td>5 A-C</td></tr>
<tr><td>V</td><td>Middle Bronze age</td><td>2000-1550 BC</td><td></td><td>2B</td><td rowspan="2">2-4 (MBA-LBA)</td></tr>
<tr><td>VI</td><td>Late Bronze age I</td><td>1550-1300 BC</td><td>1</td><td>2A</td></tr>
<tr><td>VII</td><td>Early Islamic</td><td>636-1000 AD</td><td></td><td>1</td><td></td></tr>
<tr><td>VIII</td><td>Modern</td><td>1922-present</td><td>0</td><td>0</td><td></td></tr>
</table>

Tab. 1 Site periodisation table (modified from Peyronel et al. 2019).

5. Aims of the study

Due to its particularly well-preserved living units and stratigraphy, covering a long-time span, the site of Helawa represents the ideal context to analyse for understanding early developments of lithic traditions and distribution networks during the Chalcolithic in the eastern Tigris Region. The study is focused on the analysis of the lithic assemblages from raw material and technological perspectives. In particular, the attention is devoted to the modalities of selection and procurement of suitable rocks for knapping, the identification of the features of on-site and off-site productions, their socio-economic significance within the communities settled at the site through time and their relationship within broader systems of distribution and exchange networks (see also chapter 7). Data regarding obsidians are also presented since they allow to understand specific dynamics of technological and socio-economic interest.

6. Sampling strategy

Repeated occupation of the site through time caused the superimposition of buildings by erasing of already existing structures or filling them with debris taken elsewhere. The reuse and/or reorganisation of the spaces, excavation of spoliation/damage pits and destruction layers caused the collapse of mudbricks into the ground and the mixing of archaeological layers. In addition to these anthropic factors, natural agents (weathering, erosion, soil alteration) have also affected the preservation of the deposits. As an example, Step Trench B suffered a strong rate of erosion of its slope, causing the almost complete loss of data for

some loci which yielded only a few artefacts. On the contrary, intrusive phenomena were quite frequent on the superficial units.
However, these mixed deposits did not have a statistic impact on the surface distribution of finds, allowing us to recognise specific patterns related to activities, identified and confirmed through the excavation (Vacca et al. 2020).
An evaluation of assemblage's integrity was therefore necessary. Artefacts concentrations on the living floors were the preferred situation to be analysed. Room fillings were separately evaluated depending on their chrono/stratigraphical attribution and the presence or absence of thick closing layers which allowed the preservation of the underlying deposits. Artefacts recovered in room fillings, as they do not take part in the spatial reconstruction of activities carried out by prehistoric communities, could even be representative of the adopted technologies. For these reasons, room fillings were considered in this study and selected based on the associated pottery assemblages. Finally, the state of preservation or alteration (chemical, mechanical or heating) of the artefact's surfaces were representative of the assemblage integrity or, in some cases, of the activities carried out on the living floors. Any other types of contexts were not considered in the present analysis.

7. The lithic assemblages

The stratified evidence regarding chipped stone artefacts production and use at Helawa is represented by 1055 *in situ* artefacts (Tab. 2). The largest part of the sample composes the assemblages coming from the step trench (area B) excavated from the top to the bottom of the mound, on its southern slope, and covering the Halaf period[1] until the Late Chalcolithic 2/3. In 2018, the enlargement of the excavated area westward (Operation B1), allowed to identify a huge building with administrative function (building 1), used and reused between the LC 2/3 and the early LC 3, whose preserved loci contained further assemblages of great interest. Additional evidence concerning the latter period is yielded by the sounding realised in Operation D, where an informative assemblage was recovered.
Unfortunately, the badly preserved domestic structures with fireplaces, pottery and faunal remains do not allow the contextualisation of the finds, due to the later installation of a

[1] The present study has been carried out on the materials excavated during the 2016/2018 field campaigns. At that time, the most ancient occupation, corresponding to the Halaf cultural horizon, was not reached and only materials coming from surface scraping were available. Preliminary observations carried out on the collection, allowed to confirm the non-stratified nature of the finds. Although *in situ* layers of the Late Neolithic have been excavated during the 2019 field campaign and will be analysed in the next campaigns, earlier chronologies at the site are beyond the scope of the present research.

building with productive facilities during the LBA I period. A small number of artefacts come from the overlying structures and are related to this latter phase of site occupation. Despite chipped stone artefacts were quite abundant in these layers, they have been interpreted as intrusive phenomena.[2] Apart from the LBA assemblages, the number of artefacts per each period is quite equivalent and allow a comparison between the different phases of site occupation.

Period	Phase	Area	N. of artefacts
Helawa III	Ubaid	Step Trench B	295
Helawa IVA	LC 1	Step Trench B	377
Helawa IVB	LC 2	Step Trench B	91
Helawa IVC	LC 2/3	Step trench B - Op. B1 - Op. D	292
		Total	1055

Tab. 2 Total amount of the artefacts analysed and relative periodisation

7.1. Raw materials

Results from the raw material analysis allowed to identify a wide spectrum of lithic resources exploited at the site (Tab. 3). The largest part of the artefacts has been realised through the reduction of pebbles and cobbles, locally available in the river course flowing around the site.

The surrounding plain features synclinal troughs filled with polygenetic sediments of Pleistocene age (alluvial, colluvial, aeolian, residual etc.), mainly deriving from the erosion and weathering of surrounding reliefs, and flood sediments of Holocene age transported by the effort of the main drainage systems of the Greater Zab plain (Sissakian and Al-Jibouri 2012). Sediments composition includes rocky fragments of limestone, gypsum, and sandstone, and rounded small pebbles coming from the late Miocene-Pliocene Bai Hassan and Mukdadiya Formations, exposed in the Dameer Dagh and Kirkuk anticlines (Sissakian and Al-Jibouri 2012). In addition, several tributary rivers, flowing east to west, contribute to the transport of rocks from the eastern sector of the Zagros Mountains featuring

[2] Visual and microscopy examination of the artefacts retrieved in LBA layers in Operation D by V. Oselini yielded no indication of reuse or recycling behaviours toward some artifact categories (e.g. large blades, bladelets and flakes).

carbonatic formations, including silicifications embedded in dolomitic limestones sedimentary facies. These dynamics allowed the creation of secondary outcrops featuring a large variety of lithotypes of knappable qualities (also compare chapter 6, for an overview of secondary sources identified further north in the LoNAP area).

Raw material	**Helawa III**		**Helawa IVA**		**Helawa IVB**		**Helawa IVC**	
lithotype	*n.*	*%*	*n.*	*%*	*n.*	*%*	*n.*	*%*
chert	252	85	133	35	59	65	198	68
jasper	15	5	7	2	8	9	8	3
limestone	6	2	4	1	2	2%	2	1
sil. limestone	2	1					8	3
quartz	1	0,3					3	1
quartzite	4	1,4	8	2	1	1	2	1
sandstone	3	1			10	11		
obsidian	10	3	225	60	11	12	71	24
other	2	1						
Total	295	100	377	100	91	100	292	100

Tab. 3 Frequency of raw materials exploited at the site per each phase of occupation.

The survey conducted around the site confirmed these observations. From a section exposed in the proximity of the Helawa modern village has been possible to document these deposits. Moreover, drainage works conducted by excavating the stream bed at the bottom of the site permitted to observe similarities in lithotypes composition with the ones exploited at the site.

Chert is, by far, the most represented lithic raw material exploited during all the phases of occupation (Fig. 7). About 58 varieties have been recognised and described. On the one hand, they strongly represent the polygenetic nature of the local secondary outcrops, on the other, specific work is needed to distinguish which varieties represent specific genetic types (*sensu* Fernandes and Raynal 2016) and which of them would be indicative of the physical-chemical transformations occurred during the post-genetic geologic cycle (see chapter 2). However, the issue is beyond the scope of this research.

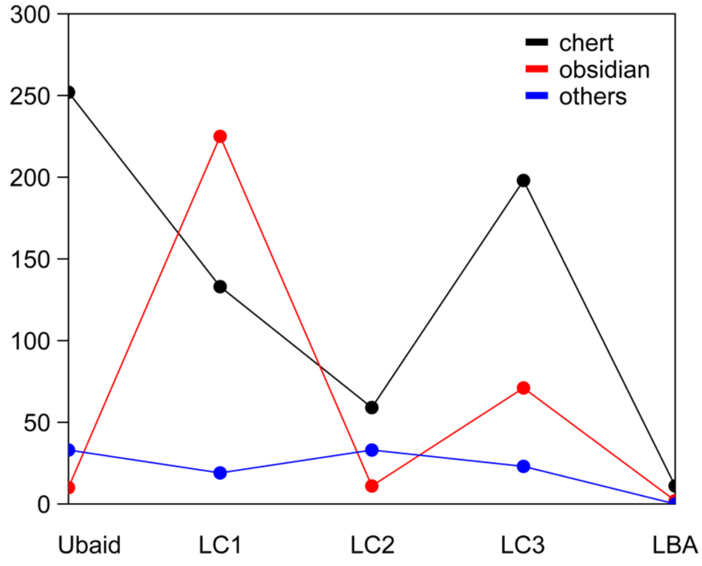


Fig. 7 Comparison of the frequencies of chert, obsidian and other minor attested lithotypes at Helawa.

From a macroscopic point of view, the chert types differ in colour from light to dark grey shades, from brown to red and black-yellowish shades. Frequently these varieties are non-translucent, with a sub-conchoidal fracture. The structure of the inclusions varies from spotted to mottled, or shaded inclusions. Laminations and bandings are quite rare. Homogeneous varieties are absent. Microscopically, they exhibit moderately- or poorly-sorted textures. Most of these varieties can be considered of mid-low knapping qualities due to tectonization.

Within the represented types, which are often related to expedient or domestic productions, few chert varieties can be interpreted as imported from non-local or at least extra-regional outcrops. These types are exclusively related to blades and large blades appearing during the late LC 2 and LC 3, and no other by-products of their knapping sequences have been found in the excavation. Moreover, their size suggests their extraction from larger and high-quality nodules, virtually absent in the local sphere of resources availability. These varieties exhibit light or dark grey colours, well-sorted textures associated with homogenous, spotted, or banded structures (see chapter 7).

The remaining part of the local resources is represented by other types of sedimentary and metamorphic rocks (Tab. 3). Red-black jasper of good-quality is exploited in all the prehistoric periods and its frequency decreases gradually from the Ubaid to the LC 3. Limestones and siliceous limestones are sporadically exploited as well as quartz and coarse varieties of sandstone. This latter knows a pick during the LC 2. Cobbles of metamorphic rocks, such as quartzite, are mostly exploited during the Ubaid and LC 1, even to produce bladelets.

The above-presented data restitutes a picture in which the prehistoric communities settled in Helawa fully exploited the locally available resources. Even though chert was the preferred lithic raw material, the integration and adaptation of the toolkits to other knappable resources were practised as a consolidated tradition. This trend is evident during the Ubaid period and becomes less evident during the Late Chalcolithic (Fig. 7), where a higher degree of erosion affected the preservation of the deposits. It is worth to mention that the supply of non-chert raw materials it is underestimated at the present state. Cobbles and pebbles were also employed as filling material as well as floor component; their use as percussion and/or grinding tools needs to be verified also through specific analyses.

A separate discussion deserves to be made for the obsidian exploitation at the site. As this type of volcanic rock is not locally available due to the geologic setting of Northern Iraq, its entire amount was imported from the Anatolian sources.[3] Obsidian was used in all the periods and it represents a relevant component of the toolkits, especially within the blade component (Fig. 7). Its frequency rapidly increases during the LC 1 and remains constant during the LC 2-3. Its use dramatically decreases during the LBA I horizon. At the present state of the knowledge, this kind of rock was securely reduced *in situ* during the LC 1, since in Step Trench B the remains of a blade-knapping workshop dating to that period have been retrieved. It is also worthy of note that an obsidian bladelet core comes from Building 1 dated to the LC 2/3 period.

7.2. Helawa III

The inventory related to the Ubaid phase is represented by 295 artefacts (Fig. 8). The lithic assemblages of the most ancient phases of occupation (7A-B) are related to the living floors and fillings of a series of small rooms L.123, L.124, L.107 and L.108. Further artefacts come from a pit (P. 112) which cuts some anthropic sloping layers rich in materials. The assemblages from the latest phases (6A-C) relate to the use and

[3] Preliminary results obtained by P. Acquafredda and M. Pallara, of the University of Bari, on a selection of samples from the LC2-3 layers allowed to identify an eastern Anatolian provenance (Lake Van) for the obsidian. Analysis of samples from Ubaid and LC1 layers are currently in course.

maintenance of the pottery workshop (6C). Its filling/dumping area (6A), related to the deactivation and obliteration of the kiln (K.119), yielded wide evidence of discard of lithic tools (TH.18.B.62).

Technological categories	chert		obsidian		others	
	n.	*%*	*n.*	*%*	*n.*	*%*
tools	45	15	3	1	9	3,4
large blade fragments	1	0,3				
blades	5	2				
bladelets	4	1,4	6	2	1	0,3
laminar flakes	21	7				
flakes	137	46,4	1	0,3	16	5,4
chunks	3	1			1	0,3
bladelet cores	2	1				
flake cores	34	12			5	2
Total	252	85,4	10	3,4	33	11,2

Tab. 4 Composition of the lithic assemblages dated to the Ubaid period coming from Step Trench B.

These contexts are related to the domestic/productive sphere of the Ubaid communities settled in Helawa. The lithic productions are characterised by a massive extraction of flakes and elonged products from local pebbles and cobbles (Tab. 4). Flakes and elonged blanks constitute the main goal of the production, constituting about 52% of the entire amount. Most of the evidence is related to cortical and semi-cortical blanks produced through direct and bipolar percussion (splintered pieces). Flakes detached from the ventral faces of wider blanks are also documented as well as core maintenance flakes and platform rejuvenation elements.

Flake cores are very well attested and represent about 14% of the assemblage. Most of them are discarded at an advanced stage of their productivity. They follow recurrent schemes of reduction entirely performed through the interaction of the direct and bipolar percussion techniques. Unidirectional modalities with a single flat platform represent the initial stage aimed at the extraction of flakes and elonged blanks. The evolution of the exploitation through multi-platform modalities (orthogonal, centripetal, or multi-directional débitage schemes) usually follow opportunistic choices, the possibilities (natural platforms) and/or constraints imposed by the raw material features. Ventral faces of larger flakes were also exploited as cores. Just one item represents the employment of a more predetermined laminar method over-exploited to extract flakes from two opposed platforms on the same face.

Tool typology	**chert**		**obsidian**		**others**	
	n.	*%*	*n.*	*%*	*n.*	*%*
glossed inserts	24	*8*			4	*1,4*
scrapers	8	*3*			1	*0,3*
points	1	*0,3*				
retouched flakes	7	2				
denticulates	1	0,3			2	1
borers	1	0,3				
bladelet segments			1	0,3		
blade segments	2	1	1	0,3		
core/tools	1	0,3			3	1
large blade segments			1	0,3		

Tab. 5 Typology of the retouched tools, from the Ubaid period, according to raw materials.

Blade/bladelets are little documented and represent about 6% of the total. Most of the unmodified laminar items have been produced on chert (n= 9) and obsidian (n= 6). Chert blades and bladelets exhibit technical and morphological attributes matching with the adoption of the direct percussion. Only one item could be related to the pressure technique. The blade is a proximal fragment showing a punctiform non-prepared butt and a flat bulb. The profile is straight, and the section is trapezoidal (2-1-2') with previous removals very regular and unidirectional. The same phase (7A) yielded evidence of a larger neo-crested blade showing the same technical features. The width interval represented by these blades

(17-24 mm) fits well with the adoption of the pressure with a long crutch in a standing position with an antler tip as no cracks, indicating the use of metal, have been observed on their butts (Pelegrin 2012b; Vosges 2019).

Obsidian bladelets are quite homogeneous and are represented by 2 proximal and 4 mesial fragments. They exhibit a trapezoidal section with unidirectional parallel previous removals. Technical attributes observed on the proximal items show a prominent bulb just under an orthogonal-punctiform butt. The diagnosis has been thus possible on all the specimens but one, badly preserved, pointing out through the adoption of the pressure technique with a short crutch in a sitting position (width interval 15-10 mm). However, no evidence of in situ production has been found.

The filling/dumping area unhearted in SU TH.18.B.62 yielded the largest evidence of retouched tools discard. The whole inventory of formal tools (Tab. 5) is mainly characterised by glossed inserts (9,4%), scrapers (3,3%) and retouched flakes (2%). The other tool categories are underrepresented; they comprise denticulates, borers, blade segments and retouched cores.

Glossed inserts are entirely realised on flakes and elonged blanks. Blank modifications are always present. The transformation involves the blank extremities and occurs through direct abrupt or semi-abrupt retouch aimed at delineating a transversal (or concave/straight) end usually opposed to a convex or transversal one.

A heavy gloss is macroscopically quite evident on all the items and is developed following one (or both) the edges transversally. Bitumen residues are often preserved, indicating that these items were hafted and were part of more complex and composite tools supposedly used in vegetal harvesting activities.[4]

Blade/bladelet segments exhibit no naked-eye gloss and are realized on both chert and obsidian on direct percussion blanks and a pressure bladelet showing marginal retouch on its left edge. It is worth to mention the presence of a larger blade mesial fragment made from obsidian and showing edge modifications possibly due to use. The item exhibits a thin trapezoidal section (1-2-3) with parallel ridges and a straight profile. The width of the blade (24 mm) is consistent with the adoption of the pressure technique with a long crutch in a standing position (Pelegrin 2012).

[4] Use-wear analyses on a selection of samples per each period will be soon performed at LTFAPA Laboratory, Sapienza University of Rome.

Fig. 8 Chipped stone artefacts from the Ubaid period. Multi-directional cores (1-2); unidirectional bladelet core (3); unidirectional core with two dependent platforms (4); unidirectional flake core set on a flake (5); unifacial flake core (6); glossed inserts (7-13); proximal fragment of a large neocrest (14); bladelet fragments (15-20).

7.3. Helawa IVA

The lithic assemblages of the LC 1 phase are related to three phases of occupation (5A-C) for a total of 377 pieces (Fig. 10). All the artefacts from the ancient phase (5C) come from the layers of a large pit (P.115) interpreted as an adapted and filled gully cutting the earlier Ubaid levels. The evidence from the second phase (TH.17.B.60; Phase 5B) is related to a beaten floor interpreted as an open space, with evidence of obsidian knapping activities. The latest phase (5A) is related to dumping layers alternated to a beaten floor and deactivation layers, with ashes and furnace wasters, probably pertaining to a pottery production area.

The lithic production exhibits the main technological characters and tools assemblage composition of the previous period. However, some differences have been recorded. A first difference regards the increasing introduction of obsidian tools (Tab. 6).

Chert flakes and elonged blanks production represent 24% of the total. This is confirmed by the analysis of the cores which show the same modalities of reduction of the Ubaid period.

Blades and bladelets are present in low percentages. Unmodified laminar blanks on chert raw materials (n= 5) have been obtained through direct percussion (n= 4) and possibly by pressure (n= 1). This latter is a semi-cortical mesial fragment (width 15 mm) showing trapezoidal section (1-2) and unidirectional and parallel previous removals. A particular context (TH.17.B.60) yielded evidence of very regular bladelets made out of quartzite. Unfortunately, the artefacts are represented by 1 mesial and 2 distal fragments. They exhibit trapezoidal (n= 2) and triangular sections (n= 1) and very regular previous removals with pointed or straight terminations. Finally, 6 blade/bladelets made from obsidian from phase 5A provided evidence of further knapping activities. The sample is composed of 2 bladelets produced by direct percussion, a surface maintenance blade fragment with plunged termination, exhibiting 8 convergent removals, and 2 distal fragments of pressure bladelets.

As for the Ubaid phase, also during the LC 1, the largest part of retouched tools evidence comes from a single unit (TH.18.B.63; P.115), which was filled with discarded materials. Formal tools (tab. 4) are mostly represented by glossed inserts (5%). The remaining types are represented by scrapers, retouched blades and bladelets, blades and bladelets segments. Finally, some types are represented by just 1 element: borers, endscrapers, points and pièces esquillée.

Technological categories and tool typology	chert		obsidian		others	
	n.	*%*	*n.*	*%*	*n.*	*%*
glossed inserts	14	4			2	1
scrapers	2	1	2	1		
endscrapers	1	0,3				
points			1	0,3		
denticulates	1	0,3				
borers	1	0,3				
backed microliths			1	0,3		
blade segments			8	2,1	1	0,3
bladelet segments	1	0,3	10	3		
retouched blades	1	0,3	2	1		
notched bladelets			2	1		
retouched bladelets			2	1		
retouched flakes			2	1	1	0,3
pièces esquillée			1	0,3		
core/tools			1	0,3		
neo-crests			2	1		
blades	2	1	4	1,1	1	0,3
bladelets	3	1	14	4	4	1
chunks					1	0,3
chips			107	28		
laminar flakes	14	4	3	1	1	0,3
flakes	77	20	63	17	6	2
flake cores	16	4			2	1
Total	133	35	225	60	19	5

Tab. 6 Composition of the lithic assemblages dated to the LC 1 period coming from Step Trench B.

The inserts for composite tools have been realized on flakes and elonged blanks, adopting the same modalities of retouch and distribution of the gloss on the edge (transversal). However, during the LC 1, some inserts are realised on bladelets (n= 5). The blanks exhibit the features of the pressure technique (n= 3) together with different modalities of production characterised by simple patterns of fragmentation through direct percussion or flexion, without any retouch. The distribution of the gloss on the edge is also different: it is parallel to the axis of the tool, associated with bitumen residues on the opposed edge. Unfortunately, only 1 item preserves its proximal portion.

Obsidian tools from phases 5A-5C have been realised on bladelets. The retouch is abrupt or semi-abrupt, delineating a straight edge. Two blanks exhibit multiple notches.

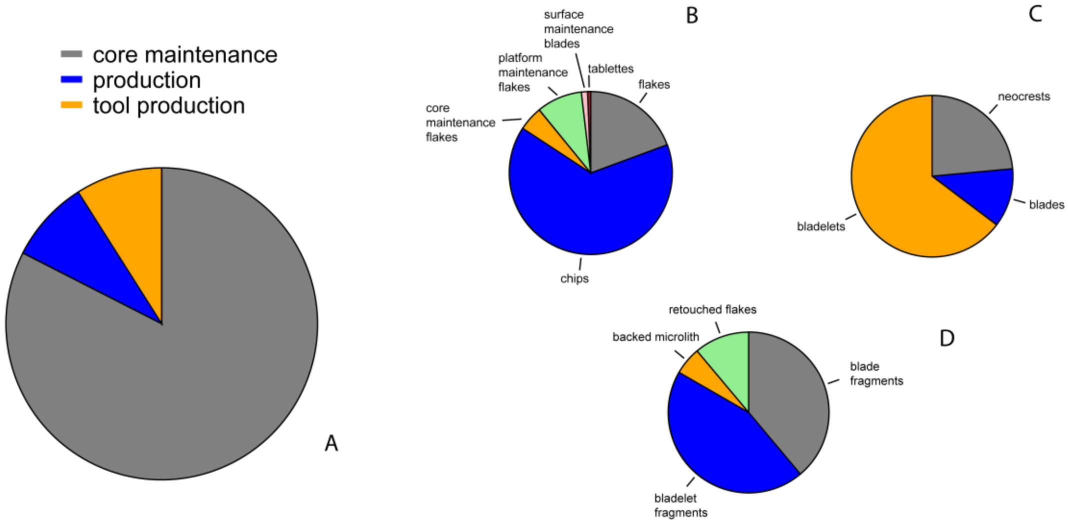


Fig. 9 Pie charts showing the identified stages of SU TH.17.B.60 obsidian knapping workshop (A), detail of core maintenance related items (B), detail of production-related items (C), detail of tools production stage (D).

The obsidian knapping workshop evidence found in SU TH.17.B.60 better clarify how this raw material was processed during the LC 1. The artefacts were concentrated in an open-spaced beaten floor, discarded together with few chert flakes and quartzite bladelets above discussed.

The total amount of artefacts related to the obsidian processing is of 200 artefacts. Several knapping phases have been identified and related to a single reduction trajectory aimed at the production of bladelets which were subsequently fragmented and exported in the nearby areas of the settlement (Fig. 9). The represented stages are core volume maintenance (83%), initialization and blade extraction (9%), and tools production (9%).

Cores, which are absent, have been introduced already exploited and were re-prepared through the configuration of a neocrest to restart the extraction of the blades. During the process, the platform was managed through the removal of tiny flakes. The decreasing size and morphology of the bladelets, together with maintenance flakes and 1 tablette, testify the evolution of the core volume towards small pyramidal shapes.

Morpho-technical attributes of blades and bladelets have been observed on 28 items. They are represented by 9 proximal, 17 mesial, 1 distal fragment and 1 entire bladelet. Among these, 4 items have been produced by direct percussion and would not represent the real goal of the production. Most of the items show the typical features of the pressure technique. The butt is orthogonal, with punctiform or dihedral-convex preparation.

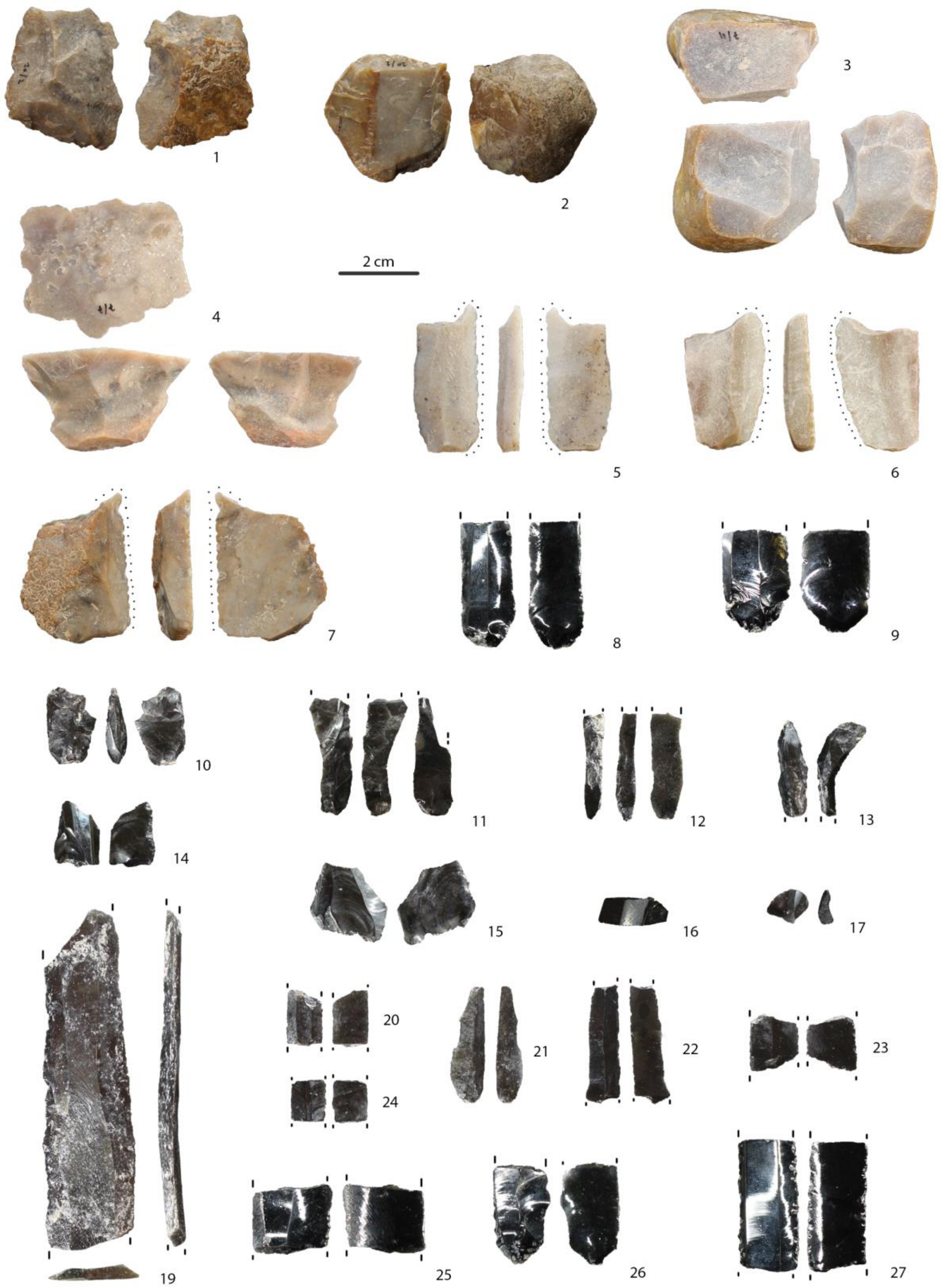


Fig. 10 Chipped stone artefacts from the LC 1 period. Multi-directional cores (1, 3); splintered piece (2); unidirectional flake core (4); glossed insert on bladelet (5); glossed inserts on flake (6-7); bladelets (8-9; 20-27); core maintenance flakes (10-11, 13-15, 16); neocrested blade (12); tablette (16); pressure blade produced by the crutch system (19).

The bulb is pronounced and marked by ripples. The section is trapezoidal or triangular and the termination is straight or pointed. The complete item is a small bladelet (length 26 mm, width 9 mm, thickness 2 mm). The width range (5-19 mm) may suggest the adoption of the pressure technique with a short crutch in a sitting position, or the switch through a hand-held baguette during the later stage of core reduction (Pelegrin 2012b).
Tools production stage is testified by 18 items. These are blades and bladelets segments bearing fracture hits on 1 or both the extremities, 1 blade fragment with abrupt retouch, 2 retouched flakes and a micro-flake with double ventral surfaces exhibiting a backed edge.

7.4. Helawa IVB

The inventory related to the LC 2 phase consists of a total of 91 artefacts (Tab. 7). The evidence from period IVB pertains to two main phases (3-4). The earliest phase (4) yielded lithic materials in relation with two rooms (L.30 and L.26) of a building dated to the early LC 2. The second phase namely the “silos phase” (3) is dated to the same LC 2 period. In this phase, the evidence comes from storage structures (silos S.13 and S.15) and their spatially related-use floors. Moreover, a working area (L.24), probably an open space located in peripheric position respect the silos, yielded an additional assemblage.
The lithic productions of the LC 2 phase exhibit slightly different characters respect the early periods (Fig. 11). While flakes and elonged blanks are regularly produced, it is recorded an increase in laminar productions and a major shift in raw materials and *débitage* economy. A first change regards the incidence of the retouched tools on flake, which seems to decrease and represented only on chert raw materials. Non-chert materials (except the obsidian) bear no retouch and could be exclusively related to expedient productions. This is also confirmed by débitage analysis, which features a high percentage of cortical and non-cortical flakes. An increase in the adoption of the bipolar percussion is recorded, that represents, along with direct percussion, the main used techniques. For the moment, it is not known if these changings are indicative of a new organization of the living spaces and changing subsistence strategies. Only in-depth excavations and loci assemblage’s analysis will clarify these aspects.
Blades and bladelets frequency increases during the LC 2. Within a total of 20 artefacts, 13 items have been produced through direct percussion (including 3 crests). A total of 7 blades/bladelets exhibit the characters of the pressure technique. Unfortunately, these items are represented by 6 distal and just 1 proximal fragment. Morphological attributes point out through trapezoidal and triangular sections, very regular and parallel (or convergent)

unidirectional removals. The proximal fragment has a small orthogonal butt associated with a prominent bulb. The width range (12-20 mm) may indicate the adoption of the pressure technique with a long crutch in a standing position.

Technological categories and tool typology	**chert**		**obsidian**		**others**	
	n.	%	n.	%	n.	%
glossed blades	2	2				
glossed bladelets	2	2				
bladelet segments			6	7		
borers			1	1		
core/tools					1	1
blades	1	1			1	1
bladelets	13	14			5	5
chunks	2	2	1	1	1	1
laminar flakes	4	4			1	1
flakes	34	37	3	3	12	13
flake cores	1	1				
Total	59	65	11	12	21	23

Tab. 7 Composition of the lithic assemblages dated to the LC 2 period coming from Step Trench B.

The obsidian artefacts related to blade/bladelets are represented by 6 items. No diagnostic elements support their on-site production. They consist of 5 mesial and 1 proximal fragment. The technical diagnosis indicates the adoption of the pressure technique. The width range (10-15 mm) suggests the employment of a short crutch in a sitting position.

The retouched tools are little represented (9%). Tools on blade/bladelets are the most frequent. During the LC2, glossed inserts are now manufactured on laminar blanks with a trapezoidal or triangular section, on both exotic and local chert raw materials, and bear no edge modification, apart from 1 item exhibiting an oblique truncation associated to abrupt direct retouch on its right edge. Most of these blanks could have been produced by pressure, using a long crutch (width range 14-20 mm). Although, only 1 insert preserves its proximal portion, featuring no diagnostic attributes. Gloss distribution is parallel to the main axis of the blade and it is often associated with bitumen residues, used as glue for hafting.

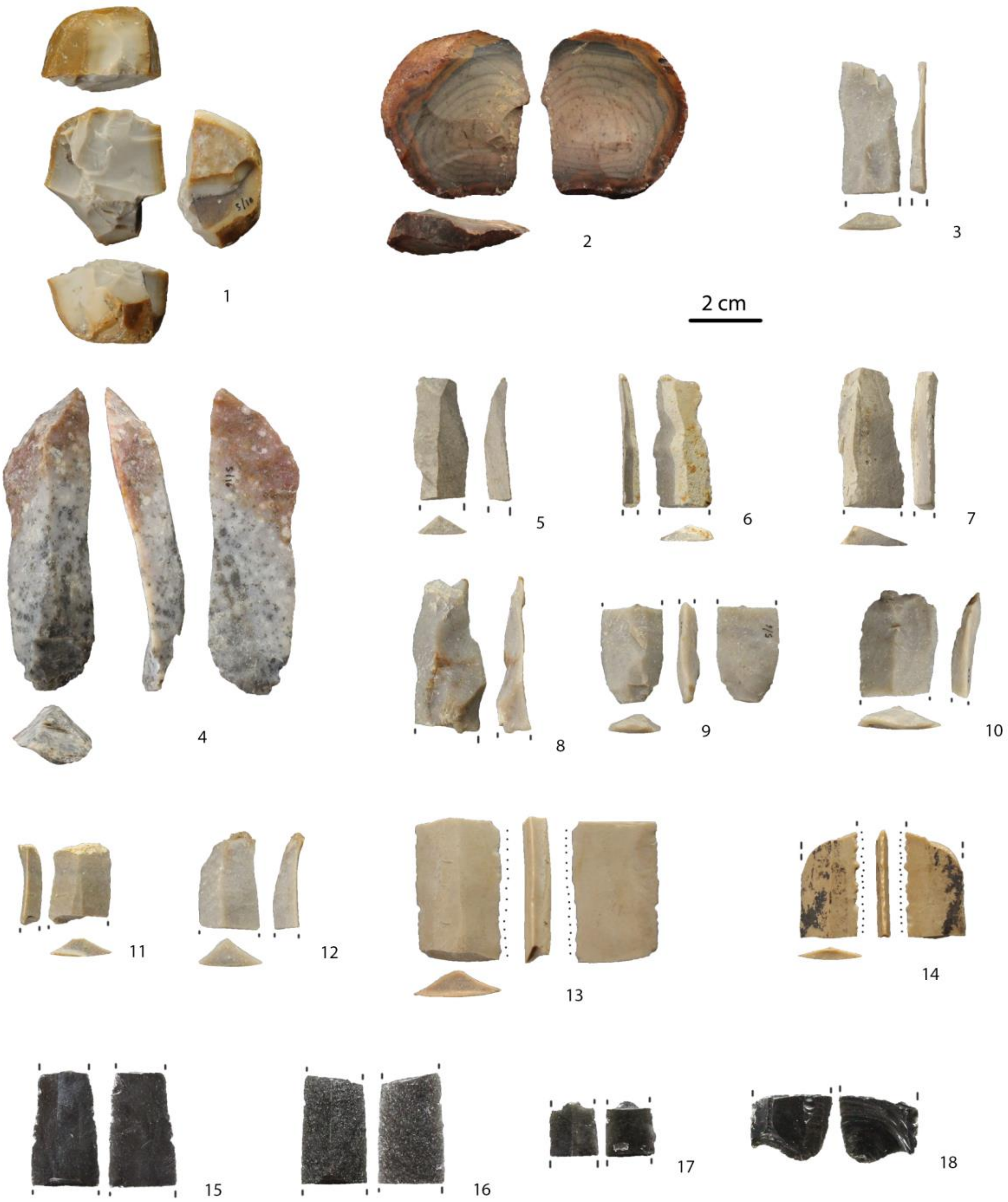


Fig. 11 Chipped stone artefacts from the LC 2 period. Multi-directional core (1); splintered piece (2); bladelet fragments (3, 5-12); blade produced by direct percussion (4); imported large blade fragment used as glossed inserts (13-14); obsidian bladelets (15-18).

7.5. Helawa IVC

The LC 3 phase at Helawa is represented by 292 artefacts (Tab. 8). The early phase has been identified within the step trench B (phase 2) and it is characterised by 138 artefacts.

Technological categories and tool typology	chert						obsidian						others					
	step trench B		op. B1		op. D		step trench B		op. B1		op. D		step trench B		op. B1		op. D	
	n.	%	*n.*	%	*n.*	%	*n.*	%	*n.*	%	*n.*	%	*n.*	%	*n.*	%	*n.*	%
glossed large blades					7	2,4												
glossed blades	1	0,3	5	2	5	2												
glossed bladelets	1	0,3																
retouched blades			1	0,3	1	0,3	1	0,3										
retouched bladelets					1	0,3	2	1	1	0,3	1	0,3						
large blade segments					6	2					1	0,3						
bladelet segments					1	0,3					4	1,4						
blade segments	2	1	1	0,3	6	2												
polished object									1	0,3								
borers	1	0,3					1	0,3			2	1						
scrapers	2	1																
denticulates	2	1																
retouched flakes	1	0,3	1	0,3			1	0,3	2	1	1	0,3			3	1		
piéce esquillées							2	1	1	0,3	1	0,3						
core tools					1	0,3												
large blades					1	0,3												
blades	7	2	2	1	3	1	5	2			1	0,3						
bladelets	6	2	3	1	1	0,3	5	2	3	1	11	4						
laminar flakes	5	2	2	1	4	1					4	1,4	1	0,3				
flakes	66	23	24	8	12	4	3	1	2	1	9	3	7	2	3	1	1	0,3
chunks			3	1	2	1					2	1	1	0,3			1	0,3
bladelets cores	1	0,3							1	0,3								
flake cores	10	3	3	1									4	1,4	1	0,7	1	0,3
Total	105	36	45	15	51	17,5	20	6,8	11	3,8	37	12,7	13	4,5	7	2	3	1

Tab. 8 Composition of the lithic assemblages dated to the LC3 period and coming from Step Trench B, Operation B1

Three sub-phases characterise the occupation. The first sub-phase yielded lithic assemblages from the rooms (L.5 and L.16) related to a building (2C) contiguous to Building 1 in Operation B1. During phase 2B, a second building (Building 2) is built up directly on the earlier one. The assemblages come from L.10, L.11 and L.40. Further artefacts come from the latest sub-phase (2A) which is represented by the reuse of the structures of the former Building 2.
The administrative building identified in operation B1 yielded 52 artefacts coming from L.6, L.232, L.236 and L.241 and belonging to its early phase (3B), dated to the very end of LC 2 or early LC 3. The brief reoccupation of the structures after its burning (3A) also restituted few artefacts, in association with a fireplace (T.229). The sounding in operation D (Phase 5) yielded 91 artefacts. However, phase 5 which might belong to a mature LC 3. The samples mostly belong to dumping layers (phase 5A) rich in materials (pottery and faunal remains) covering badly preserved domestic structures of the early LC 3 (phases 5B-C).
The lithic productions of the LC 3 phase exhibit similarities with the previous period. However, some relevant innovations are recorded within toolkits composition (Fig. 12). The assemblages coming from the step trench B are characterized by flake production from cores abandoned at an early stage of their productivity. It is worth to mention the presence within L.5 of a bladelet core of prismatic shape reduced by direct percussion associated with blades and bladelets (including 2 crests) produced by direct percussion. Glossed inserts are realized on pressure blades (width range 16-20 mm), on both local and imported cherts. Pressure blades/bladelets made from obsidian show two distinct width range (13-14 mm; 24 mm) that could indicate the adoption of short/long crutch modes of pressure. However, no diagnostic elements indicating on-site production have been unearthed. Finally, the presence of *pièces esquillée* on both blades and flakes, as the result of multiple actions and uses performed on the same object, deserves further attention.[5]
The assemblage from Building 1 (3B) includes several flake cores and retouched flakes made from chert, quartzite, and limestone. It also features some very regular blades and bladelets, made out on both local and exotic cherts, produced by pressure with a long crutch in a standing position (width range 12-19 mm). Glossed inserts, represented by blades, are realized exclusively on imported cherts and show the same characters of the above described unmodified blades (16-19 mm; 23 mm width range).

[5] Macro- and microwear traces are well preserved (C. Lemorini *pers. comm.*) and are currently under study.

Fig. 12 Chipped stone artefacts from the LC 3 period. Flake core reduced by bipolar percussion (1); crest fragment (2), blades produced by direct percussion (3-5); pressure blade produced by the long crutch system (6); blade produced by the long crutch system on non-local chert raw material (7); large blades produced by the lever pressure system (8-12); obsidian bladelets (13-14; 17); bladelets core reduced by pressure (15); polished and holed object (16); pièce esquillée (18).

The obsidian assemblage from Building 1 (3B) is characterised by 3 unmodified bladelets produced by pressure, a retouched bladelet, few flakes and a piéce esquillée. From L.6, which also yielded container sealings, comes a well-preserved obsidian pyramidal core exploited for the extraction of bladelets through pressure. Finally, L. 241 restituted a fragmentary personal ornament (TH.18.B.276.Ob.2) made out on an obsidian bladelet (length 28 mm; width 8 mm; thickness 2 mm). The dorsal face is completely polished, and the distal end exhibit a small fragmentary hole.

Finally, the assemblage from area D testifies, for the first time at the site, the appearance of imported large blades made from chert. These blades are very regular with trapezoidal section and a straight profile. Among these, 3 items preserve their proximal portion, characterised by small orthogonal and flat butts and a pronounced bulb associated with ripples. No cracks have been observed. The width range represented (24-30 mm) could indicate the adoption of the pressure technique by the lever system. The total amount includes 7 blades exhibiting a heavy gloss on one edge and bitumen residues, along with 6 items bearing fracture hits on their extremities but no gloss evidence.

8. Discussion

The present study provided several inputs for interpreting the lithic evidence at the site and its evolution through time. A first point concerns the types of contexts that returned the assemblages. During the Ubaid period, the documentation belongs to domestic and productive units. In these spaces, stone knapping activities were oriented towards the production of tools and inserts for composite instruments on flakes produced by exploiting local raw materials. The occurrence on the whole knapping sequences in domestic areas indicates that each living unit directly produced the blanks and managed the tools to carry out subsistence activities.

During the LC 1 period, two waste pits yielded wide evidence of tools discard (e.g. glossed inserts) which allowed to in-depth study the strategies of their production. Strategies of glossed inserts production remained unchanged, even if a little evidence of inserts produced on pressure bladelets by exploiting local chert raw materials begins to appear. Such items also testify different modalities of composite tools handling and use, as the gloss is parallel to the blank axis.

In addition, the open space provided unmistakable evidence of specialised knapping activities related to the exploitation of obsidian by the pressure technique to produce bladelets. This evidence is currently lacking for the other periods at Helawa, as well as at general level in the region. The context is relevant for two reasons: (1) it testifies that obsidian was imported at the site as rough blocks or prepared cores, (2) the technical system of lithic production was characterised by people who owned the skills and knowledge to perform the pressure technique in its variants (e.g. hand-held baguette/short crutch modes). Given these assumptions, it is not surprising the employment of the pressure technique even on local chert raw materials. However, the organisation of this space suggests that the area was also devoted to other activities (e.g. pottery production) probably integrated within the communal sphere of the LC 1 settlement.

A real change is testified during the LC 2 phase, were an increasing laminarity of the blanks adopted for composite tools manufacture is recorded, together with the first evidence of imported large blades on non-local chert raw materials. The coexistence of two modalities of raw materials supply is significative from two reasons: (1) since the LC1 local people were experimenting new tools and modalities of plant harvesting in relation with changing primary economic strategies at a broader scale, (2) the integration of off-site produced blades during the LC2 can be interpreted as a direct consequence of the success of these new economic strategies and the activation of distribution networks on a broader scale, testifying that the development of socially shared large "idea". The graduality in the process of replacement of lithic technologies at the site was previously seen even in the modalities of composite tools manufacture and use. During the LC 3, the domestic sphere did not produce anymore their blades for composite tools. Imported large blades produced by the lever system replaced the local tradition, revealing that the living units only managed the manufacture of composite tools. However, blades and bladelet productions using locally supplied materials are attested, even by employing the pressure technique (short/long crutches), indicating continuity from earlier periods. However, none of such items bears macroscopic evidence of gloss. Decreasing trends in the degree of cores exploitation aimed at producing flakes are also attested.

The LC 2/3 period at the site also represents the phase of maximum expansion of the site (10 ha) and growing social complexity is evidenced by the presence of a public building (LC2) and a large tripartite administrative building (LC3).

The LC 3 period represents a chronological marker for the appearance of such specialised products in the Erbil Plain, as the Surezha evidence also suggests which showed similar evolutive trends through time (see chapter 1). Large blades characterises also the lithic assemblages coming from new research carried out in the Erbil Plain at the LC-EBA site of

Bash Tepe (Angevin 2015) and further south at the Gir-i-Shamlu which revealed comparable trends with Helawa evidence (Manclossi *forth.*).
During the 4th millennium BC, the activation of specialised knapping workshops to produce large blades directly beside the sources is supported by the Jebel Zawa chert mines, located further north (see chapter 4). Possible extra-regional relationships between these areas are faced in chapter 7.

6. BUILDING A GEOLOGICAL REFERENCE COLLECTION

1. The regional geological setting

Iraq lies at the transition between the Arabian Shelf in the west and the intensely deformed Taurus and Zagros Suture Zones in the north and north-east (Jassim and Goff 2006). The Zagros Fold and Thrust Belt is an orogenic belt and it is seismically active. It extends longitudinally, with NW-SE orientation, over 1800 km, starting from Northern Iraq until the Strait of Hormuz in Iran; the highest peaks (2000-2500 m asl) are in correspondence of the geographic and political borders with Iran. The whole geologic history of the territory is thus related to the events that caused the uplift of the Zagros Mountains, which originated as a result of the collision between the Eurasian and Arabian Plates. The convergence began in the Late Cretaceous and was the last of a series of extensional-convergent events within the extensive Alpine-Himalayan orogenic system (Jassim and Goof 2006). From a structural point of view, the territory corresponding with the Kurdistan Region of Iraq, which entirely covers the northern area of the country, is conventionally subdivided into two domains: the High Folded Zone (HFZ) and the Low Folded Zone (LFZ).

1.1. The High Folded Zone (HFZ)

The limits of the HFZ correspond with the unstable Imbricated Zone in the north (the main thrust fault of the Zagros Suture Zone; Sissakian et al. 2014a), while the southern limit is represented by the continuous ridge of the Pila Spi Formation (Fm) which is exposed at his footsteps all over the area (Sissakian et al. 2014a).

From a geomorphological point of view, the HFZ features elongated and elevated chains reflecting the anticlinal structures which are separated by synclinal troughs, forming flat plains with local slight undulations (Sissakian et al. 2014b). The mountainous areas reach elevated altitudes and are intercalated by small valleys and streams. The flat areas constitute the initial parts of the main plains, little covered by vegetation and clastic sediments belonging to different formations up to the Quaternary era (Sissakian et al. 2014a).

The oldest rock units exposed belong to the Early Triassic-Eocene cycle, which mainly consisted of the deposition of marine carbonates. These sediments were deposited within an open deep to narrow close sea regime and later lagoon episodes.

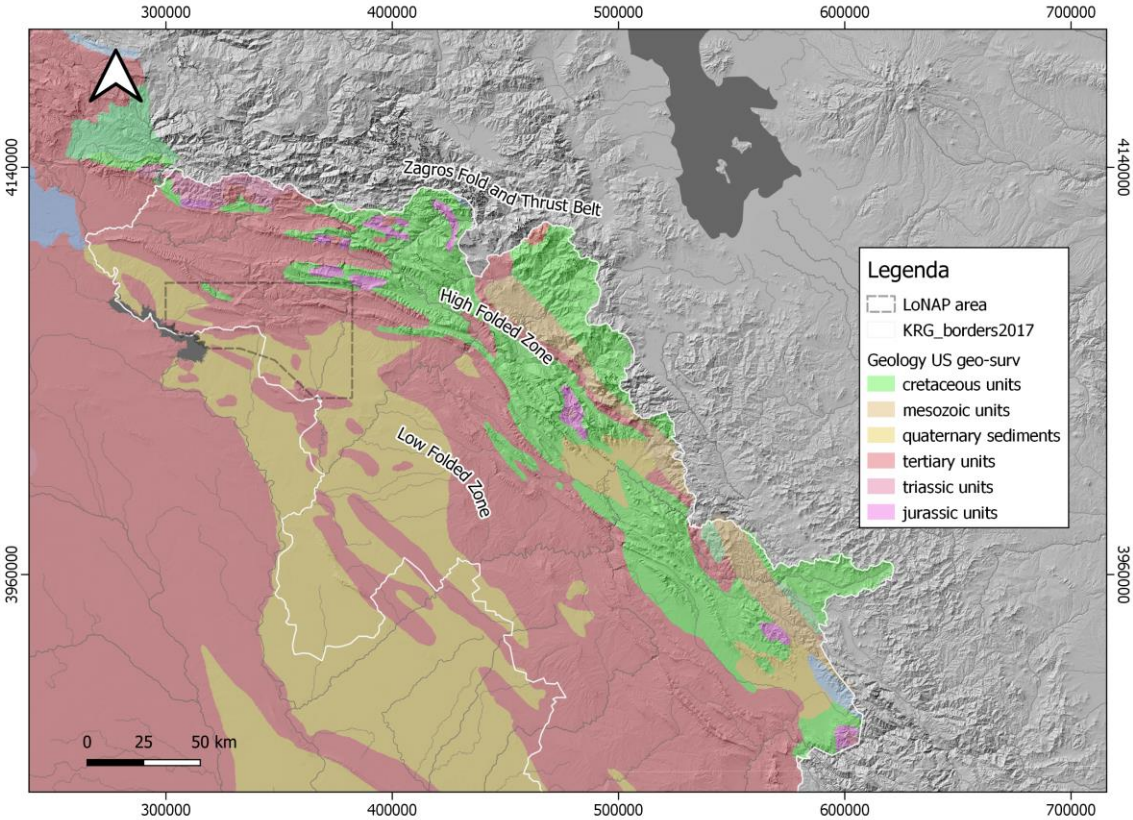


Fig. 1 Geology of the Kurdistan Region of Iraq, scale 1:2.000.000 (data source shapefile USGS).

The Oligocene, of restricted exposure, is characterised by reef to backreef environments, while the Early and Late Miocene features carbonates of marine, lagoonal and developed evaporites. The beginning of a continental setting is recorded since the Late Miocene until the Pleistocene when sediments of various nature deposited in a sinking foredeep. The final setting of landscape occurred since the latter period, when river terraces, alluvial fans and calcrete deposits, along with rare glacier moraine sediments, are recorded.

1.2. The Low Folded Zone (LFZ)

The LFZ corresponds with the territory comprised within the continuous ridge of the Pila Spi Fm in the north and the Mesopotamian plain in the south. The area is also known as "Foothills Province" due to its undulated morphologies (Yacoub et al. 2012). It covers a less significative area – for the present work – of the Kurdistan Region and Iraqi territory. Tectonic and structural effects have controlled the type of the exposed rocks, their thickness, and surface to subsurface extensions of the involved formations (Sissakian et al. 2012). Certain complexes – dating back to the Late Cretaceous – are restricted to the anticlines, which have longitudinal orientation and narrow shapes (Sissakian 2014b).

Two major fluvial basins dissect the area: the system of the Tigris River and the Mosul Lake in the northwest, and the Greater Zab, and its tributaries, in the northeast (Sissakian et al. 2012).

1.3. Paleogeography

Few data are available for the depositional history preceding the Triassic, whereas a detailed scan of the geologic events is recorded from 252 Ma onwards (Buday 1980). Starting with the Triassic (252.6 – 201.3 ± 0.2 Ma), the Neo-Tethys ocean was gradually widened, and a breakup unconformity formed along the northeastern edge of the Arabian Plate. The unconformity led to the deposition, due to thermal subsidence, of a massive sequence along the eastern and northern margins of the Arabian Plate (Sissakian 2014a). During the Mid-Late Triassic, the separation of the Iranian from the Arabic Plate provoked a rapid collapse of the previous basin and the thinning of the continental crust.

It is only during the Early Jurassic (201.3 ± 02 – 174.1 ± 1 Ma) that the rate of subsidence on the northern margins of the Arabian Plate slowed and caused the deposition of shallow-water lagoonal carbonates, uniform marginal clastics and evaporites. During this time, the Neo-Tethys ocean reached its maximum thickness (Sissakian et al. 2014a).

A new phase of Neo-Tethys ocean floor spreading occurred during the Cretaceous (145 ± 0.8 – 66 Ma) when a large intra-shelf basin was filled. The opening of the ocean floor caused the split of a micro-continent from the Arabian Plate which during the Late Cretaceous had approached the trench of the intra-oceanic subduction zone (Sissakian et al. 2014a). A foreland basin formed around the northern margin of the Arabian Plate in response to loading of the crust by thrust sheets generated due to compression. The Neo-Tethyan ophiolites were thrusted further onto the Arabian Plate and elevated above the sea level and, finally, rapidly eroded. The erosion products were deposited as flysch sediments (Jassim and Goff 2006).

Of major interest is the subsequent cycle, pertaining to the Middle Palaeocene - Late Eocene (61.6 – 33.9 Ma), when the Neo-Tethys ocean was restricted and closed during the final phase of the subduction. The old Late Cretaceous thrust belt was uplifted and delivered sediments to the new foreland basin in which the Kolosh and Gercus Formations were deposited (Buday 1980). The presence of conglomerate and pebbly sandstone in the top of the Tanjero Fm (Sissakian et al. 2014a) indicate the break in sedimentation and sub-aerial weathering, which marks the Cretaceous-Tertiary contact (Al-Shaibani et al. 1986). Alongside the foredeep and within shallow lagoons the Pila Spi Fm was deposited.

At the end of the Eocene and during the Oligocene (33.9 – 23.03 Ma), the main intraplate basin became narrower due to the tilting of West Arabia and uplifting of the present days' area of the HFZ. The following Miocene sequence (23.03 – 5.33 Ma), developed in broad and shallow basins and was characterized by a great sea-level drop causing very limited depositional basins. The main intraplate basin became narrower due to the tilting of west Arabia (Sissakian et al. 2016).

Finally, the end of the marine and the beginning of the continental phase occurred during the Late Miocene - Pliocene, when the basins formed due to a major thrusting of the Sirjan Zone (today's south-western Iran) with the Arabian Plate, were filled by continental sediments. In the meantime, the Zagros Suture Zones continued to intensely increase, and the erosion products were deposed in the foreland basin, originating the Injana, Mukdadiya and Bai Hassan Formations (Sissakian et al. 2014a). It is only with the Pleistocene - Holocene that the present landforms started to develop. Polygenetic sediments filled the synclinal troughs and the alluvial fans originated along the main mountain chains. A considerable part of the area (i.e. Ninive and Erbil Plains) was covered by residual soil due to weathering processes (chemical and mechanical) which also still affect today the anticlinal ridges consisting mainly of carbonate rocks (Sissakian et al. 2012).

2. Chert availability in the Northwestern Iraqi Kurdistan

To reconstruct the regional availability of suitable cherts to produce large blades, a survey was conducted in the whole study area (Fig. 2). Priority has been given to the identification of chert outcrops in a primary deposition. Secondary deposits have been also checked (Tab. 1). This paragraph provides a brief overview by highlighting the criteria (i.e. suitability, availability) that led to contextualise the importance of the Jebel Zawa chert within the wide spectrum of local knappable resources.

Cherts lying in primary deposition have been identified in three outcrops: Gahli Hasherki (Gara Baran anticline), Eskafte Zeri valley (Jebel Al-Qosh) and Der Koch (Jebel Maqlub anticline). Their distribution follows the exposures of the Pila Spi Fm, which constitutes the ridge of most of the mountains along the convergence between the HFZ and LFZ. In the specific, two outcrops are located within the HFZ, while the last one belongs to the LFZ. The difference is not only geographic; several factors that influenced the suitability of the contained cherts need to be highlighted.

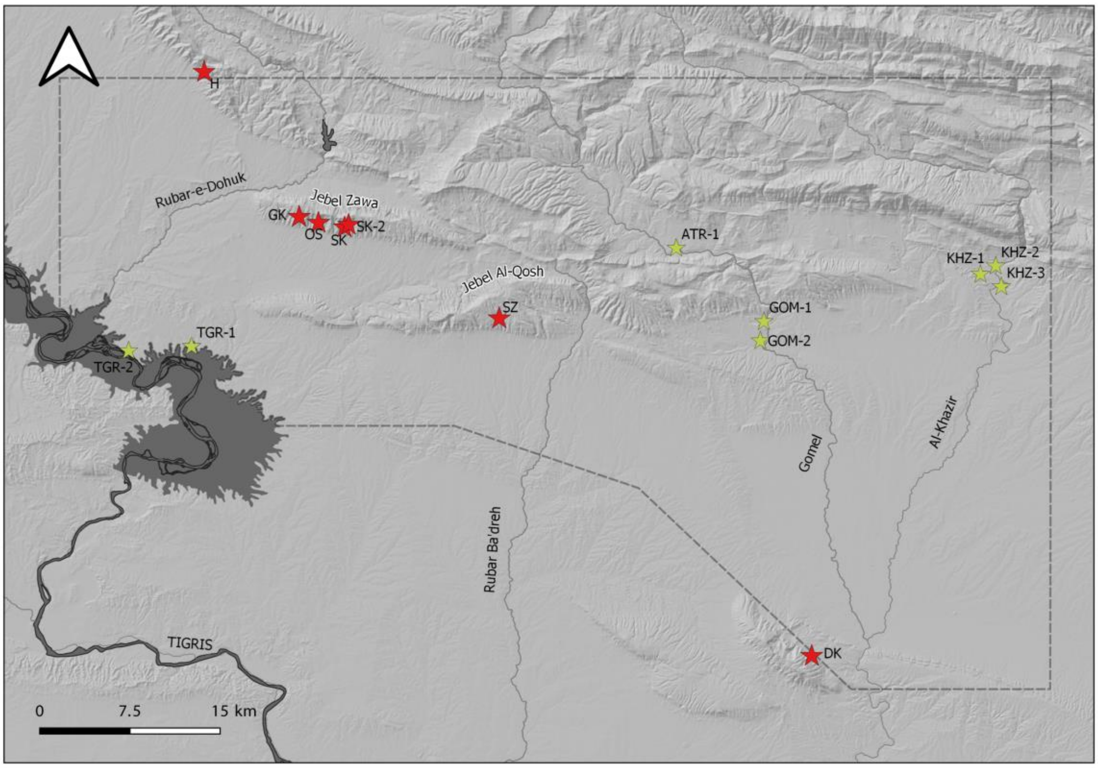


Fig. 2 Map of the LoNAP area showing the sampled outcrops: the red stars indicate primary sources, while the yellow ones indicate secondary alluvial deposits.

The Gahli Hasherki valley opens along the northwestern border of the study area (Fig. 2) and its morphology resembles those of the Jebel Zawa characterised by steep slopes. Although, the valley is less deep but rather large. A key point is represented by the presence of a major fault belonging to the Gara Baran anticline and related to compressive and deformative forces (Al-Obaidi and Al-Moadhen 2015). Thus, despite the high number of nodules observed in the outcrop, they appear completely fractured and their dimension is not suitable for knapping large blanks (Fig. 3, a).

A similar situation was found in the Eskafte Zeri valley on the Jebel Al-Qosh. The nodules belong to the Pila Spi Fm, which is the only geological formation exposed in the mountain (Sissakian et al. 2016). They have been identified along the deeply cut valleys which characterise its southwestern sector. Large variability in size and shapes has been recorded, with prevailing thin lenticular and irregular shapes (Fig, 3, b).

A further primary outcrop has been recognised on the northern side of the Maqlub anticline, which lies at the southern border of the study area and characterised by an almost exclusive exposure of the Pila Spi Fm (Fig. 2).

Code	Name	Type	Geology	N of samples
SK	Shik Hidir, Jebel Zawa	primary	Pila Spi Fm	45
SK2	Shik Hidir 2, Jebel Zawa	primary	Pila Spi Fm	7
GK	Gahli Kahni, Jebel Zawa	primary	Pila Spi Fm	21
OS	Old Sharya, Jebel Zawa	primary	Pila Spi Fm	10
SZ	Eskafte Zeri, Jebel Al-Qosh	primary	Pila Spi Fm	6
H	Gahli Hasherki, Gara Baran	primary	Pila Spi Fm	4
JM	Der Koch, Jebel Maqlub	primary	Pila Spi Fm	10
ATR-1	Atrush River, Meersida	secondary	old alluvium	13
TGR-2	Tigris River, Chamerash	secondary	old alluvium	17
TGR-1	Tigris River, Nemrik	secondary	recent alluvium	14
GOM-1	Gomel River, Khinis	secondary	old alluvium	8
GOM-2	Gomel River, Khinis	secondary	old alluvium	7
KHZ-1	Al-Khazir, Newrok	secondary	recent alluvium	5
KHZ-2	Al-Khazir, Newrok	secondary	old alluvium	5
KHZ-3	Al-Khazir, Newrok	secondary	recent alluvium	3
	Total			175

Tab. 1 Table showing general information about the sampled outcrops.

Here, the quality of chert raw material is fine, but the nodules are small and low in number (Fig. 3, c). In addition, some outcrops – and related nodules embedded in the formation – are highly weathered.

A series of secondary deposits have been identified. These are related to several alluvial phases (old and recent ones) related to the main tributaries of the Tigris River: Atrush, Gomel and Al-Kazhir rivers. In these contexts, cherts occur sporadically in form of small rounded pebbles and gravels, alongside a wide variety of different lithotypes (Fig. 3, d, f-h). Even the knapping aptitudes are quite diversified: it can vary from medium to low.

Finally, it is important to discuss the secondary deposits of the Tigris River (Fig. 3, e). The morphology of the northern course of the river has deeply changed due to construction of the Mosul Dam. This has had an impact, not only on the preservation of archaeological sites located along its course (Killick and Black 1985) but also on the visibility of the Quaternary terraces.

Nowadays, the highest terraces (about 150 m asl) are visible only in few points within the study area (TGR-1/2; Fig. 2) and form small hills eroded on the flanks by wadi streams. The exposed rocks in the river basin are mainly of clastic nature with very rare limestone and

Fig. 3 Overview of the primary and secondary chert outcrops identified in the area: Gahli Hasherki (a); Eskafte Zeri (b); Der Koch (c); Atrush valley (d); Tigris River (e); Gomel River (g); Al-Khazir River (h).

gypsum of the Fatha Fm. The age of the exposed rocks ranges from Middle Miocene up to Pliocene with different types of Quaternary sediments, such as river terraces, flood plain and valley fill sediments (Al-Dabbagh and Al-Nabiq 1991). Here, the availability of chert is high and consists of small rounded pebbles as well as large nodules. Even if these latter allow to produce large-sized blanks, their quality (internal fractures and heterogeneities) to not permit to systematically exploit them to produce standardised blades.

3. The Pila Spi Fm in the context of the Jebel Zawa

The geology of the Jebel Zawa, also known as the "Dohuk anticline" (Fig. 4), is characterized by the Mid-Upper Eocene (40 Ma) Pila Spi Limestone Fm, deposited in suspended basins on a passive plate margin during the Alpine orogenic phase (Numan et al. 1998; Kadhim and Hussein 2016). The Pila Spi Fm was deposed in a restricted to semi-restricted marine and lagoonal environment (Sissakian and Al-Jiburi 2014a). Locally, the formation consists of a succession (Fig. 5), from top to bottom, of a series of lithified beds of calcareous dolostone to well-bedded dolostone and massive cherty dolostone. The chert horizons occur toward the middle-lower part of the formation, in a layer of dolostone with karst cavities, and toward the top in correspondence to a dolostone stratum (Fig. 5).

The overall carbonate content of the Pila Spi Fm is extremely high and still dolomitized (Numan et al. 1998). The soluble nature of these rocks, widely attested on a regional scale, produced the development of karstification, particularly intense in areas along the regional faults, with numerous surface and sub-surface forms (Stevanović et al. 2009). The local karst system is characterized by small caves and rock-shelters in correspondence with a more permeable horizon consisting of massive cherty dolostone interbedded with grey marls. These cavelets (entrances mean length 1-1.90 m; mean height 0.80-0.90 m) are often found in clusters, giving rise to deep and complex galleries, often interconnected (Fig. 6, c). Karst forms are testified by water percolation and occasionally associated with the deposition of thick layers of white carbonates on the ground. Due to uplifting and folding movements, the overall formation is very well exposed and accessible along the southern valleys and it is characterized by strong inclination (Fig. 6, a). Here the geomorphology has been modelled by the wadis, that have created valleys with very steep, eroded slopes, filled with rock debris and colluvial sediments transported by seasonal floods.

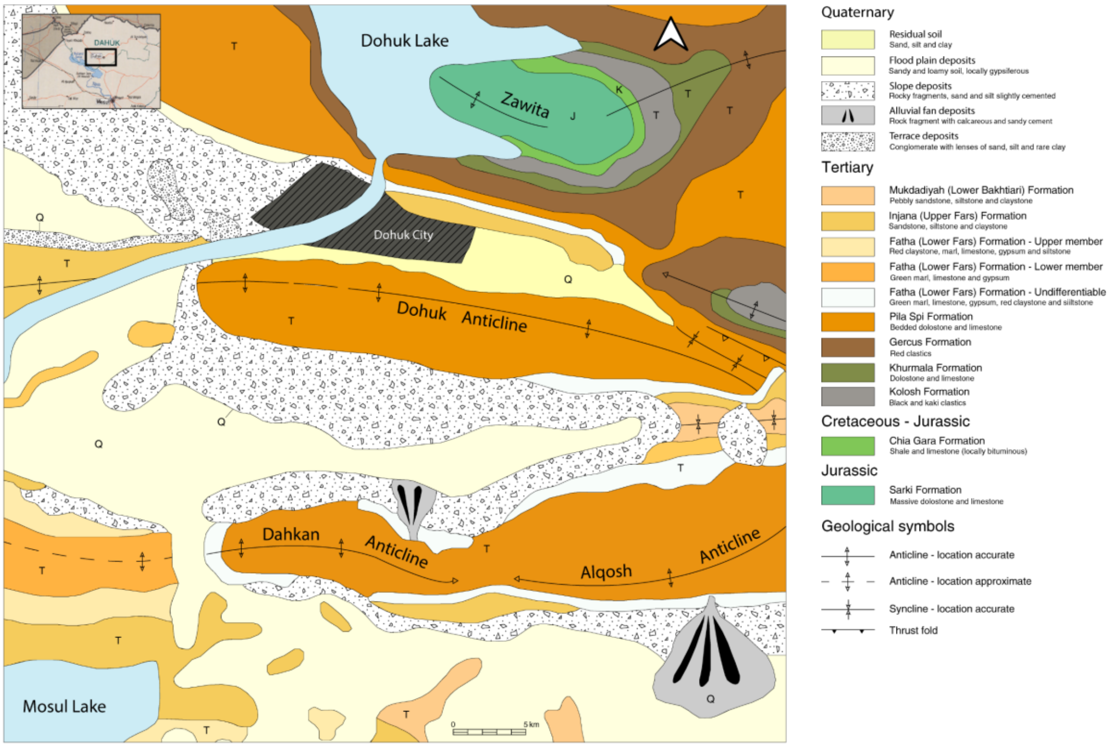


Fig. 4 Geology of the Dohuk area (modified from the Geological Map of Iraq 1995, Sheet NJ-38-13 Al-Mosul, scale 1:250.000).

The horizon containing chert nodules reaches a maximum thickness of about 20 m towards the top of the Jebel. Chert horizons can easily be recognized from the bottom of the valleys; they follow the inclined geological strata from there to the top of the mountains. Even today, chert is still available in large quantities, especially in the central valleys of the Jebel, where the mountain reaches its higher elevation and the chert-bearing layers are totally exposed. The raw material is thus easily accessible by following the limestone beds and the paths of modern shepherds along the cliffs. The chert horizon contains a large quantity of closely spaced nodules of various sizes. Large nodules are sub-circular or lenticular in shape. Tabular chert has been rarely recorded at higher altitudes along eroded ridges.

3.1. Sampling strategy

A total of 83 geological samples considered in this study were collected in three valleys: 45 from SK, 7 from SK2, 10 from OS and 21 from GK (Fig. 5). The valleys were selected according to their accessibility, extension, and the nature of the archaeological evidence.

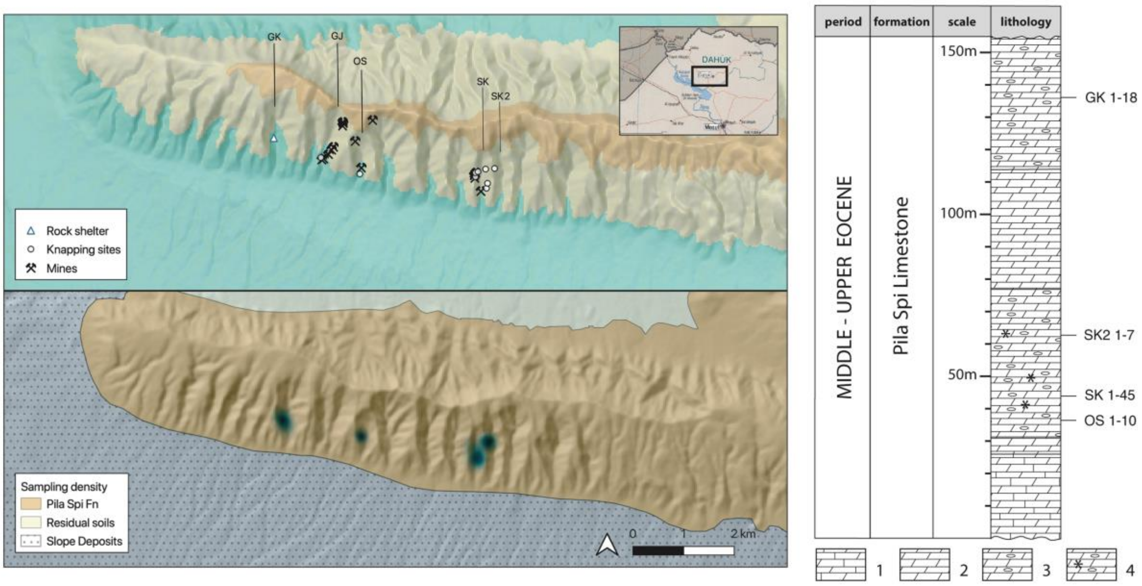


Fig. 5 Map of the archaeological discoveries made by the 2016-2018 LoNAP survey field campaigns in the Jebel Zawa (top); detail of the geological map showing the location and density of chert samplings (bottom); stratigraphy of the Pila Spi Fm in the Jebel Zawa (right; modified from Agha et al. 1978): calcareous dolostone (1), dolostone (2), cherty dolostone (3), cherty dolostone with karstic cavities (4).

Chert mining and knapping workshops are testified in the OS, SK and SK2 valleys (Fig. 6, f; Fig. 7, c; f; Fig. 9, f). The latter is now accessible only from the main SK valley, as the wadi cuts very deeply into the bedrock, giving rise to a canyon (Fig. 7, a).
OS valley is the smallest valley among the surveyed ones but also the largest in width. GK valley, located on the western part of the mountain, features the most ancient occupation,[1] but no evidence of chert mining related to the periods under examination has been recorded. Moreover, the typical karst cavities exploited for chert extraction in the former valleys do not exist in this valley, thus the chert exposures belong to the upper part of the Pila Psi Fm. The samples have been studied to highlight differences in chert selection and exploitation respect the other mining valleys.

4. Results

The data collected on the samples through the application of NM-PCI protocol[2] are (see Chapter 2) listed in the open-access database and ordered for each variable (Appendix A;

[1] The highly eroded archaeological deposit of the Gali Kahni rock shelter restituted evidence of three chronological phases of occupation at least: Middle Palaeolithic, Upper- or Epipalaeolithic and Neolithic/Chalcolithic (Conati Barbaro et al. 2019).
[2] Preliminary results from this work have been recently published (Moscone et al. 2020).

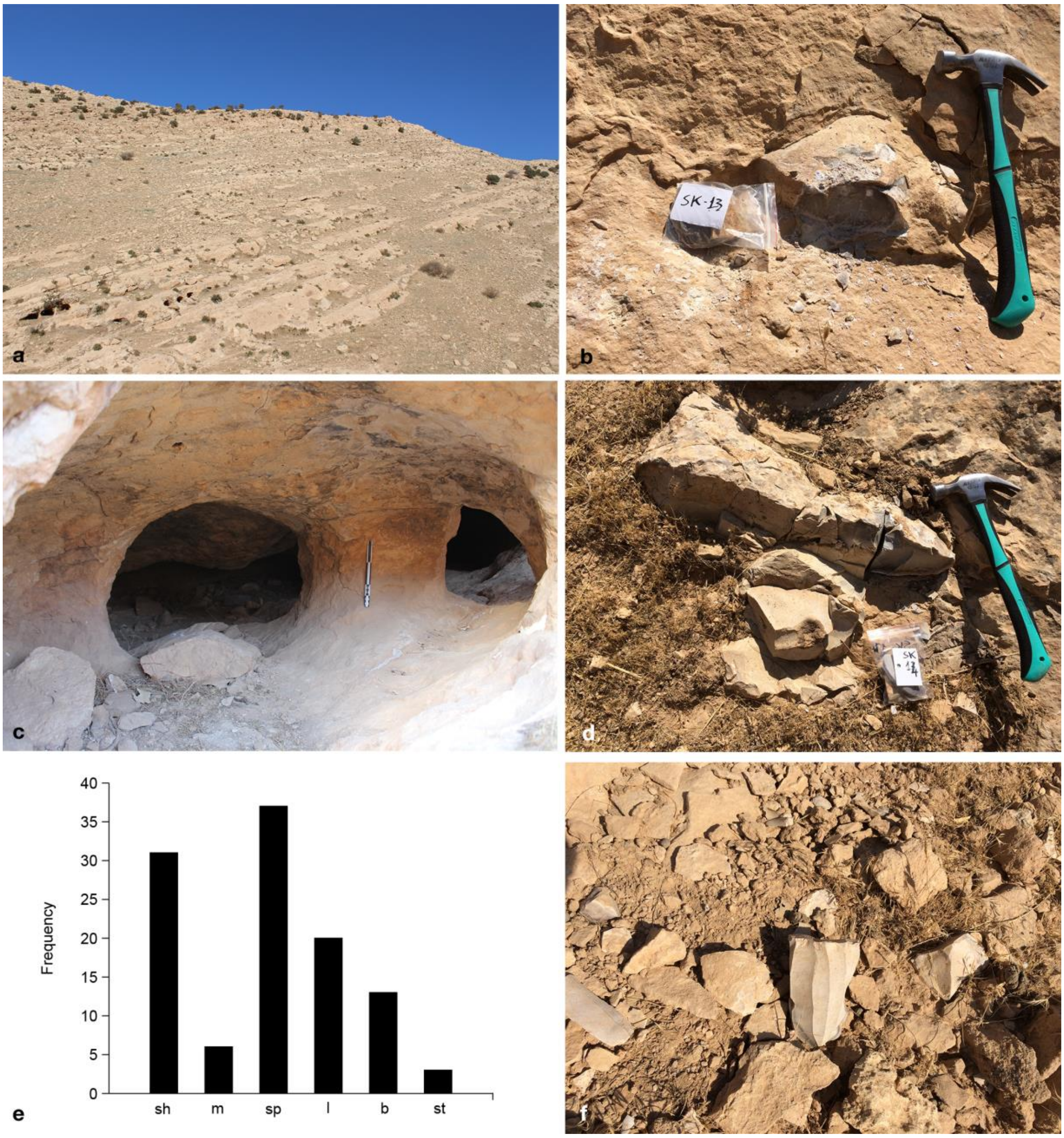


Fig. 6 Overview of the SK valley. Pila Spi Formation showing the cherty dolostone layers with karstic cavities (a); chert nodules (b, d); the entrance of one of the karstic cavities (c); pie chart showing chert structure variability (sh= shaded; m= mottled; sp= spotted; l= laminated; b= banded; st= streaked) (e); detail of artefact density in one of the lithic workshops (f).

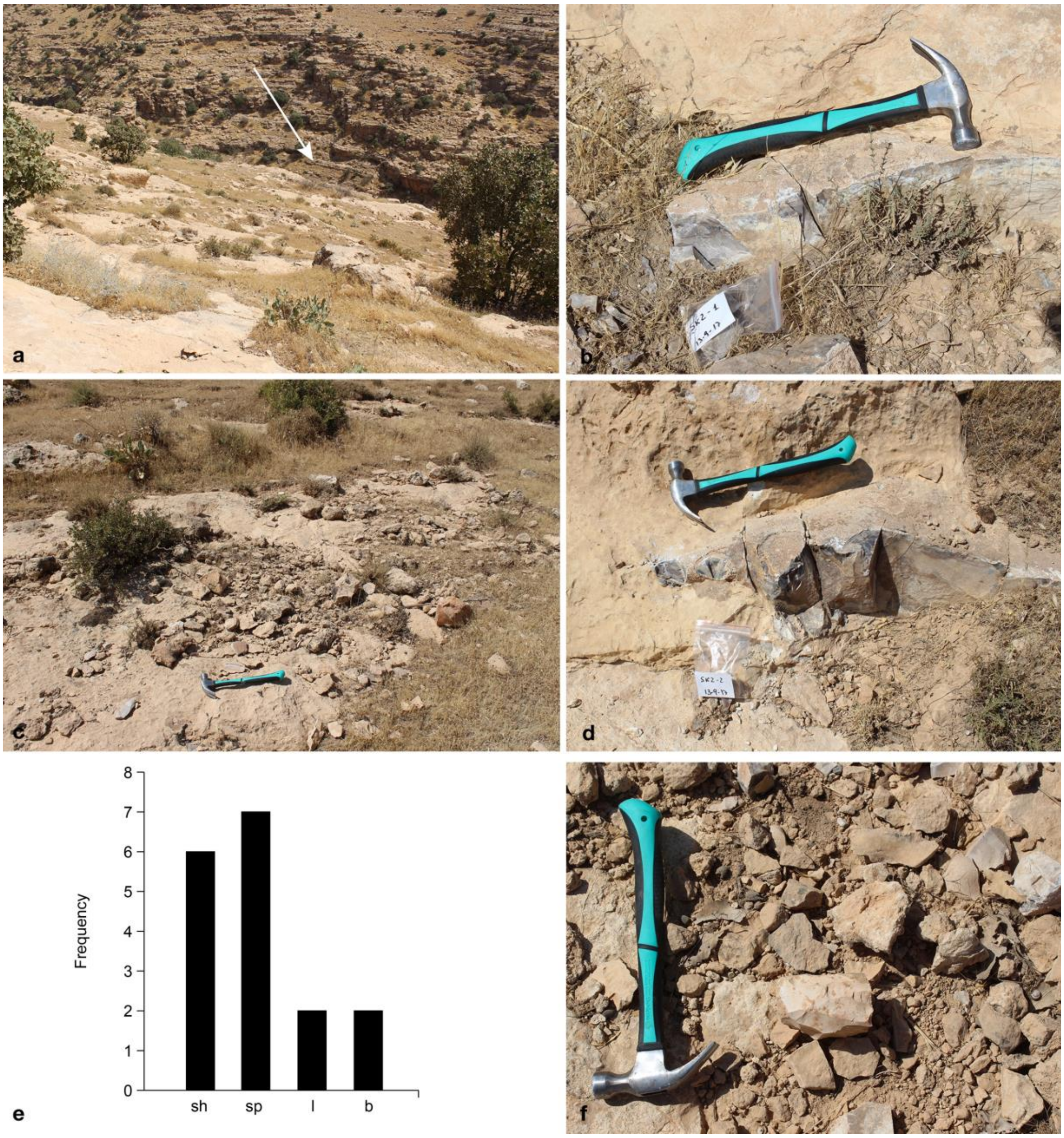


Fig. 7 General view of the SK2 valley. View of the valleys deeply cut by a narrow wadi (arrow) (a); chert nodules (b, d); view of the lithic workshop (c); histogram showing the occurrence of chert structures within the samples (sh= shaded; sp= spotted; st= streaked; l= laminated; b= banded) (e); artefact density inside the lithic workshop (f).

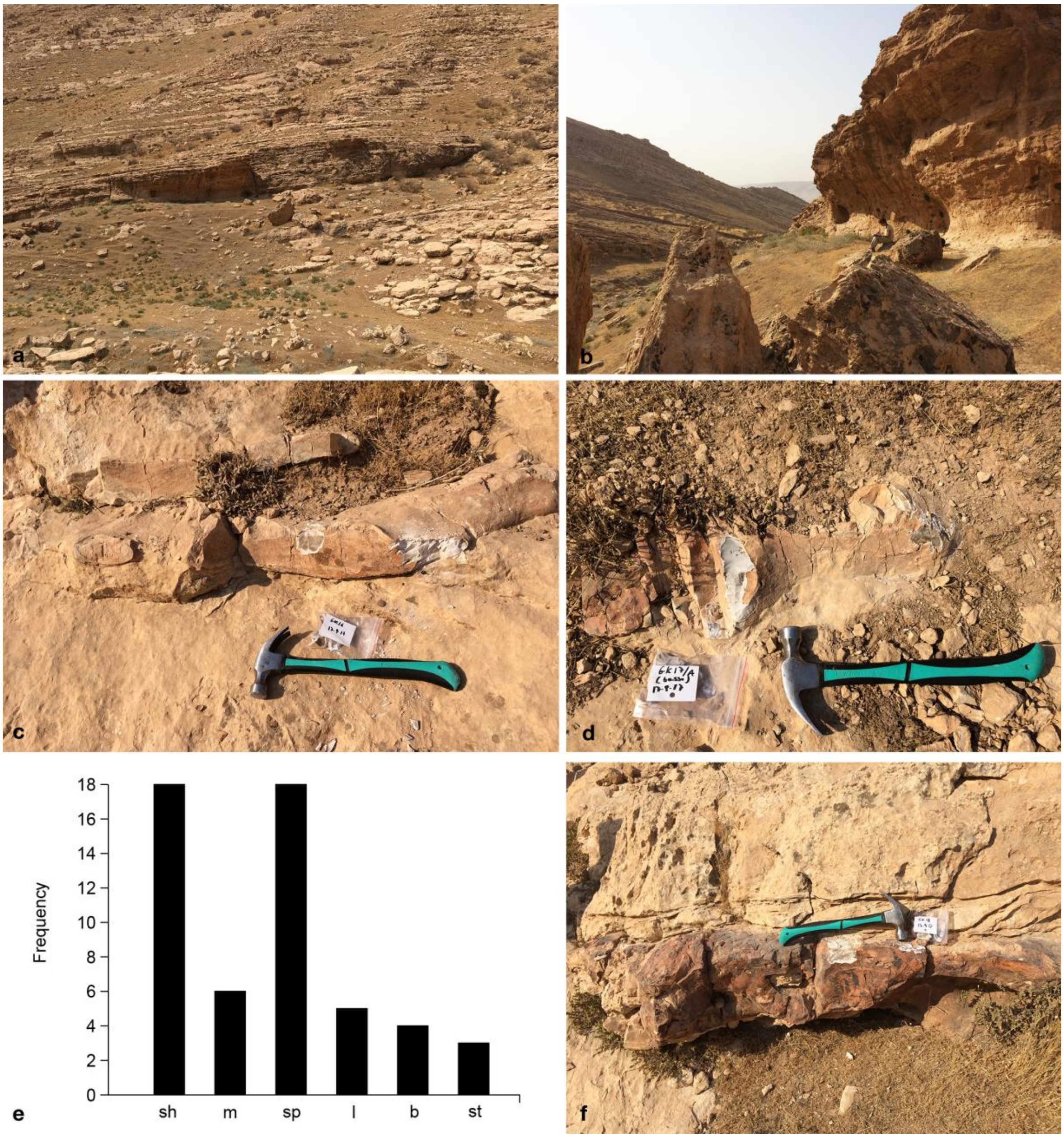


Fig. 8 General view of the GK valley. View of the valley (a); detail of the Gali Kahni rock shelter (b); chert nodules (c, d, f); histogram showing the occurrence of chert structures within the samples (sh= shaded; sp= spotted; st= streaked; l= laminated; b= banded) (e).

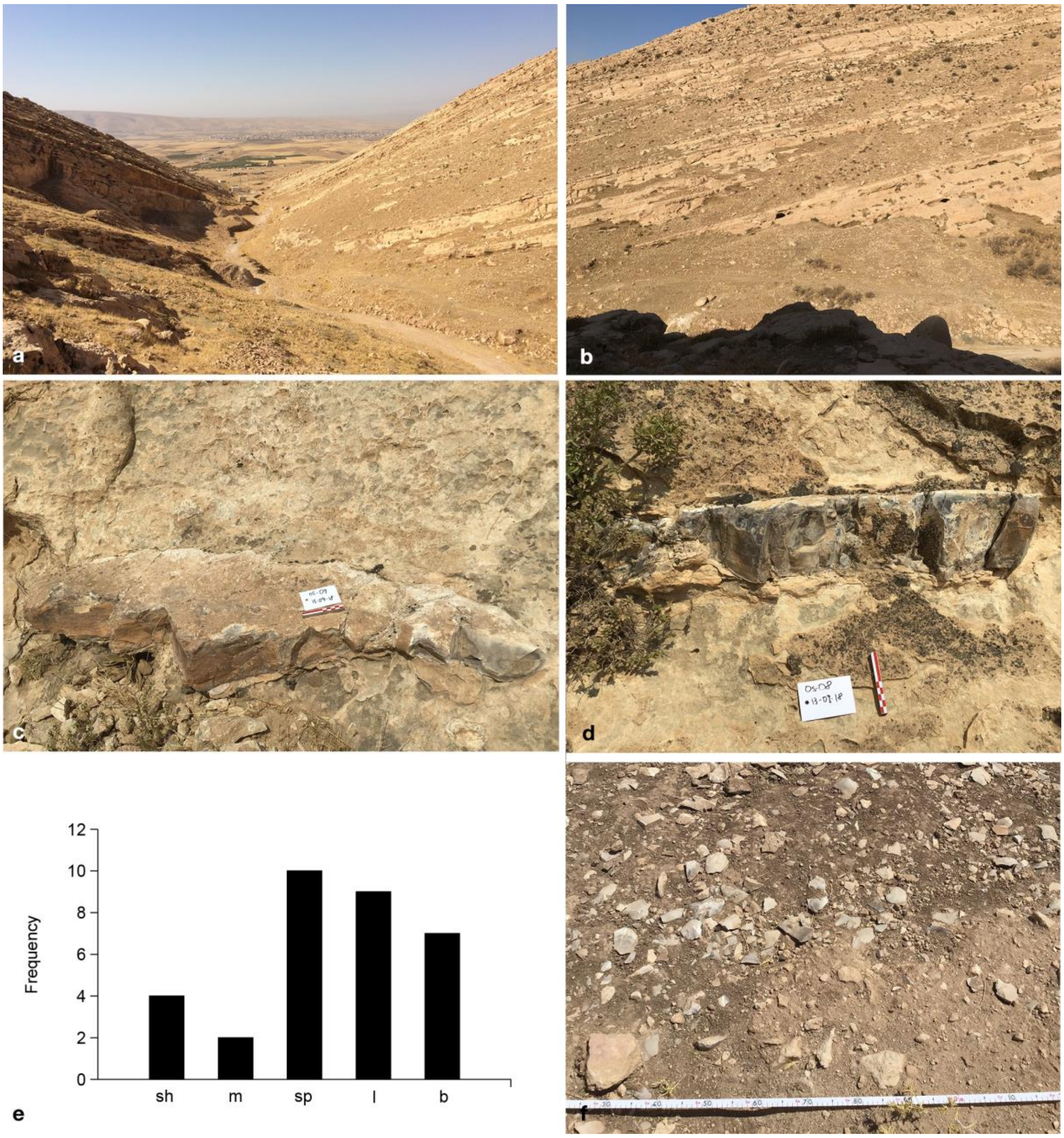


Fig. 9 General view of the OS valley. View of the valley (a); detail of the karst cavities (b); chert nodules (c, d); histogram showing the occurrence of chert structures within the samples (sh= shaded; m= mottled; sp= spotted; l= laminated; b= banded) (e), artefact density inside the lithic workshop site 980 (f).

Group		Cortex			Chert		
		Thickness (mm)	*Induration*	*Surface*	*Subcortex*	*Sorting*	*Fraction*
SK	*median*	1	1	1	1	1	3
	min	0	0	0	0	1	2
	max	5	2	3	1	3	3
SK2	*median*	1	2	2	0	3	3
	min	0	0	0	0	1	2
	max	3	2	3	1	3	3
GK	*median*	2	2	2	1	1	3
	min	1	1	1	0	1	1
	max	3	2	3	1	3	3
OS	*median*	1	1	2	1	1	2
	min	0	0	0	0	1	2
	max	2	2	3	1	2	3

Tab. 2 Median, maximum and minimum values for the most variable parameters observed in the four groups of cherts: Thickness (mm), Induration (1= friable; 2= hard), Surface (1= harsh; 2= rough; 3= smooth), Subcortex (0= absence, 1= presence), Sorting (1= poor sorted, 2= moderately sorted; 3= well sorted), Fraction (1= 0-10%; 2= 10-50%; 3= 50-100%).

see also Appendix B for further examples). Given the assumption that all the chert samples belong to the same geological formation – the Mid-Upper Eocene Pila Spi Fm – the median values for each variable highlighted some discriminant factors between valleys (Tab. 2), which allowed to discuss in more detail the compositional features' variability at intra- and extra valley scales.

4.1. Compositional variability: intra-valley scale

4.1.1. SK group

The largest set of samples was collected in SK valley (45 samples; Fig. 10), which also yielded the largest amount of archaeological evidence. Nodules show a medium-high degree of sphericity (median=3) with high values of rounding (median=5) (Fig. 6, b, d; Tab. 3). Their visible size (Fig. 11) is generally 20-45 cm on the main axis (max. value 80 cm) and 10-15 cm on the minor axis (max. value 40 cm). Cortex is present on all but five of the nodules. The distribution of cortex thickness values (Fig. 12) shows a major peak of frequency at around 1 mm, and a minor one around 3 mm. The cortex is siliceous in all cases but two. The induration is generally friable, although a hard cortex was found on several nodules (Fig. 12). The surface is harsh or rough (Fig. 12) and there was a clear boundary

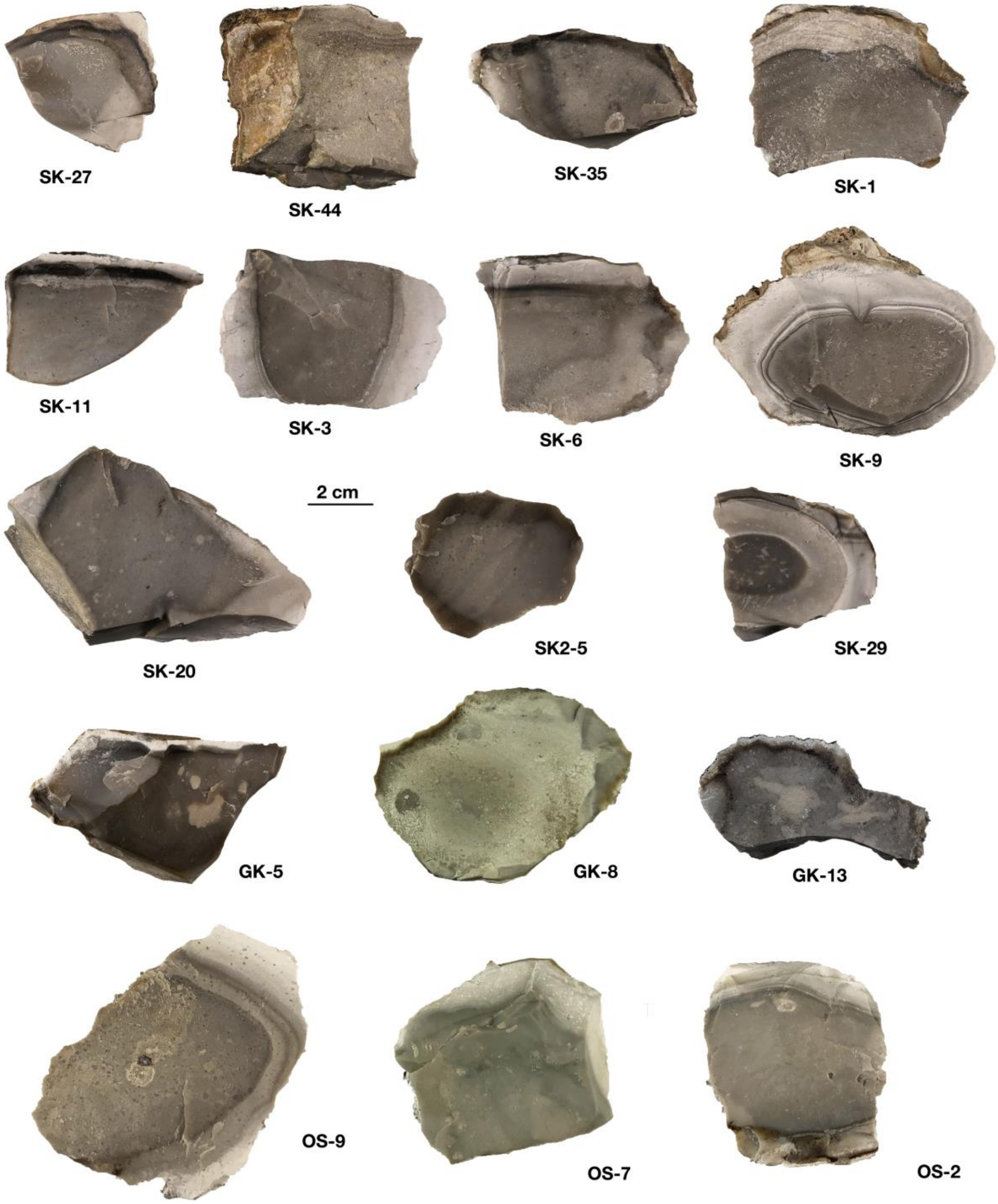


Fig. 10 Selection of chert samples analyzed.

with chert *sensu stricto*. As far as the latter is concerned, the subcortex is generally present (Fig. 12). Large variability was found concerning the structures. Mixed structures are mostly represented (Fig. 6, e). A prevalence of shaded and spotted heterogeneities is recorded, combined with mottled, laminated and banded ones. In some cases, thin concentric laminations are intercalated with bands. Chert colour coordinates (L*a*b*) are shown in

Group		Sphericity	Rounding	Main axis (cm)	Minor axis (cm)
SK	*median*	3	5	40	10
	min	2	3	10	5
	max	4	6	80	40
SK2	*median*	2	4	45	15
	min	2	4	40	10
	max	3	5	90	25
GK	*median*	2	4	40	10
	min	1	1	10	5
	max	4	6	100	20
OS	*median*	2	4	33	15
	min	2	4	25	10
	max	4	4	70	25

Tab. 3 Median, maximum, and minimum values of visible nodule size, sphericity and rounding recorded during the fieldwork. Sphericity values 0-1 (1= 0-0.25; 2= 0.25-0.50; 3= 0.50-0.75; 4= 0.75-1); rounding values 1-6 (1= very angular; 2= angular; 3= sub-angular; 4= sub-rounded; 5= rounded; 6= very rounded).

figure 13. Bands or specific areas of the cherts were treated as separate measurements and are listed as "non-dominant colour" in the statistics. The chert matrix dominant colour was mainly shades of light-grey. Bands and laminations, recorded as non-dominant colours, display blackish shades.

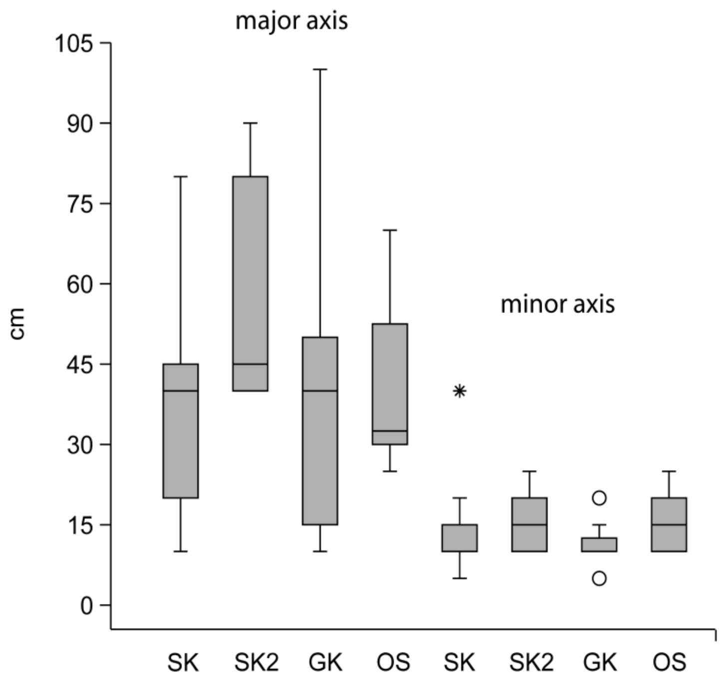


Fig. 11 Comparison of nodules visible size from the four valleys.

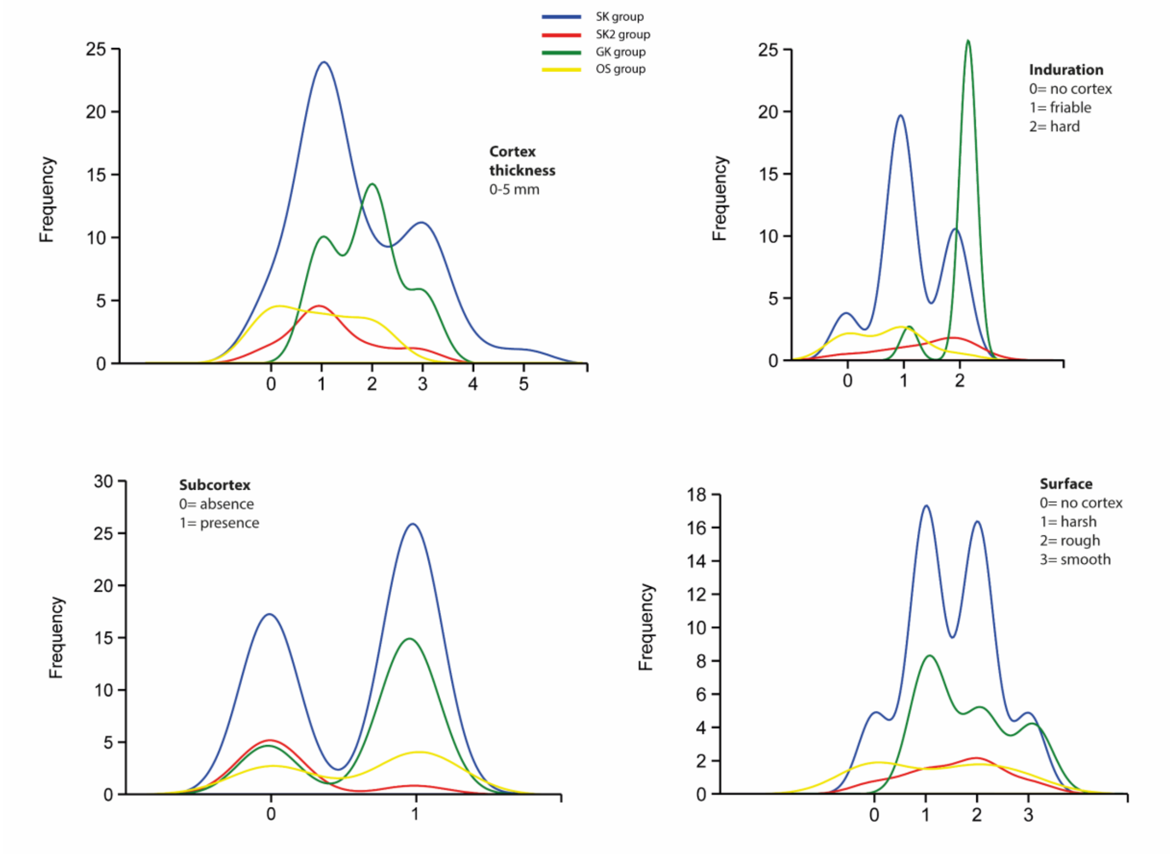


Fig. 12 Kernel density of values of the most variable macroscopic features, highlighting the variability of the chert samples from the four valleys.

At a microscopic scale, most of the chert samples were found not to be translucent. The textures are generally poorly-sorted with particle amounts (fractions) of more than 50% per sample (Fig. 14). Microfacies analyses (Fig. 14) highlighted a prevalent association between foraminifera and sponge spicules in a matrix rich in bioclasts and organic matter. Algae and gastropod shells are present in a few samples.

Figures 16-17 give the distribution maps of the samples, to show the spatial variability of distinctive features. Taking into account the macroscopic evidence concerning the cortex, it may be noted that the thickness of the different layers varies both vertically and horizontally. In the case of cortex induration, vertical and horizontal continuity is recorded in some parts of the outcrop, although there are significant differences between the two sides of the valley. Similar patterns have been observed for the cortex surfaces, too. As for the distribution of microscopic features, specific areas of the valley feature horizontal continuity in sorting distribution (Fig. 17). A large amount of poorly-sorted textures is found at contour line 720 m asl on both sides of the valley. Finally, the distribution of micro-palaeontological remains, namely bioclasts, foraminifera and sponge spicules (Fig. 17), attests horizontal more than

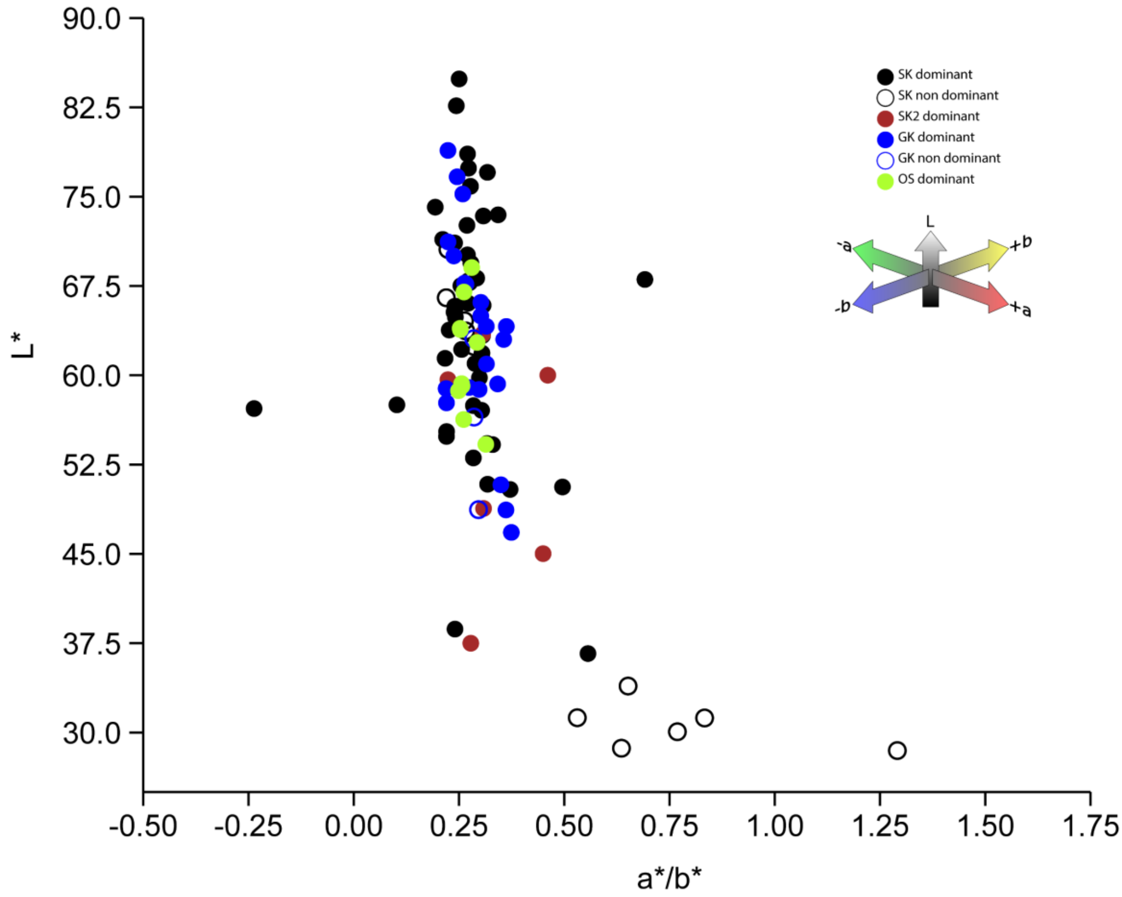


Fig. 13 Scatterplot of the colourimetric coordinates related to the four groups of cherts.

vertical continuity. However, differences may be noted in the distribution between the two valley sides.

4.1.2. SK2 group

The SK2 valley is in direct geomorphological continuity with the previous one. Archaeological evidence of blade-knapping has been found on the Western side of the wadi at high-altitude. Seven samples were collected from this area (Fig. 10). Nodules are less spherical compared to the previous valley (median=2; Tab. 3) and show less rounding (Fig. 7, b, d; Tab. 3). Maximum nodule size (Fig. 11) is found to be quite dissimilar with respect to SK; a major difference involves the main axis, which is larger (40-90 cm), while the minor axis follows the trend discussed for the previous valley (median=15 cm).

Cortex is present in all the samples except one, showing a peak in thickness frequency at around 1 mm (Fig. 12). It is siliceous in all cases. The induration is generally hard, and the surface is – in most of the cases – rough (Fig. 12). The subcortex is not present, except in one specimen (Fig. 12). The boundary with chert is generally clear. Chert structures are mostly represented by mixed shaded and spotted heterogeneities; as in the previous valley, combined laminations and bandings also occur. However, mottled inclusions have not been recorded here (Fig. 7, e). Chert colours display some significant variations compared to the former valley, especially in the overall prevalence of a single colour (Fig. 13). Dark colours appear to be dominant in a few samples analysed and they share some similarities with the non-dominant colour shades of the SK valley. The rest of the samples generally have light-grey colours.

The chert is not translucent. Conversely, the texture was found to be well-sorted (Fig. 14) with particle amounts of more than 50% per sample. As for the former valley, micro-palaeontological remains featured a predominance of bioclasts, foraminifera and sponge spicules (Figs. 14-15). The distribution maps (Figs. 16-17) show a similar trend of the variables discussed for the SK valley, although the reason may simply be the valleys' relative proximity. Either way, the reduced sample numbers did not allow comparison with the other side of the valley.

4.1.3. GK group

A total of 21 samples were analysed (Fig. 10). Nodules show similar morphological features to those of the previous valley (Fig. 8, c, d, f). The degree of sphericity has median values of 0.25-0.50 and the rounding is 4. However, nodules size shows substantial differences from SK2, whereas similarities are recorded with SK. The valley features the largest visible nodule main axis size (Fig. 11), which is around 1 m (median=40; Tab. 3), while the minor axis is smaller (median=10 cm).

The cortex is present in all the sampled nodules, a major difference is found with respect to the previous valleys (Fig. 12). As for the SK2 valley, it is siliceous. A peak in the thickness frequency values is recorded, at around 2 mm (Fig. 12). However, both thin (1 mm) and thicker (3 mm) cortexes are found (Fig. 12). The induration is hard for almost all the samples, while the surface tends to be more variable compared to the previous valleys (Fig. 12). The boundary with the chert is generally clear and the subcortex was noted on the largest number of samples (Fig. 12). Chert structures show essentially the same features described above, thus representing a common trait of all the sampled valleys. Most of the samples feature shaded and spotted heterogeneities. Laminations and bandings are also present. Finally, the presence of mottled inclusions can be compared to the SK valley, but locally assumes major importance in the composition of mixed structures (Fig. 8, e).

The dominant chert colour is light grey. Non-dominant colour shades, here again recorded, fall within the same main range, testifying minimum variations at intra-nodular scale, but significant differences with the other valleys (Fig. 13).
Microscopically, the chert is not translucent. Poorly-sorted textures (Fig. 15), with particle amounts of more than 50% per sample have been described, once again as in the SK valley. Micro-palaeontological remains are essentially the same also for this valley (Fig. 14).
As in the previous valley, the vertical and horizontal variability of selected features is high. Apart from the cortex induration (Fig. 16), which is prevalently hard, horizontal continuity was found only regarding the content of bioclasts, foraminifera and sponge spicules (Fig. 17).

4.1.4. OS group

The OS valley is located between GK and SK ones. A total of 10 samples has been collected from the left side of the valley, in correspondence with site 980, and then analysed.
The sphericity values of the nodules fall within the range (0.25-0.50) attested for both the SK2 and GK valleys (Tab. 3). At the same time, the rounding degree confirms this correspondence (median= 4; Tab. 3). However, their visible size is comparable with the nodules of the SK2 group for what regards the minor axis, while the main axis values are coherent with the general trend, even if the median value is slightly lower if compared with the other groups (Fig. 11). The cortex, attested on 6 samples, is siliceous and its surface is prevalently rough, while the induration is friable (Tab. 3). The boundary with chert is usually clear, and for most of the samples, a subcortex is present (Fig. 12).
The already described variability in chert structures seems to be a rule also in the present group. A major difference regards the incidence of banded and laminated structures which characterize almost all the samples, in association with spots. Shaded and mottled heterogeneities are little represented (Fig. 9). Any distinction was necessary to differentiate colour shades on the cherts. The main colour represented is light-grey (Fig. 13).
From a microscopic point of view, the chert is mostly non-translucent, and the texture is poorly-sorted, with few samples exhibiting moderately-sorted textures (Fig. 14). For what concerns the particle amount, most of the samples fall in the range between 10-50%.

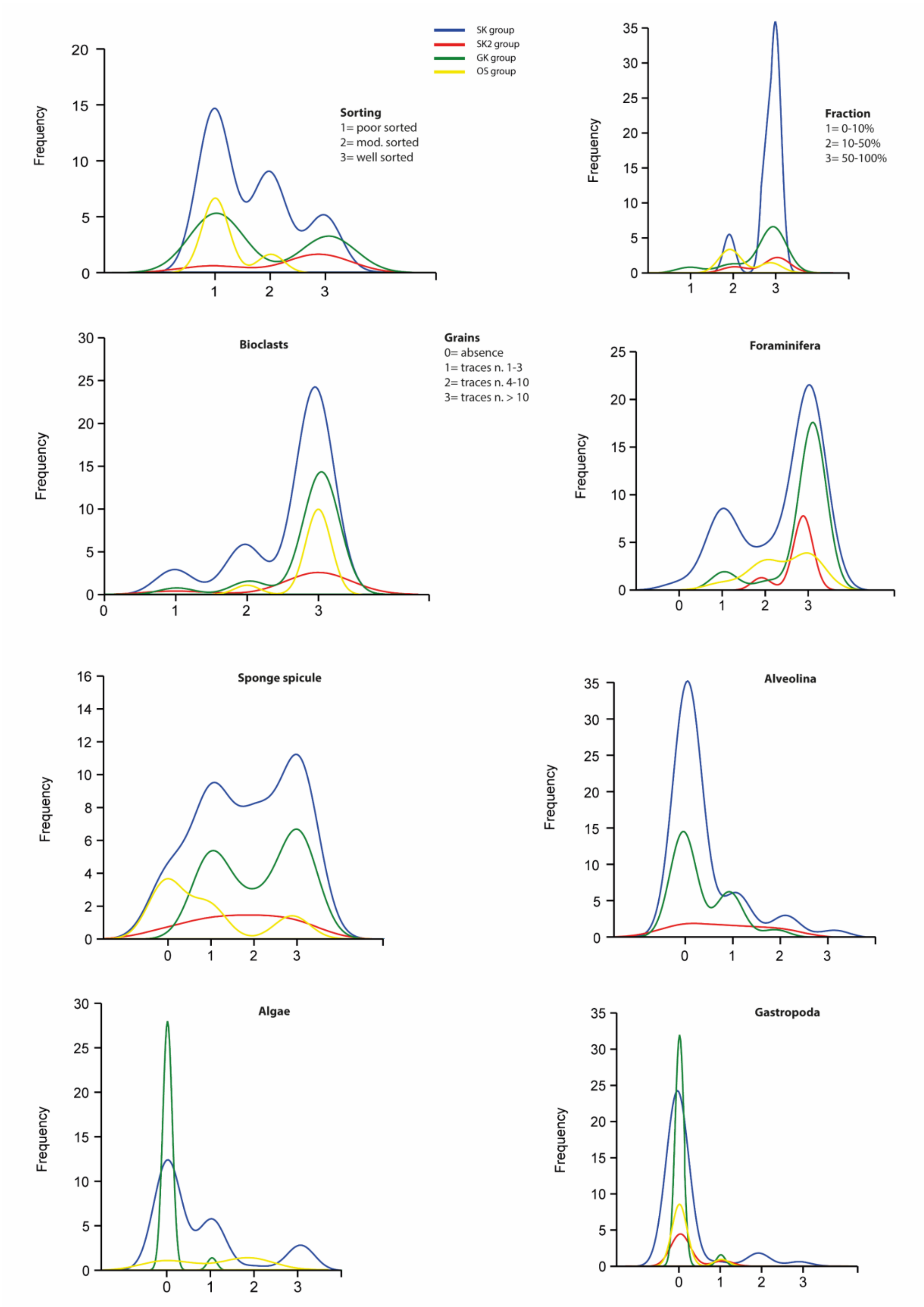


Fig.14 Kernel density of values of the most variable microscopic features and micro-paleontological content, highlighting the variability of the chert samples from the four valleys.

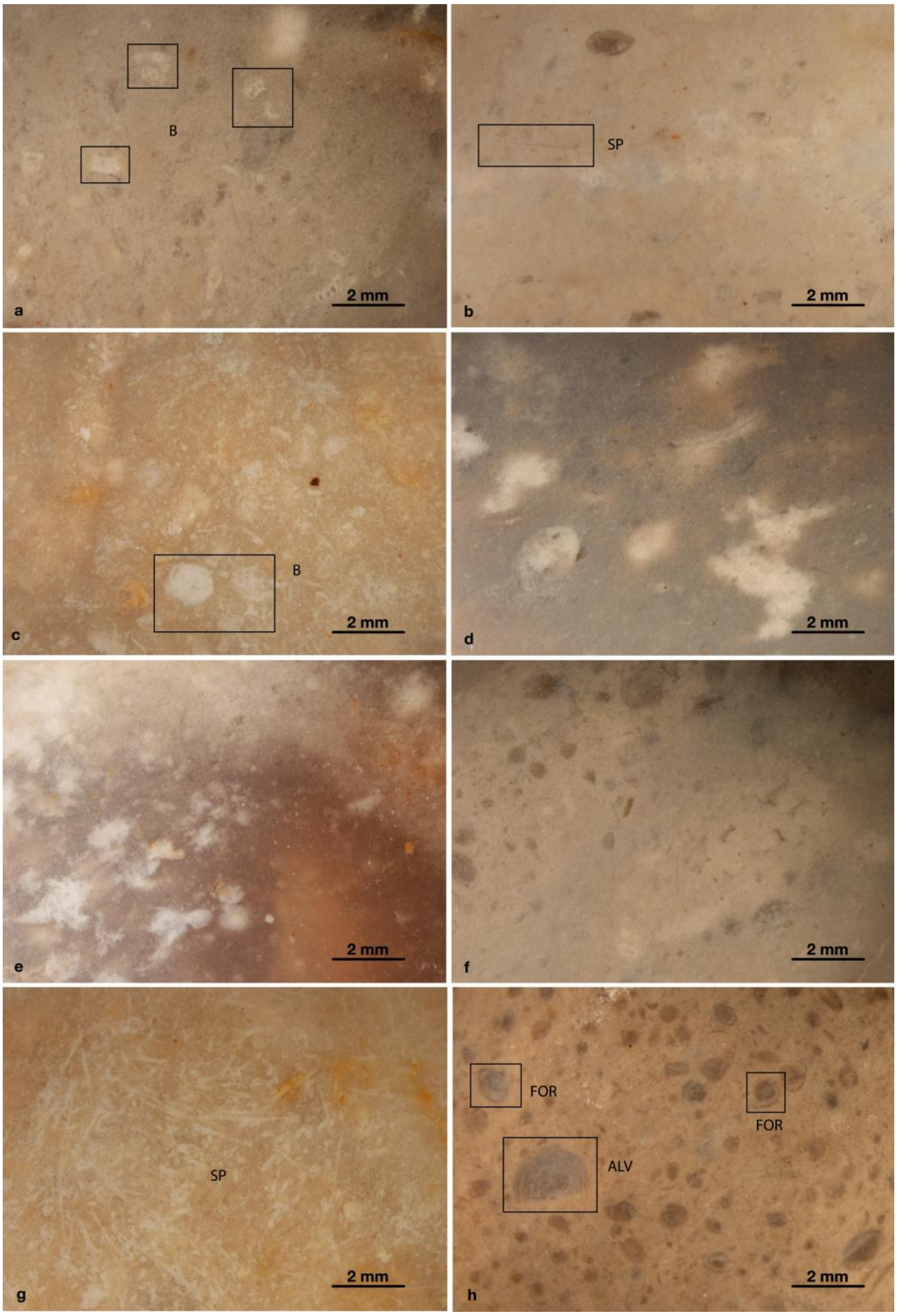


Fig. 15 Photographs taken with a stereomicroscope at low magnification (10x): textures and micro-palaeontological content of selected samples from the three valleys. Sample SK-4: poor-sorted texture, fraction >50%, B=bioclast (a); sample SK-11: moderately-sorted texture, fraction >50%, SP=spicula (b); sample SK-15: poor-sorted texture, fraction >50%, B=bioclast (c); sample SK-29: poor-sorted texture, fraction 10<x>50% (d); sample SK2-1: poor-sorted texture, fraction 10<x>50% (e); sample SK2-5: well-sorted texture, fraction >50% (e); sample GK- 17c: poor-sorted texture, fraction 10<x>50%; SP= spicula (f); sample GK-10: poor-sorted texture, fraction >50%, FOR=foraminifera, ALV= alveolina (h).

Few samples are comparable with the other groups (50-100%) (Fig. 14).
As for the other groups, the micro-palaeontological remains follow the trends already observed. It is worth to mention that in the present group, algae are well represented, while foraminifera decrease their importance (Fig. 14). These features separate the group from the others. The distribution of all the highlighted features is not of great significance as the case of the former chert groups, due to the reduced representativity of the valley's extension in the sample.

4.2 Compositional variability: extra-valley scale

These results highlight differences between cherts from the four valleys more at a macroscopic scale (Fig. 12) than at a microscopic one (Fig. 14). Regarding the former, several variables were found to be relevant: morphometric features of the nodules, presence or absence of cortex, thickness, induration, surface, subcortex and chert colours.
From a morphometric perspective, the nodules from the four valleys are different regarding their size. Although the median values show correlations between the groups, differences have been noted between the maximum and minimum values of the three groups (Tab. 3). Specifically, the GK group contains the largest nodules (main axis max. value=100 cm) but also the thinnest (minor axis range 5-20 cm). Values of sphericity and rounding for the latter contribute to a further separation of this group from the rest. In addition, the nodules from the SK group are found to be the most regular in shape of the entire sampling, along with the nodules from the OS group (Tab. 3).
SK, SK2 and OS samples possess a thinner cortex compared to GK. Although SK shows a wider range of values (thickness 1 to 5 mm), a thin cortex is more frequent (Fig. 12). Moreover, unlike GK, where all the specimens display cortex, several sampled nodules from the SK, SK2 and OS valleys do not have it. The induration is friable in SK and OS, while SK2 and GK display differing trends, with a predominance of hard cortex (Fig. 12). As for the surface, SK shows values between harsh and rough; smooth cortex is rare. This last trend is also observed for SK2 and GK (Fig. 12), which differ from the former valley for higher values of harsh cortex (SK2) and rough cortex (GK). The 6 samples from the OS valley are quite homogenous, displaying a rough one. The presence of subcortex is similar in SK, GK and OS valleys, while the trend is inverted in the SK2 valley (Fig. 12).
The chert colours recorded are prevalently light-grey and dark-grey shades. However, significant differences with respect to colour are found to be related to the structure types of

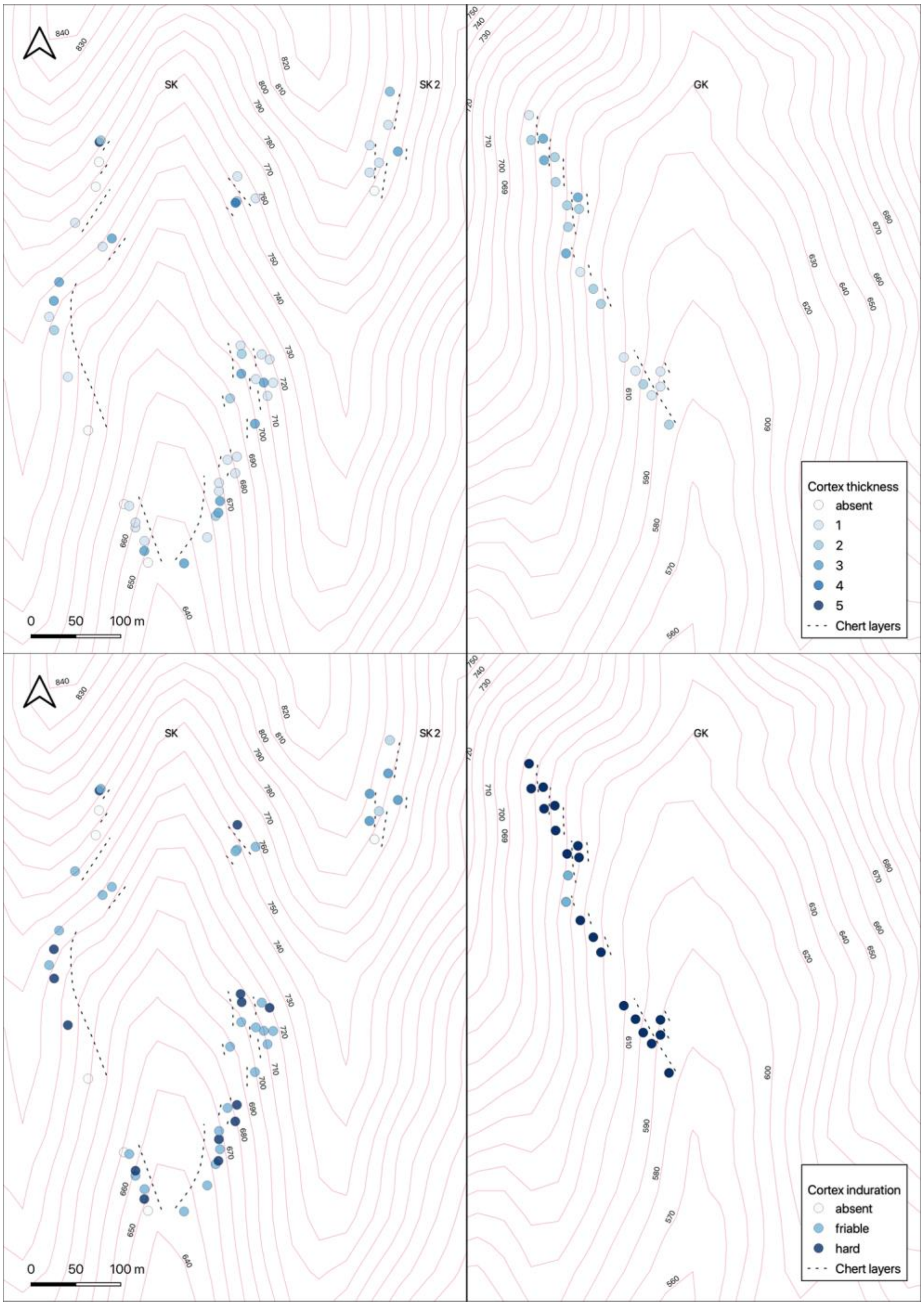


Fig. 16 Vertical and horizontal variability of cortex thickness (top) and induration (bottom).

chert *sensu stricto* (Fig. 13). This is the case for bands/laminations and specific areas, e.g. mottled or shaded inclusions. As for the SK group, these areas are very well separated in the graph (Fig. 13), featuring a black colour. In the case of GK, the non-dominant colours are mainly shades of grey. Further measurements were conducted for SK2. The cherts from this valley are quite homogeneous in colour, which varies from light to dark grey, but in this respect do not differ from the general trend. A significative homogeneity is also found in the OS group, were no intra-nodular differences between colours have been found.

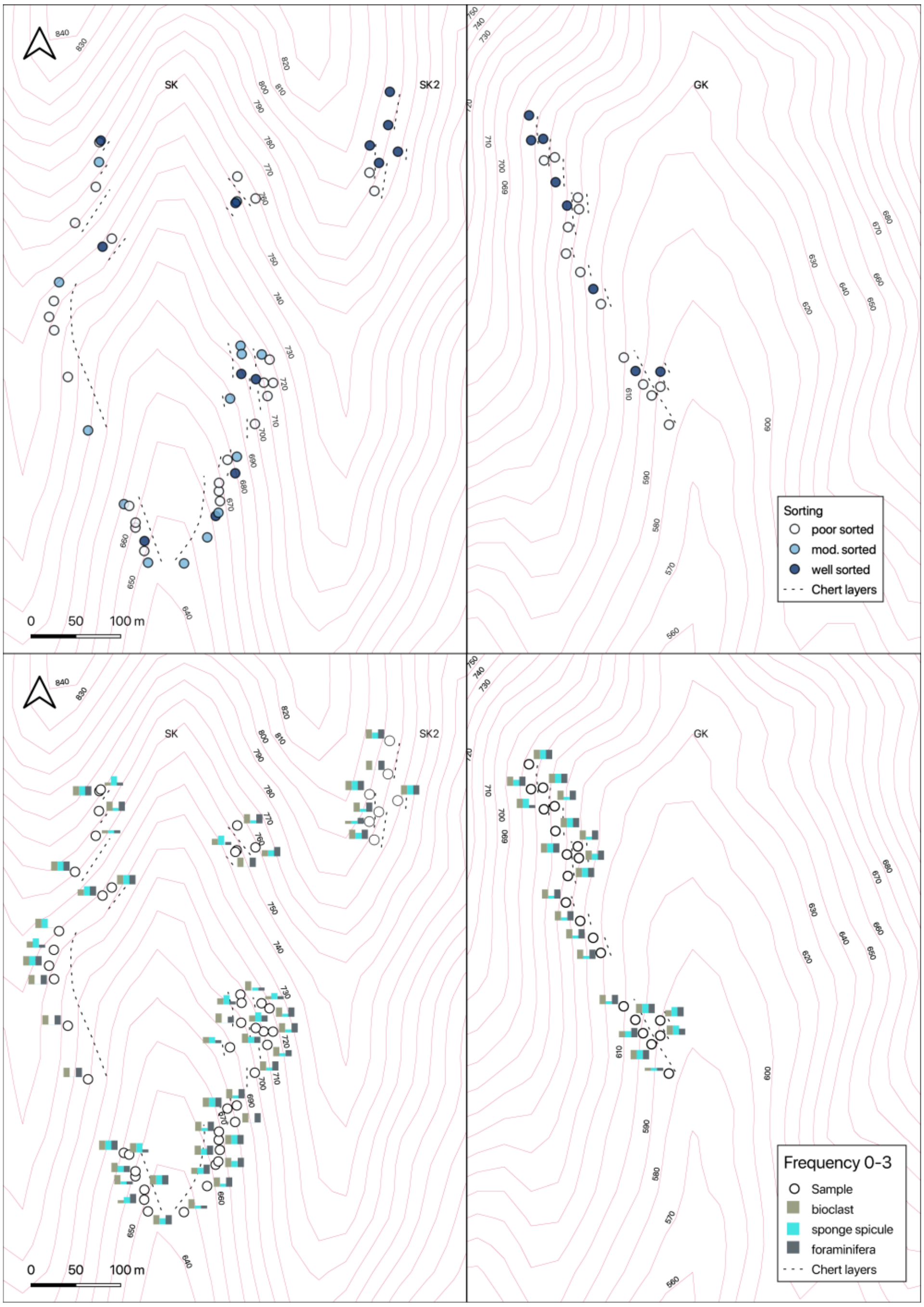


Fig. 17 Vertical and horizontal variability of micro-palaeontological content (the most represented species) in the analyzed chert samples. The histogram associated with each sample reports the values from 0-3, indicating the relative frequency of fossils and/or fragments (bioclasts) observed.

The micro-palaeontological content is generally homogeneous (Fig. 14). Despite their almost ubiquitous presence, sponge spicule content is found to be variable especially in the OS group. This latter, along with SK valley, differs for the presence of algae among the fossils. Although this distinction is statistically relevant, it must be remembered that different numbers of samples were collected from each valley. Textures were also found to be

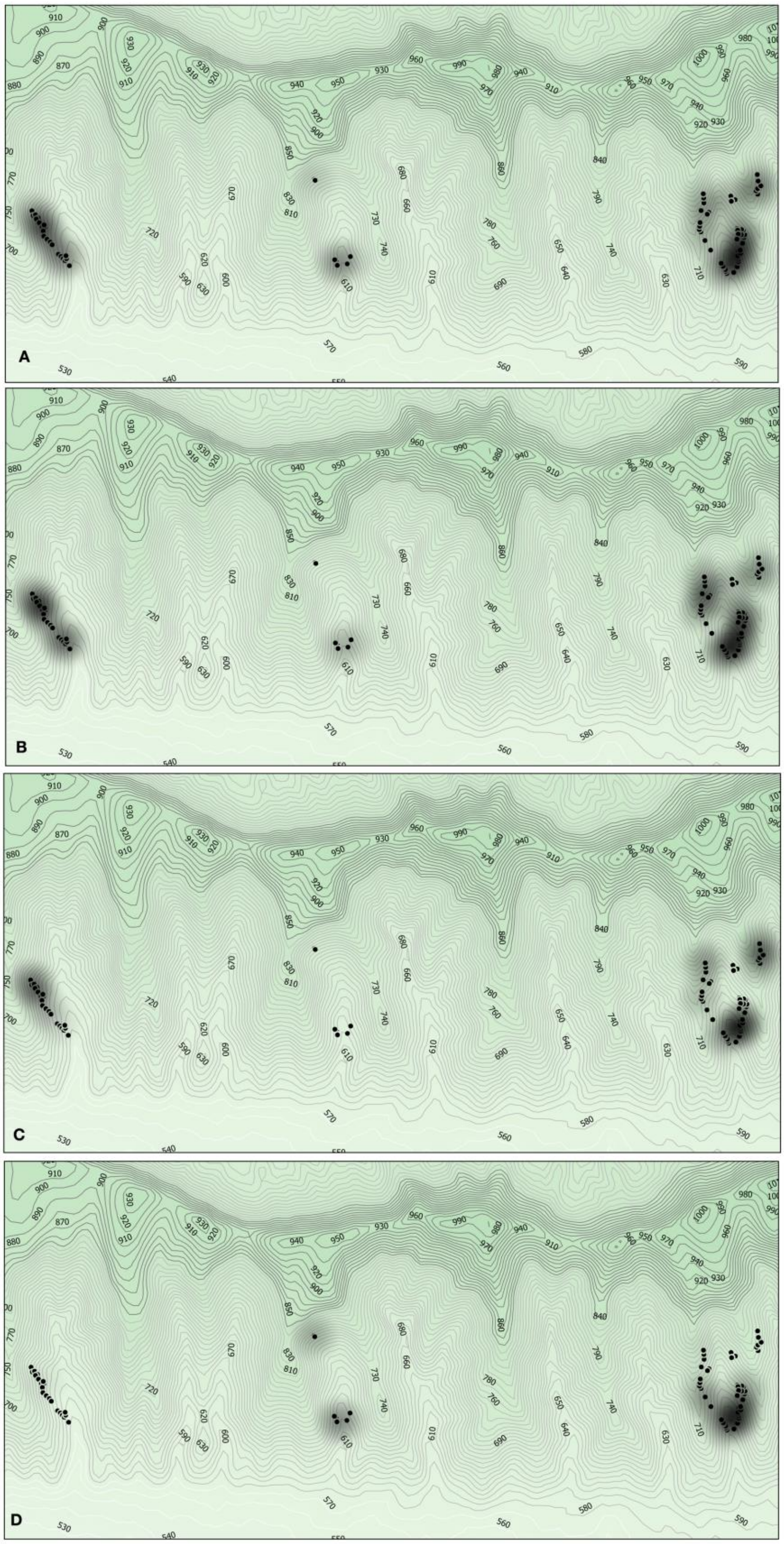


Fig. 18 Heat maps showing and comparing the frequencies of significative micro-fossil species along the whole outcrop of the Jebel Zawa: foraminifera (a); sponge spicule (b); alveolina (c); algae (d). From left to right the GK, OS, SK, and SK2 valleys are respectively represented; the black dots indicate the approximate position of the single chert sample.

variable. A major difference regards the SK2 valley, which features a well-sorted granulometry compared to the other groups (Fig. 14).

As it is possible to see from figure 18, the distribution of the frequencies of the best representative fossil species highlights some important features. Foraminifera appear to be the characterizing fossil along the whole outcrop. It is certainly followed by sponge spicule which, however, record some horizontal interruptions in the SK valley and a less visible frequency in the OS group, which however is characterized by the presence of algae.

A relevant difference is recorded in the case of alveolina which characterise specific areas in the GK, SK and minor areas within the same valley and the neighbouring SK2. It is completely absent from the OS group. To conclude, from a micro-palaeontological point of view, specific areas of the outcrops exhibit the whole variability and species frequency within the fossil assemblages.

4.3. Geochemistry

A total of 30 samples have been subjected to mineralogical analysis by means of Raman micro-spectroscopy, focusing on the inclusions observed on cherts. The chert matrix has been analysed using a portable X-Ray Fluorescence (pXRF) instrument on a total of 40 samples (see Appendix A for a complete list of the analysed samples).

4.3.1. Raman micro-spectroscopy

Fifteen samples from SK group were analysed using Raman micro-spectroscopy. Quartz was found to be the main mineral present in almost all the spots analysed, with characteristic peaks (Fig. 18, a, c, d, f) at 128, 206, 264, 356, 393, 403, 463, 517, 698, 809, 1045, 1083, 1160 cm^{-1} (Kingma and Hemley 1994). In many cases, due to fluorescence, only the principal signal at 463 cm^{-1}, together with peaks at 128, 206 and 356 cm^{-1} are visible. A peak from 500 to 505 cm^{-1} is very often associated with quartz (Fig. 18, d, f). It could be attributed to moganite (Heaney et al. 2007; Kingma and Hemley 1994), although studies have revealed that the presence of this Raman band in silica rocks might be the result of a convolution of a silanol (SiOH) and a moganite vibration (Schmidt et al. 2012). Therefore, this assignation must be viewed with caution. Apart from the silica (SiO_2) polymorphs quartz and – presumably – moganite, which were found in all the groups, the presence or absence of other minerals or their associations is found to be specific for each group (Tab. 4).

One spectrum of gypsum ($CaSO_4*2H_2O$) was measured from sample SK27 (characteristic signals at 183, 416, 494, 670 and 1008 cm^{-1} (http://rruff.info/) (Fig. 18, b)). In all the groups, calcite ($CaCO_3$: 154, 282, 714, 1085 cm^{-1} (Dufresne et al. 2018; Sun et al. 2014)) or anatase (TiO_2), the latter being mainly recognizable through its fundamental signal at about 143 cm^{-1} (Fig.18, a) (http://rruff.info/), are sometimes found when analysing whitish inclusions. Conversely, manganese oxides characterize the black or dark spots present in a few samples in the SK and GK groups. The Raman spectra of these minerals display two bands at c. 585 and 630 cm^{-1}. It is very difficult to reveal and discern them due to their strong absorbance and their shift towards lower wavenumbers when using green excitation and high-power values (Fig. 18, f) (Caggiani and Colomban 2011).

Group	Qz	Mog	Dol	Cal	Gyp	Mn-ox	Ant
SK	15/15	14/15	0/15	1/15	1/15	2/15	2/15
SK2	5/5	5/5	2/5	0/5	0/5	0/5	1/5
GK	10/10	7/10	8/10	0/10	0/10	1/10	1/10

Tab. 4 Minerals detected by means of Raman micro-spectroscopy for each group of samples; the number of samples out of the total in which each mineral was present is noted below. Qz = quartz, Mog = moganite, Ant = anatase, Dol = dolomite, Mn-ox = manganese oxides, Cal = calcite, Gyp = gypsum.

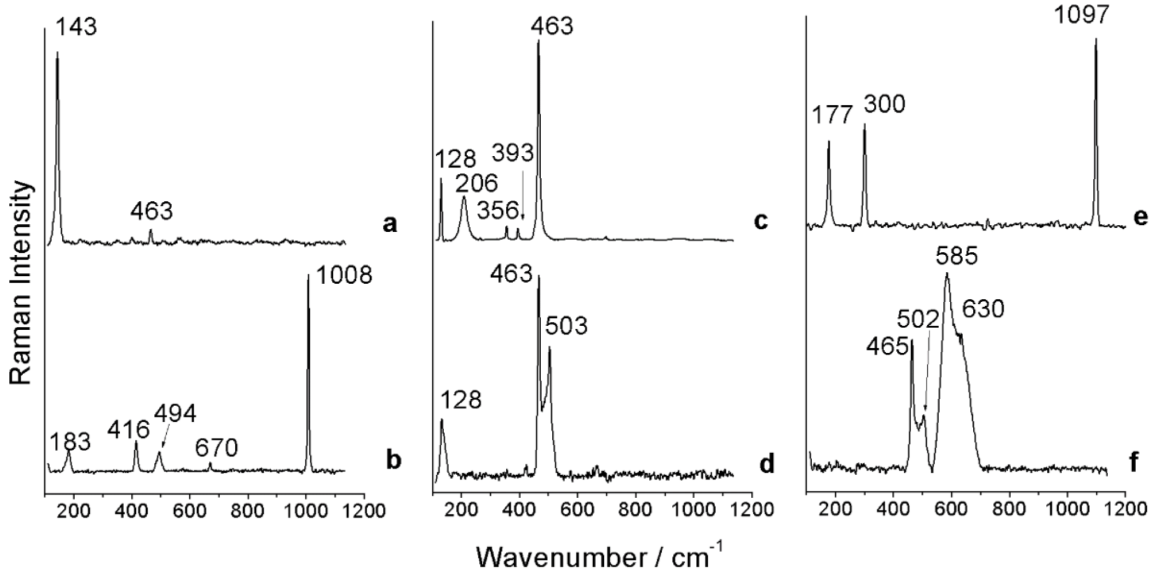


Fig. 18 Representative baseline subtracted Raman spectra of anatase and quartz from SK-35 a); gypsum from SK-27 b); quartz from SK2-5 c); quartz and moganite from SK2-3 d); dolomite from GK-13 e); manganese oxides, quartz and moganite from GK-17a f).

The Raman spectra obtained from 5 samples from the SK2 group essentially revealed the same minerals as in SK (Fig.18, c, d), except for the absence of Mn-ox and the presence of dolomite in two samples (Tab. 4).

Finally, 10 samples were selected from the GK valley. This group yielded some differences compared to previous ones: essentially, dolomite ($MgCa(CO_3)_2$) is quite frequent, having been found in many spots on 8 samples out of 10. As mentioned above, it was also found in samples SK2-3 and SK2-4 whereas, at least for the spots analysed, it appears to be totally absent in the fifteen samples of group SK. The position of the principal signal – often the only one visible – at 1097 cm^{-1}, that is halfway between those of magnesite (1095 cm^{-1}) (Dufrense et al. 2018) and dolomite (1099 cm^{-1}) (Sun et al. 2014) makes difficult its correct attribution. In a few cases, however, the finding of other characteristic peaks of dolomite (177, 300 cm^{-1}) (Sun et al. 2014) led to this assignment (Fig. 18, e). Manganese oxides were found in one sample (Fig. 18, f).

4.3.2. pXRF

Analyses carried out on the chert matrix of 40 samples allowed to select 6 elements, based on a good accuracy of the measurement compared to the standards: Sr, Ni, Fe, Mn, K, Ba. A further element – namely Ca – despite being revealed in high concentrations in most of the analysed samples, was not considered being diagnostic as its oscillations might be affected by the relative adjacency to the cortex zone (Delluniversità et al. 2019; 2020). Moreover, Ti was also escluded as it was found under the detection limit in several samples. The graph in figure 19, compares the values of each revealed element among the four groups of cherts, corresponding to the mining valleys of the Jebel Zawa (SK, SK2, GK, OS).

As it is possible to see, some differences are highlighted. Firstly, the Si and Ni contents are quite homogeneous in each valley. Fe content varies in a wider range, with few outliers reported for the GK and OS valleys. Conversely, Mn is found being coherent in every valley and very well comparable. Different is the case of K, which is found being the most variable element among the valleys. Finally, Ba shows some variations in the SK2 and GK valleys, while its values are similar in the SK and OS.

The chemical trends are shown in figure 20 since the median values are less sensitive to outliers than mean. It emerges that for what regards Sr, Ni, Mn there is a good correspondence between the four valleys. In the case of Fe, some correspondence is reported for the cases of GK and OS, while SK2 shows higher values followed by SK. The values of

K separate the four groups. SK reports the higher values, while OS and SK2 are in close vicinity.

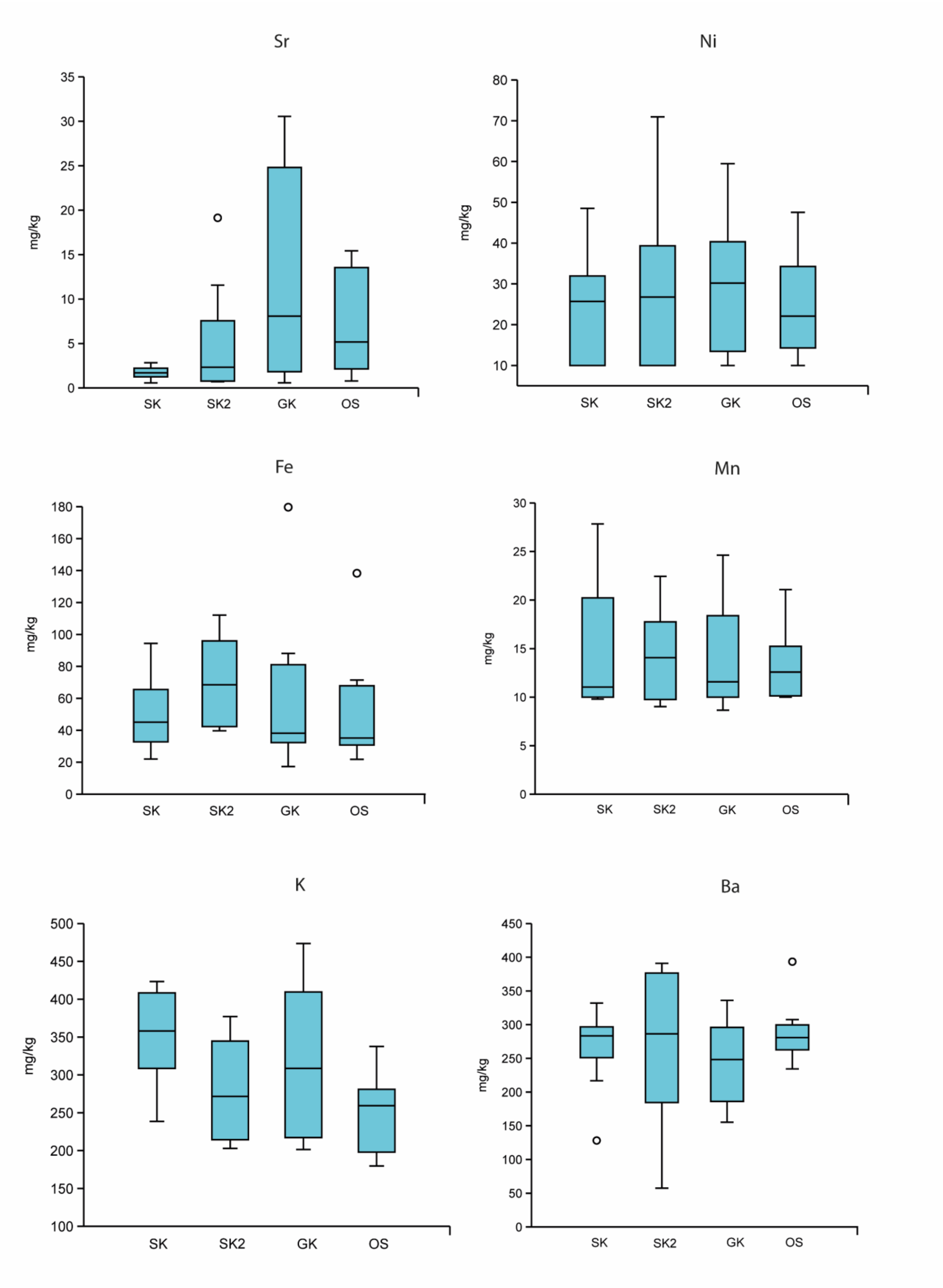


Fig. 19 Boxplot of geochemical values of the samples from the different valleys of the Jebel Zawa.

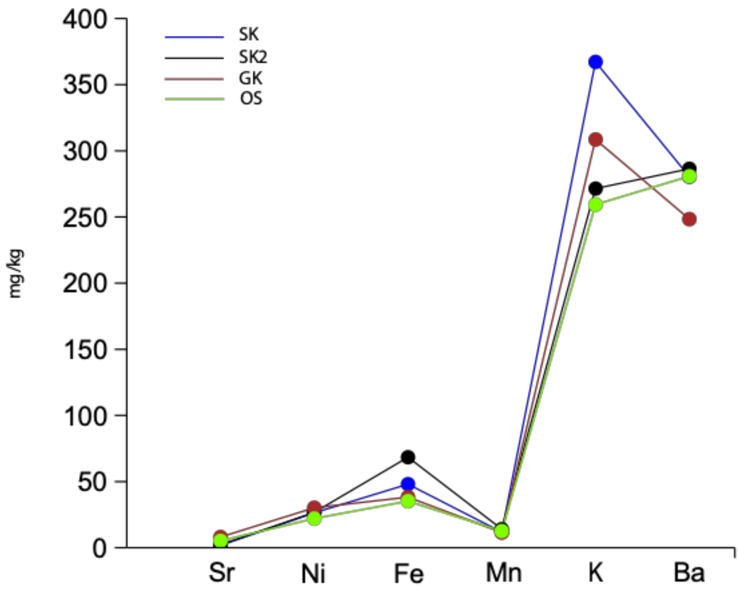


Fig. 20 Median values and geochemical trends of the chert from the different valleys within the Pila Spi Fm in the Jebel Zawa.

Finally, the values of Ba are quite comparable for 3 of the 4 groups. GK valley exhibits the lowest values among the groups.

4.4. Implications for chert exploitation strategies

Archaeological investigations in the foothills of the Zagros Mountains of Northern Iraq have revealed the existence of a previously unknown primary chert source, which was systematically exploited during late prehistoric times to produce large blades. The geographical position of the Jebel, the extensive availability of the raw material and the easy accessibility of the outcrops, together with the possibility of making use of several valleys at the same time, could have spurred the local human communities to exploit this lithic resource from the Middle Palaeolithic onwards (Conati Barbaro et al. 2019).

The Jebel Zawa chert contained in the Mid-Upper Eocene Pila Spi Fm was thus of some importance among the regional availability of further outcrops containing this type of chert, and the wide spectrum of other lithic resources available - such as the abundant secondary deposits along the fluvial terraces of the Tigris River and those of its tributaries (for previous work in the area see Tixier and Inizan 2000; Szymczak and Kozlowski 1989). As emphasized by Andrefsky (1994), suitable raw material availability plays a major role in the organization of technology on a regional scale. The choices made relating to a specific type of raw material could indicate specific needs related to technological and functional characteristics or reflect cultural traditions (Goodman 1944).

The results of this study highlight the internal heterogeneity of the chert from the Pila Spi Fm and allow an evaluation of how this variability influenced human behaviours and techno-economic strategies during the Late Chalcolithic and Early Bronze Age.

From a knapper's perspective, the morphometric characters of the nodules (e.g. size, sphericity and roundness) are the main factors affecting the choice of the appropriate raw material, particularly for large blade production.

As shown in Fig. 11, the nodules from the Pila Spi Fm are generally of elongated shape. This morphology is well suited for blade production, as the core can be easily 'planned' according to the available volume, by following two strategies: exploiting the minor axis as a platform and the main axis for blade production or directly using the naturally occurring flat surfaces as platforms for blade removals with very few adjustments. As highlighted by several scholars (Abbès 2013; Manclossi et al. 2019; Pelegrin 2012b) the core-shaping phase represents a crucial step in the large blade production process. As suggested by Pelegrin (2012), naturally convex nodules and tabular chert are well suited for these purposes, allowing the knapper to start the production directly by the removal of cortical blades without any crest preparation. Based on these experimental observations, the nodules from the GK valley would require more shaping operations because of their less spherical and rounded shape. Conversely, the nodules from the SK, SK2 and OS valleys would theoretically allow production to be started by means of this strategy. As suggested by measured median values (Tab. 3), the presence of some irregularities in their shape also led to the preparation of bifacial preforms to initialise the production process by the removal of crested items. This fact is supported by the archaeological evidence from the lithic workshops (see chapter 3), while in the GK valley no evidence of large blade production has been found. By the selection of large, regular nodules, carried out also by excavation in the karst cavelets, the Jebel Zawa knappers could have optimized these operations.

Macroscopic differences in the cortex area – presence/absence, thickness, induration, and surface – could have been a further factor influencing raw material selection. An experienced knapper would have preferred nodules with a thin, friable, smooth cortex to maximize time and energy expenditure during block decortication and blade extraction. This may have assumed importance in the context of a highly specialised and standardised technology, such as the pressure technique (Pelegrin 2012b).

Quality is also a function of the degree of suitability of a raw material (Andrefsky 1994; Inizan et al. 1999). Chert quality is assessed in the literature based on structure and texture (Brantingham and Olsen 2000), and consequent mechanical capacity of fracture under stress (Cotterell and Kamminga 1985; Crabtree 1967), as well as on the absence of post-genetic alterations, such as those due to tectonization. The latter can strongly influence the propagation of force inside the block, causing deviation along existing fracture lines or block fragmentation (Goodyear 1989; Luedke 1992), and would have been a relevant consideration during the *débitage* of large blades. For these reasons, experimental knappers usually prefer the best quality chert, so as to exercise optimal control over the morpho-technical features of the blades (Abbès 2013; Marchand et al. 2020; Pelegrin 1988, 2012b; Volkov and Guiria 1991; Vosges 2019).

The Jebel Zawa chert is generally opaque, with a poor-sorted texture and a particle fraction of more than 50%. Moreover, fracture is found to be sub-conchoidal in most of the samples studied from the four valleys. Tectonization has a statistically low frequency in the sample set. Coarser textures, a high number of fossils and non-homogeneous structures can increase the mechanical strength required for knapping (Brantingham and Olsen 2000; Luedtke 1992). The adoption of the lever pressure system for large blade production can bypass this issue, as recently demonstrated by Marchand et al. (2020), by exerting a greater force on the core-platform than normal percussion or other modes of applying pressure (Pelegrin 2012b; Volkov and Giuria 1991).

Conclusive evidence from this data processing highlights that only specific features within the wide range of chert characteristics in the Jebel Zawa outcrops meet the optimal requirements for complex and specialised knapping sequences such as that for large blade production.

5. Summary

The application of NM-PCI and combined Raman micro-spectroscopy with pXRF analyses outlined the compositional features of the chert available in the Mid-Upper Eocene Pila Spi Fm in the Jebel Zawa. This type of chert varies from light-grey to grey shades in colour. Occasionally, it can exhibit black shades. Macroscopic evidence reveals mixed structures: from spotted, mottled and/or shaded inclusions, to bands and laminations. At microscopic scale, a less variable situation, mostly related to poor-sorted textures, has been recorded. Finally, microfacies analyses show a prevalence of foraminifera, followed by sponge spicule and algae. As for the minerals identified by Raman micro-spectroscopy, all the cherts analysed show the prevalent presence of quartz, moganite and traces of anatase, whereas the samples from SK are characterized by the absence of dolomite, quite widespread among the samples from SK2 and GK, and the rare presence of calcite, gypsum and Mn-ox. Moreover, 6 elements are revealed by means of pXRF measurements of the chert matrix. The content of Sr, Ni, Mn and Ba are quite comparable in each group, while the content of the Fe and K highlights differences which separate the valleys.

The petrographic and chemical data account for some differences that reflect depositional and/or diagenetic conditions. Although a petrological interpretation is beyond the scope of this work, the presence of dolomite and gypsum shows incomplete silicification of the original sediments in the nodules, as well as being a further proof of their deposition in transitional environments (Knauth 1979; Tucker and Wright 1990; Sissakian and Al-Jiburi 2014a).

7. INVESTIGATION OF THE ARTEFACTS PROVENANCE

1. Aims

The present chapter is focused on the characterisation the archaeological artefacts by means of the NM-PCI protocol to reconstruct their provenance, in the light of the data acquired on the geological samples from the Jebel Zawa source. The importance of the work is twofold. On the one hand, it represents the first-ever methodological contribution exploring a specific lithic artefacts category with complex biographies, applied to the Near Eastern protohistory, such as the Canaanean blades. On the other, the analysis approaches for the first time the problem of their distribution during the Late Chalcolithic and the Early Bronze age periods in the Tigris region.

First, the applicability of the protocol on archaeological samples, coming from different contexts (i.e. surface collections, excavations), is discussed. The issues over certain variables – and their methodological implications in data processing – are even faced, as well as the suitability of specific characteristics as being used as provenance markers.

From an archaeological perspective, the goal is to highlight the presence of a regional distribution network around the source Jebel Zawa, previously hypothesized from a technological and descriptive (visual) point of view. In addition, the study aims to confirm the existence of different networks of imported items and to preliminarily identify the characteristics upon which setting the differences. A further line of research intends to investigate the extra-regional importance of the Jebel Zawa chert source within the context of the Late Chalcolithic of Tell Helawa, which is located in the Erbil Plain about 120 km south-east from the source.

2. The sample

A total of 56 artefacts have been analysed following the NM-PCI protocol (Tab. 1). The objects have been selected within the studied assemblages from the Late Chalcolithic and the Early Bronze age (Ninevite 5 period) sites discussed in chapter 4. The present sample consists of blade fragments (e.g. proximal and mesial) mostly intentionally broken to be transformed in tools. No complete blades are available within the whole inventory. A good percentage of such items exhibits use-derived gloss (visible at low magnifications) on one or both the edges and occasionally associated to retouch. On few blades, bitumen residues are a strong indication of their use as hafted inserts, especially when in association, on the same artifact, with gloss. However, unretouched and, possibly, unused artefacts are even part of the sample.

Sample	Code	Site	Dating	Type	Lith.	Patina
1	48.12.3.710	48	LC/EBA	semi-cortical proximal frag.	A	1, 2
2	48/20	48	LC/EBA	proximal frag.	A	1, 2
3	48.12.1.706.12	48	LC/EBA	proximal frag.	A	5
4	48.12.1.706.1	48	LC/EBA	proximal frag.	A	5
5	48.12.1.706.3	48	LC/EBA	proximal frag.	A	3, 4
6	48.12.1.706.10	48	LC/EBA	mesial frag.	A	3, 4
7	48.12.1.706.2	48	LC/EBA	proximal frag.	A	4
8	776.15.1.705.4	776	LC/EBA	glossed segment	A	0, 1, 2
9	776.15.1.705.11	776	LC/EBA	glossed segment	A	0, 1
10	776.15.1.707	776	LC/EBA	glossed segment	A	0, 2
11	776.15.1.705.1	776	LC/EBA	mesial frag.	A	0, 1, 4
12	776.15.1.705.15	776	LC/EBA	mesial frag.	A	0, 1
13	776.15.1.705.3	776	LC/EBA	glossed segment	A	2, 3, 5
14	776.15.1.705.7	776	LC/EBA	mesial frag.	A	0, 2
15	1085.18.1.725	1085	LC/EBA	proximal frag.	A	3, 5
16	1085.18.1.734	1085	LC/EBA	glossed segment	H	1
17	1085.18.1.711	1085	LC/EBA	mesial frag.	A	2
18	1085.18.1.707	1085	LC/EBA	semi-cortical mesial frag.	A	1
19	1085.18.2.737	1085	LC/EBA	mesial frag.	A	1, 4
20	1805.18.1.708	1085	LC/EBA	semi-cortical mesial frag.	A	1, 4
21	1085.18.1.723	1085	LC/EBA	glossed segment	A	1
22	821.15.3.707.3	821	LC/EBA	semi-cortical mesial frag.	A	4
23	821.15.3.707.5	821	LC/EBA	proximal frag.	A	3
24	821.15.1.704.7	821	LC/EBA	proximal frag.	A	1
25	821.15.3.707.4	821	LC/EBA	glossed segment	E	2
26	724.15.1.707	724	LC	glossed segment	A	1
27	724.15.1.704	724	LC	mesial frag.	B	2
28	724.15.1.718	724	LC	proximal frag.	C	2
29	108.12.3.701.2	108	LC	proximal frag.	A	3
30	108.12.3.701.1	108	LC	mesial frag.	A	5
31	285.13.4.703	285	LC*	mesial frag.	D	0
32	285.13.7.704	285	LC*/EBA	glossed segment	E	0
33	87.12.3.701.1	87	LC/EBA	mesial frag.	A	5
34	87.12.3.701.2	87	LC/EBA	mesial frag.	F	0
35	29.12.5.705	29	LC/EBA	mesial frag.	A	3, 5
36	29.12.5.701	29	LC/EBA	proximal frag.	G	1, 3
37	739.15.1.704	739	EBA	mesial frag.	A	1, 2
38	185.12.1.701	185	LC/EBA	glossed segment	E	1
39	888.16.2.705	888	LC*/EBA	mesial frag.	B	1, 2
40	151.12.2.703	151	LC	mesial frag.	A	3
41	121.12.5.701	121	LC	mesial frag.	A	2, 3
42	356.13.3.702	356	LC/EBA	mesial frag.	A	3
43	698.15.1.701	698	EBA	mesial frag.	A	4

44	941.16.5.701	941	LC*/EBA	proximal frag.	A	2
45	341.13.1.701	341	LC/EBA	glossed segment	A	2, 3
46	43.12.2.703	43	LC/EBA	glossed segment	A	2, 5
47	122.12.1.703	122	LC	mesial frag.	A	2
48	697.15.1.704	697	LC/EBA	mesial frag.	A	2
49	89.12.2.701	89	LC	mesial frag.	A	5
50	329.13.1.701	329	LC	glossed segment	A	2
51	TH.18.D.189.Ob.1	Helawa	LC 3	glossed segment	A	0, 1
52	TH.18.D.309.Ob.1	Helawa	LC 3	glossed segment	A	0, 1
53	TH.18.D.302.Ob.3	Helawa	LC 3	proximal frag.	A	0, 2
54	TH.16.D.143.Ob.6	Helawa	LC 3	glossed segment	B	0
55	TH.16.D.141.Ob.1	Helawa	LC 3	glossed segment	B	0
56	TH.16.D.141.Ob.6	Helawa	LC 3	glossed segment	B	0

Tab. 1 List of the archaeological samples analysed, their identified lithotypes (lith.) and stages of patination observed.

2.1. Selection strategy

Dealing with surface materials, not all the sites are equally represented in the sample. When possible, the highest number of artefacts per site has been selected to be exported[1] and studied following the protocol (Tab. 1). In the light of the research questions to be addressed, we preferred to include artefacts from the highest number of sites to investigate the area from a spatial perspective. The variability of the lithotypes within the single sites, and their degree of readability in the light of the surface alterations identified, have been other factors affecting the sampling. Indeed, artefacts bearing heavy patinae have been included, particularly when they represented the only possible choice within the site's inventory. Sites 48 (s. 1-7), 776 (s. 8-14) and 1085 (s. 15-21) show the highest number of items. Sites 821 (s. 22-25), 724 (s. 26-28), 108 (s. 29-30), 285 (31-32), 87 (s. 33-34) and 29 (35-36) are well represented as they restituted a low number of artefacts. Finally, samples n. 37-50 (Tab. 1) are relative to sites that yielded back just 1 artifact (Fig. 1).

Finally, a total of 6 artefacts (s. 51-56) have been selected from the MAIPE area and come from the site of Helawa, where the appearance of these blades is dated to the early LC3 period (see chapter 5). All the selected items have been unearthed in the late LC3 layers (area D), were the exclusive presence of off-site produced Canaanean blades characterises the blade component within the studied assemblages (Peyronel et al. 2019). However, during the 2018 excavation campaign at the site, the newly discovered Building A, in Area B, allowed to observe a further technological and chert raw material complexity (see chapter 5), which will be addressed with future investigations.

[1] The number of artefacts analysed in this work has been strongly affected by the possibility of exporting the samples in Italy, in collaboration with the local competent authorities, where the artefacts have been studied with laboratory facilities.

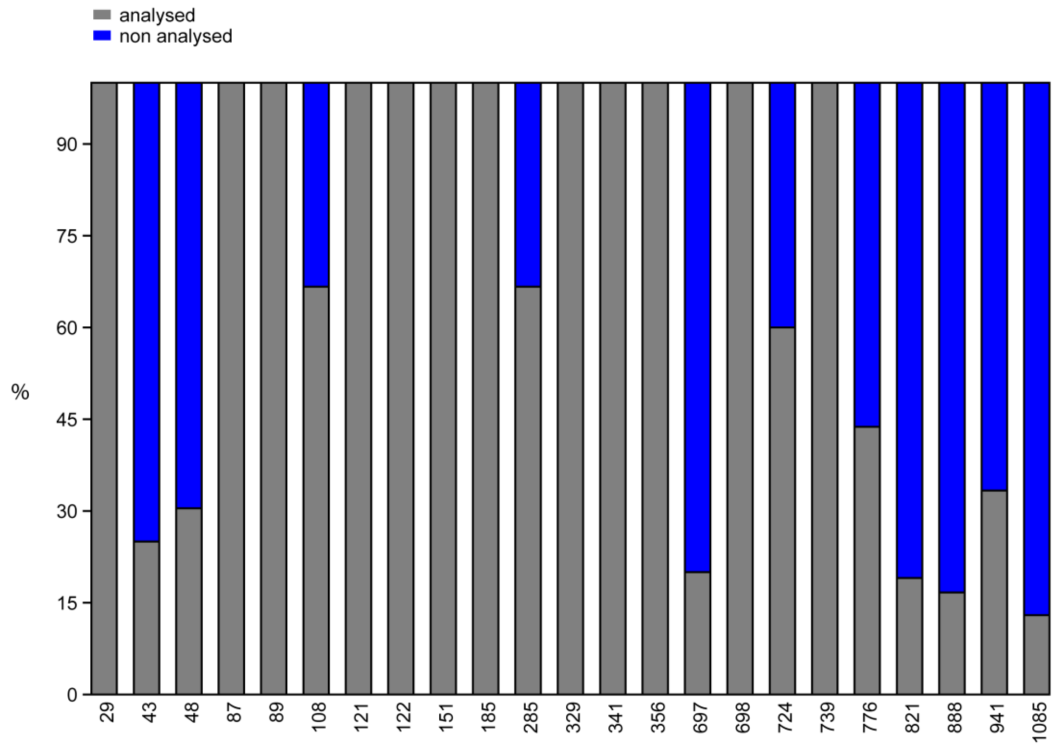


Fig. 1 Overview of the selected artefacts per site of the LoNAP area expressed in percentual.

3. Observation criteria

The type context, from which the artefacts have been collected, strongly influenced the strategies of observation and data collection. Among the analysed artefacts, a variability of tool 'surfaces conditions have been observed (i.e. patinas, concretions, mechanical damages etc.), reflecting the post-depositional histories of such objects (Van Gijn 2009).

The interest beyond the study of such issues is related to the numerous archaeological implications which can be traced out. Most of the scholars analysed taphonomic processes on chert artefacts at high-magnification (e.g. SEM-EDX, metallographic microscope), and in combination with replica experiments, to not misrepresent them with functional modifications of the tool's surfaces (Mansur-Franchomme 1986; Mazzucco et al. 2013; Plisson and Mauger 1988; Sala 1986; Stapert 1976). Other researchers, studied weathering effects to collect information useful to reconstruct formation processes at the sites, using combined high-magnification and chemical analytic approaches (Burroni et al. 2002; Médard et al. 2014).

However, it is not the aim of the present work to investigate and clarify such issues. Our goal is to understand what is the impact of these processes, in particular, the patinae intended as "covering features" occurring on the object 'surfaces, on the study of the chert characteristics over the three levels determined by the NM-PCI protocol (macroscopic, microscopic, chemical). For these reasons, the study of the archaeological samples was first based on the identification of the patinated areas on the surfaces, and secondly, their distribution and quantification using ordinal variables (Fig. 2). The existing link between the degree of alteration and the reliability of the data is highlighted by the obtained results (see paragraph 4). However, the spatial occurrence of such post-depositional feature was found to be not always homogenous, thus several areas can exhibit different stages of patination (Fig. 2). The observations and analyses, aimed at characterising the objects, have been carried out on the best-preserved areas when such differences have been identified. In the case of uniformly and heavily weathered artefacts, which are discussed below, just a few features were possible to record.

3.1. Patinae

The patinae represent a common weathering effect localised on the surfaces of most of the lithic artefacts (Van Gijn 1989, 2009). Today, we define patinae from an "evolutive" perspective as one of the effects caused by changes in texture and mineralogy of worked object 'surfaces under specific environments, thus reflecting the evidence of that conditions (Médard et al. 2014). There is a general agreement that patinae occur as chemical processes altering the visual aspect and the surface microstructure of the objects (Burroni et al. 2002; Glauberman and Thorson 2012; Luedtke 1992; Rottlander 1975; Van Gijn 1989). They depend from a wide range of environmental factors characterising the depositional contexts: the degree of the penetration of the natural agents altering the equilibrium (i.e. soil pH and humidity, chemistry of the waters, temperature, sunlight), and the internal structure of the raw material (Glauberman and Thorson 2012).

From a macroscopic point of view, patinae have been described as a white film developing on the object surface (Van Gijn 1989). At high magnification, some scholars highlighted changings due to chemical dissolution (or leaching, Rottlander 1975) that allows the creation of a secondary porosity causing light refraction (Rottlander 1975; Texier 1981). The dissolution is often attributed to dehydration of water forming the bonds between the quartz crystals and leaving minute interstitial cavities in the altered portion of the surface (Schmalz 1960).

However, patinae involve not only the object 'surface, thus related to macroscopic aspects; they can expand through the object centre (centripetal forces, Médard et al. 2014), causing the entire transformation of the object's microstructure (Médard et al. 2014; Van Gijn 2009).

4. Results

The identification of post-depositional patinae – and their distribution on the object 'surfaces – as a preventive procedure have prevented us from slipping into incorrect attributions during the study of the chert features, by basing our analysis on the less altered portions of the objects.

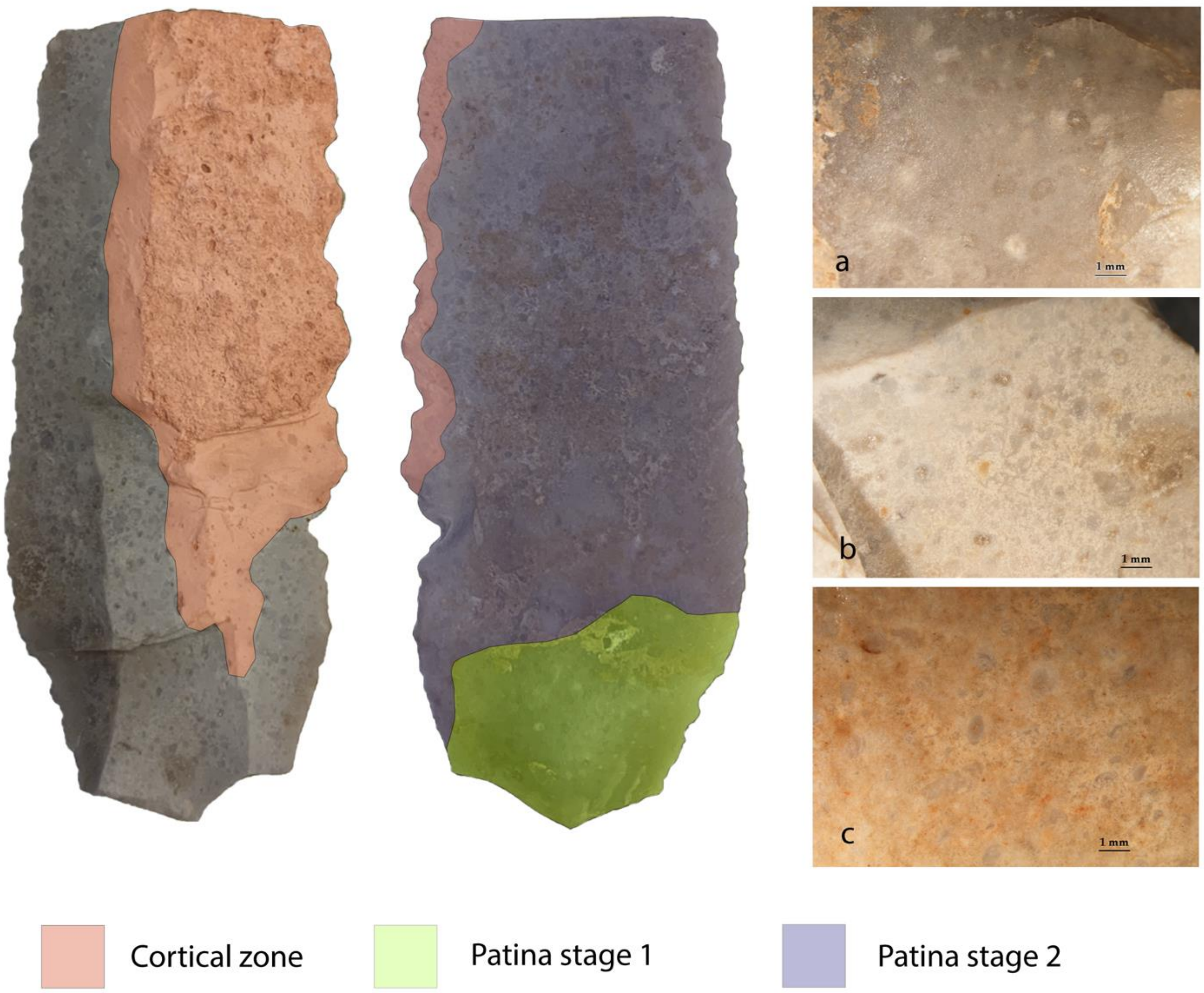


Fig. 2 Example of investigation of the patination stages on the archaeological artefacts: stage 1 (a); stage 2 (b); stage 2 covered by concretion (c).

As will be discussed in the next paragraphs, the alterations mostly affected the recognition of the chert macroscopic features, while the microscopic ones were less influenced for several reasons. This fact has had implications as in the choice of the variables upon which the distinction between the various lithotypes has been made, as on the variables involved in the comparison with the geological reference collection.

4.1. Stages of patination

The occurrence of patinae have been classified into five stages or degrees (Tab. 2). The samples have been cleaned using distilled water, to remove as much as possible the concretions, and then studied by using a stereomicroscope at low-magnification (10x-40x). The absence of patination has been named "stage 0" and represents the optimal condition to observe and describe the chert features (Fig. 1, a).

Stage	Surface description (10x-40x)
0	well-preserved surface
1	few discontinuities
2	increasing discontinuity, clustering
3	homogeneous patina, pitting
4	increasing pitting, enlargement of weakness horizon
5	minerals deposition in well-developed cavities

Tab. 2 The patination stages identified and their description at low magnification (10x-40x) using a stereomicroscope.

The “stage 1” consists of few localised discontinuities of white colour, not even forming evident clusters on the surface (Fig. 3, b). “Stage 2” features increasing white discontinuities, giving rise to clusters affecting the surfaces. Chert features are clearly visible at both the stages of patination (Fig. 3, c). “Stage 3” indicates a homogeneous patina, related to surface micro-pitting which is visible only microscopically (or indirectly visible to naked-eyes conditions, when the pits are filled with sediment). At this stage, a significant change in colour, from the original colour of the chert matrix to white/grey shades, is recorded (Fig. 3, d).

“Stage 4” is related to the development of a pronounced pitted surface which led to the enlargement of the weakness horizon in terms of surface alteration and consequent damages (increasing mechanical alteration, especially around the dorsal ridges) visible also to naked eyes. The related increasing roughness on the surface led to the deposition of minerals within the enlarged pores. However, the rate of infills is not so consistent to change the colour of the surface given by patina.

“Stage 5” represents the final set where the changings in colour are evident, testifying an important deposition of minerals within the cavities (from white/grey shades to orange/reddish and brownish shades). It is worth mentioning that stages 4-5 (Fig. 3, e-f) correspond to the definition well-known in the literature of “colour patinae” (Burroni et al. 2002; Van Gijn 1989, 2009).

In addition, we found that several stages of patination, and thus of alteration, can coexist on the same artifact (Fig. 2). As table 1 shows, half of the samples are related to this circumstance. The stages are often represented by neighbouring areas exhibiting progressive degrees of patination. Only a few cases (s. 15, 35-36, 46, 53) show significative differences between areas, perhaps indicating that intra-artifact differences in chert textures, together with aspects related to artifact deposition (e.g. polarities, Fernandes 2012), can contribute to their final post-depositional outcome (cp. Van Gijn 2009).

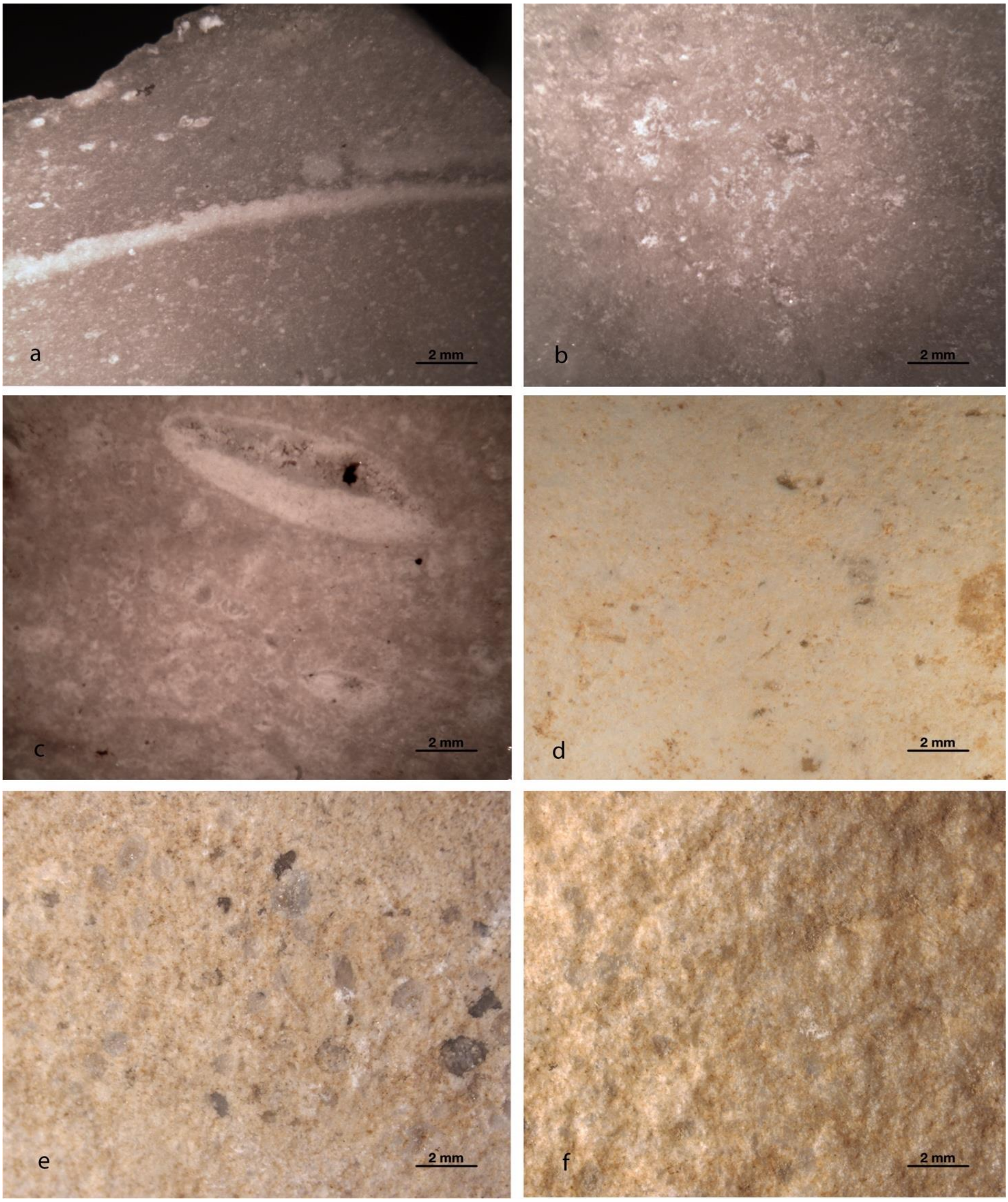


Fig. 3 Stages of patination identified on the archaeological materials analysed: unpatinated or stage "0" (a); stage 1 (b); stage 2, micro-palaeontological content is quite visible (c); stage 3 (d); stage 4, note the casts of dissolved macro-fossils (foraminifera) and the deposition of reddish minerals on the surface (e); large cavities filled with reddish minerals causing furthers colour changes (f).

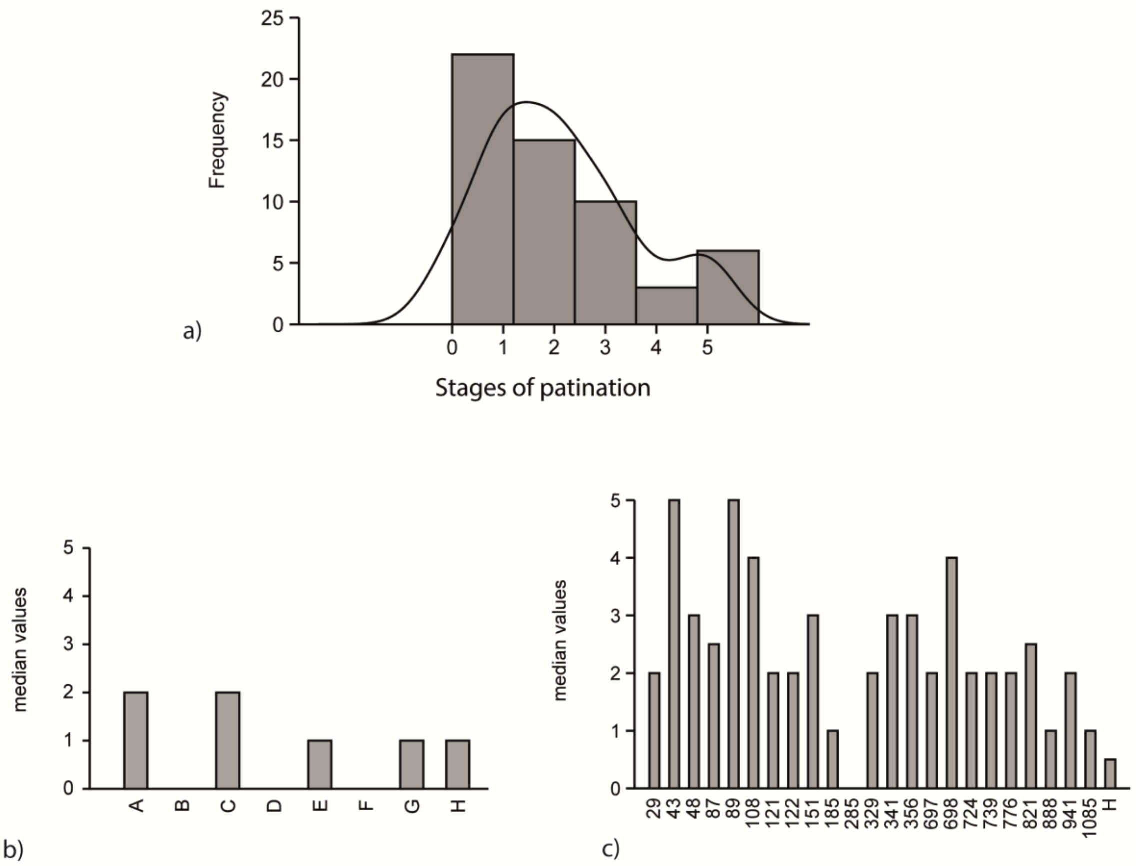


Fig. 4 Overview of the degree of patination related to the object's areas over which the observations have been carried out. Incidence of the patinae on the whole sample (a), patinae distribution on the identified lithotypes (b), patinae distribution within the single sites analysed (c).

4.2. Patina effects over the macro- and microscopic descriptions

Patinae covering effects reduced the availability of areas suitable for exhaustive analyses. However, the recognition of several stages of patination makes it possible to evaluate the whole preservation of the piece, thus allowing a complexive diagnosis of the sample to be studied. The histogram in figure 4a shows the frequencies of the identified stages per each piece, over which the observations have been carried out. The high frequency of low-patinated area match with the results obtained from a qualitative point of view. These areas find a validation even on a quantitative perspective only if represented for about the 40-50% of the total area of the object, to avoid problems of representativity of the features to be studied. These parameters have been highly considered during data processing.

Starting with the macroscopic features, the observation of the original chert structures has been possible up to stages 2-3 of patination as well as the recognition of the fracture properties (conchoidal, sub-conchoidal, uneven). A separate discussion deserves to be made for what regards the chert colours. Even though colour measures have been often collected on the best-preserved parts[2] of the

[2] A relative limit has been that of the straightness of the areas, imposed by the spectrophotometer to collect the measure.

objects, they did not significatively contribute to differentiate the identified lithotypes for the reasons explained below.
From a microscopic point of view, the application of the NM-PCI protocol obtained satisfying results, leaving apart the chert translucence which has been identified being among the most affected variables by patinae. As told in the previous paragraphs, poor-sorted textures were found to be the most influenced ones, while well-sorted textures evidenced a major resilience. Thus, their observation (e.g. sorting, fraction) was possible up to stage 3 of patination. This phenomenon is highlighted by the bar chart in fig. 4b, which reports the median values related to patinae evidence and degrees, showing the incidence they had on the different lithotypes identified (cp. tab. 3).
For higher degrees of patination (4-5), we based our description over the presence of recrystallised non-biogenic inclusions and casts of the dissolved fossils found to be very visible and well distributed (Fig. 1, e). Fortunately, these cases were the less encountered and the impact of this preventive procedure allowed us to also obtain reliable data within the single sites considered in this work (Fig. 4, c).

4.3. The identified lithotypes

Results of this work allowed to identify 8 groups of artefacts, labelled from A to H. The list is synthesised in table 3, where the variables functional to the distinction are reported - namely sorting, fraction, and micro-palaeontological content. Although the macroscopic feature of the structure is also reported, it has been not possible describing it for the whole sample analysed due to the patina covering effect.
A further assumption is needed as regards the incidence of the cortex and related features – namely thickness, nature, induration, boundary with chert and subcortex – over the macroscopic description. Dealing with blades mostly coming from full production stages, the cortex is absent on all the samples but four. We suspect that *débitage* selection at workshops sites together with the strategies of core preforming and reduction, might have had this effect over the representation of intra-cortical structural features, such as bandings and laminations if compared with the geological reference collection; thus, their presence could be underestimated within the sample.
The geochemical fingerprints obtained through measurements carried out by portable X-Ray Fluorescence (pXRF) have been explored and plotted against the geological reference collection. The ratio between some elements (Fe and K) has been studied in relation to other features (colour coordinates) to explain possible post-depositional distortions. Their correlation, in terms of artefacts provenance with the geological source, is discussed to validate or not the correspondences found through the first two steps of the analysis.

Lithotype	structure	Sorting	Fraction	Grains
A	sh-sp(m-l-b)	1(2)	3(2)	foraminifera, spicule, algae
B	h(sp)	2(3)	3(2)	radiolarians, foraminifera, spicule
C	sh-sp	1	1	foraminifera, spicule, corals, radiolarians
D	sp	2	2	foraminifera, spicule, algae, radiolarians
E	m-l(sh)	2	2(3)	foraminifera, spicule, algae, radiolarians
F	m-st	2	2	foraminifera, spicule, gastropods, ostracods, radiolarians
G	h	3	3	radiolarians
H	sh-m	1	2	foraminifera

Tab. 3 Macroscopic and microscopic variables allowing the distinction between the identified chert lithotypes.

4.3.1. Macroscopic description

As concerns the structure of the cherts, lithotype A features mainly shaded and spotted heterogeneities. Occasionally they can be associated with laminations and/or bandings, especially when the cortex is present, and more rarely to mottled ones (Fig. 5, n.1-2). Lithotype B refers to a homogeneous chert, that can also exhibit micro-spots as the case of the samples from Helawa (Fig. 3, n.3). Lithotype C is similar to A and features shaded and spotted heterogeneities (Fig. 4, n. 4). Spots characterise also the heterogeneities observed in lithotype D, while mottled and laminated ones (occasionally shaded) pertain to E (Fig. 5, n.5-6). Lithotype F is characterised by mottled and streaked heterogeneities, while G is a homogeneous chert (Fig. 5, n.7-8). Finally, lithotype H is a shaded and mottled chert (Fig. 5, n.9).

As explained earlier, the chert colours were affected by distortions caused by the presence of patinae. This fact results immediately clear looking the values of L*, indicating the grey-scale shades of the CiELab spectrum, which is far high as the degree of patination increases until stage 3, then it tends to decrease due to mineral infills within the developed porosity (Fig. 6, d).

In figure 3a, L*a*b* coordinates are plotted per each sample together with the surface conditions on which the measure has been collected. The artefacts belonging to the stages of patination from “0” to “2” exhibit different behaviour respect the advanced stages (stages 3-5). The distribution of the values is spread around grey to dark-grey shades for almost all the lithotypes. In the specific, a group of unpatinated materials, mostly belonging to lithotype B (Fig. 3, b) are clustered around grey shades, sharing similarities with lithotype A at stage “1” of patination.

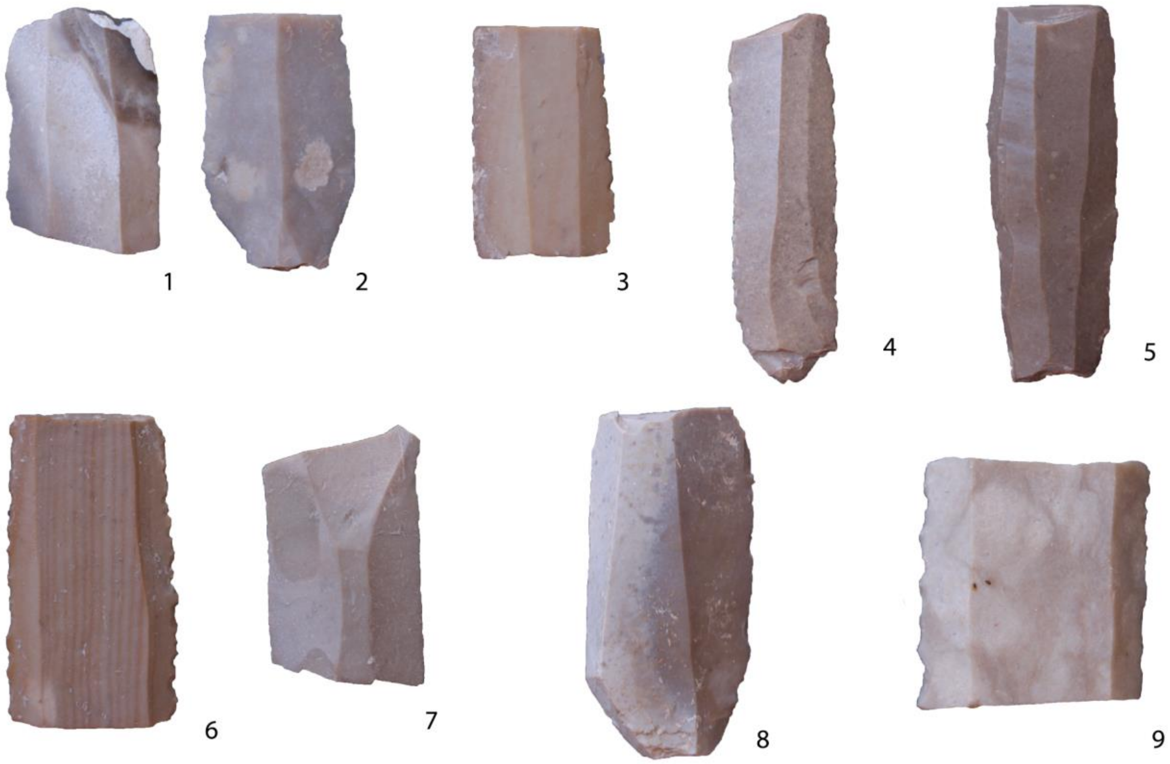


Fig. 5 Variability of the structures recorded within the archaeological artefacts (non in scale): shaded-spotted-banded (1), shaded and mottled (2), homogeneous (3), shaded and spotted (4), spotted (5), laminated (6), mottled and streaked (7), homogenous, partly covered by a stage 3 patina (8), shaded and mottled (9). Lithotype A (1-2), B (3), C (4), D (5), E (6), F (7), G (8), H (9).

Samples belonging to the stages 3-5 exhibit less variability than the earlier ones, revealing the effects of the colour change through light-grey and whitish shades. They are grouped in a single large cluster and interestingly, the artefacts belonging to the stage 3 tend to be positioned around light-grey shades, with few items dispersed, while the stage 5 is more clustered and positioned on light grey. The artefacts belonging to stage 4 lie at the same coordinates of stage 5.

In the graph 3c, the colour coordinates of the archaeological materials are plotted against the geological ones. Due to the “patina effect”, the artefacts correlate with the geological samples which are spread on the grey scale, reaching black/reddish shades as the case of non-dominant colours (see chapter 6). It is important to note that non- and low-patinated artefacts also correlates with the main cluster of geological samples. In the specific, the artefacts belonging to the lithotype A group exhibits a similar dispersion if compared to the geologic samples. The main difference is recorded for what regards the non-dominant colours, that in our archaeological record were not visible or absent.

Results from the macroscopic analysis indicate that, given the intrinsic characteristics of the cherts, their state of preservation and the macroscopic variability of the geologic source, it is not possible to distinguish clear groups.

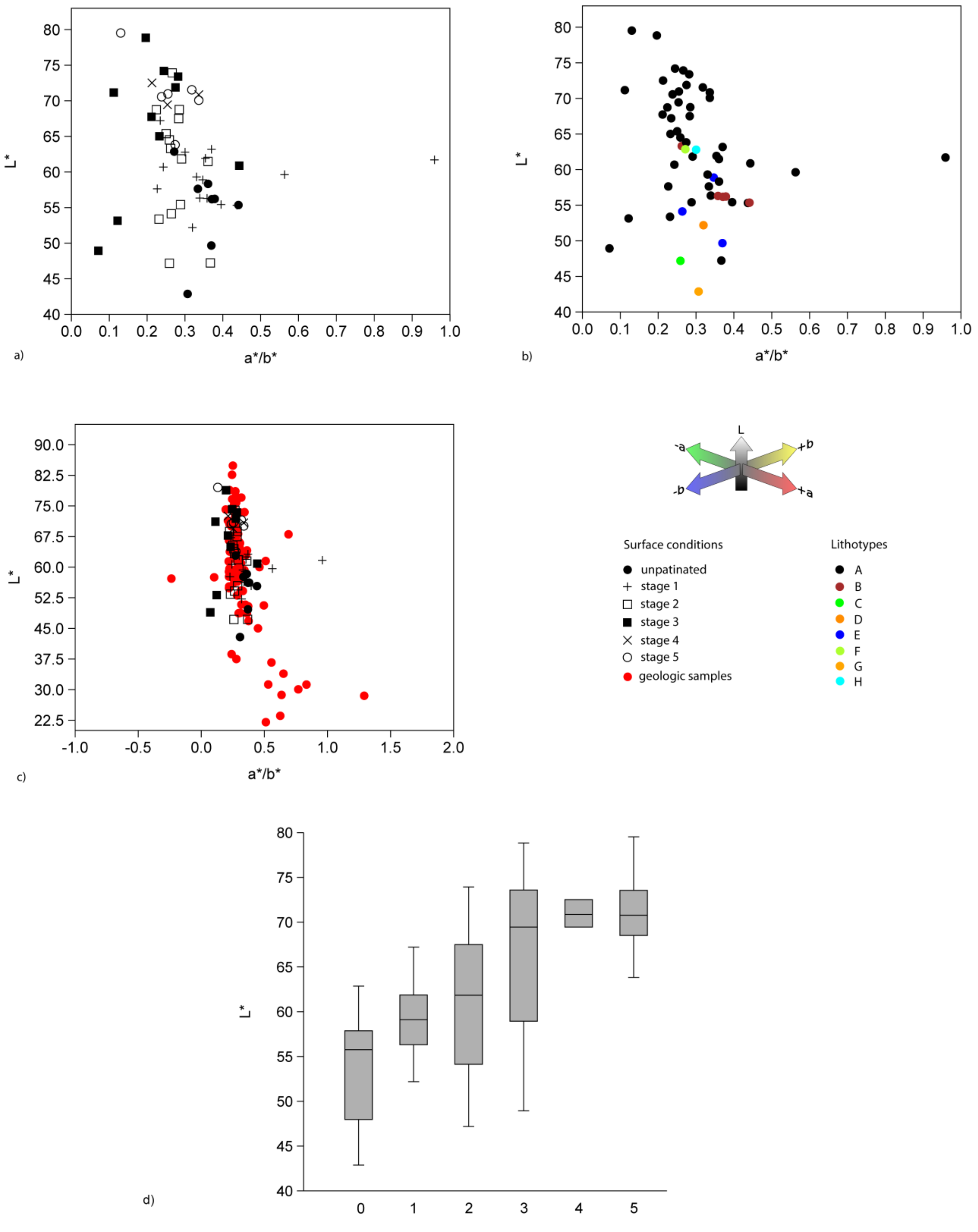


Fig. 6 CIELab coordinates plots: colour coordinates against the stage of patination per each sample (a), colour coordinates relative to the identified lithotypes (b), archaeological colour coordinates against the geological samples (c), boxplot showing L* coordinates related to each stage of patination identified.

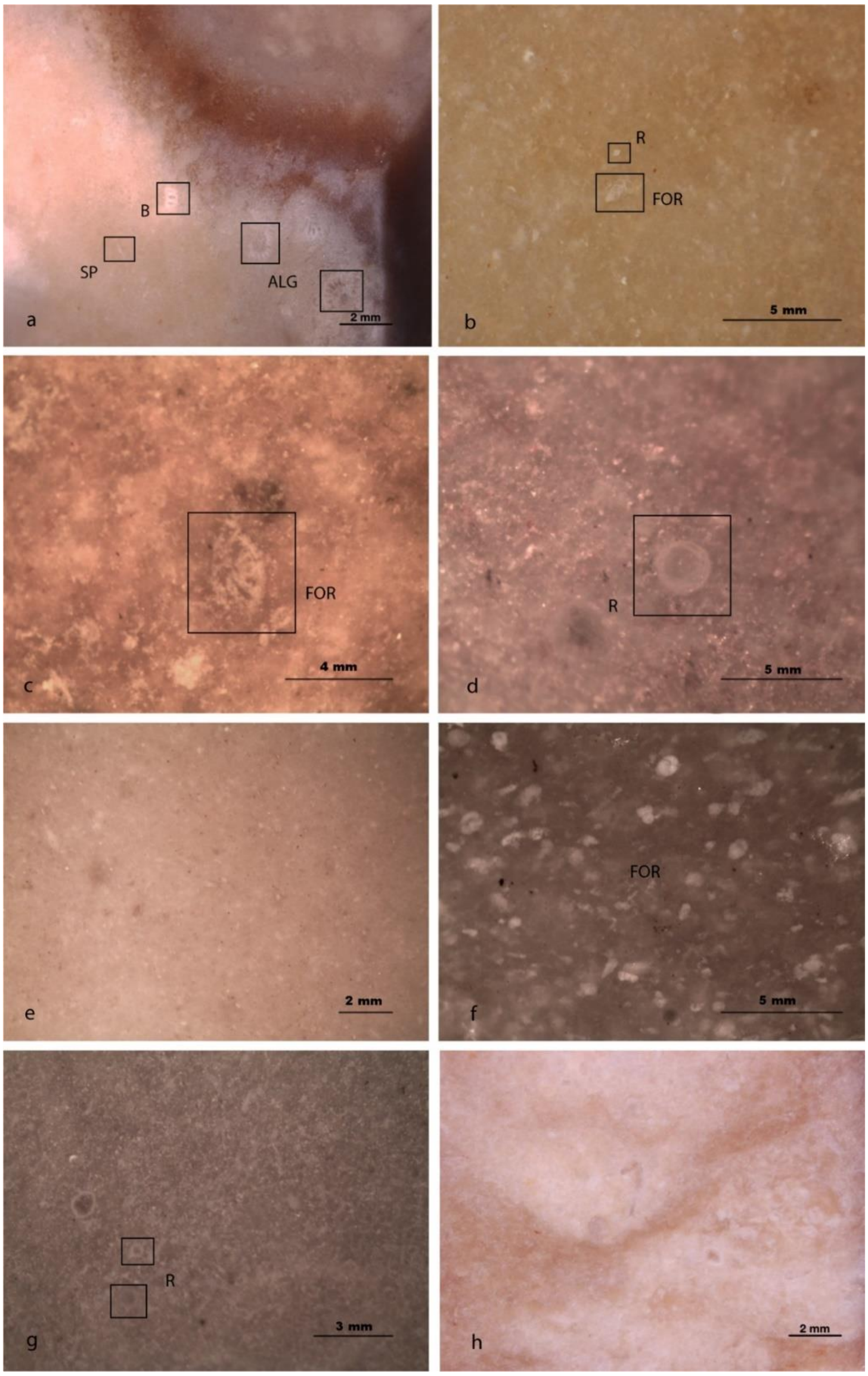


Fig. 7 Petrographic features of the analysed archaeological samples. Lithotype A, bioclasts (B), sponge spicule (SP) and algae (ALG) in a poorly-sorted texture, with particle size more than 50% (a); lithotype B, foraminifera (FOR) and radiolarians (R) in a moderately-sorted texture, with particle size more than 50% (b); lithotype C, detail of a large foraminifer (FOR) in a poorly-sorted texture, with particle size less than 10% (c); lithotype D, detail of a radiolarian (R) in a moderately-sorted texture, with particle size between 10 and 50% (d); lithotype E, moderately-sorted texture. With particle size between 10 and 50% (e); lithotype F, detail of planktonic foraminifera (FOR) in a moderately-sorted texture with particle size between 10 and 50% (f); lithotype G, radiolarians in a well-sorted texture, with particle size more than 50% (g); lithotype H, casts of dissolved macro-fossils in a poorly sorted texture, with particle size between 10 and 50% (h).

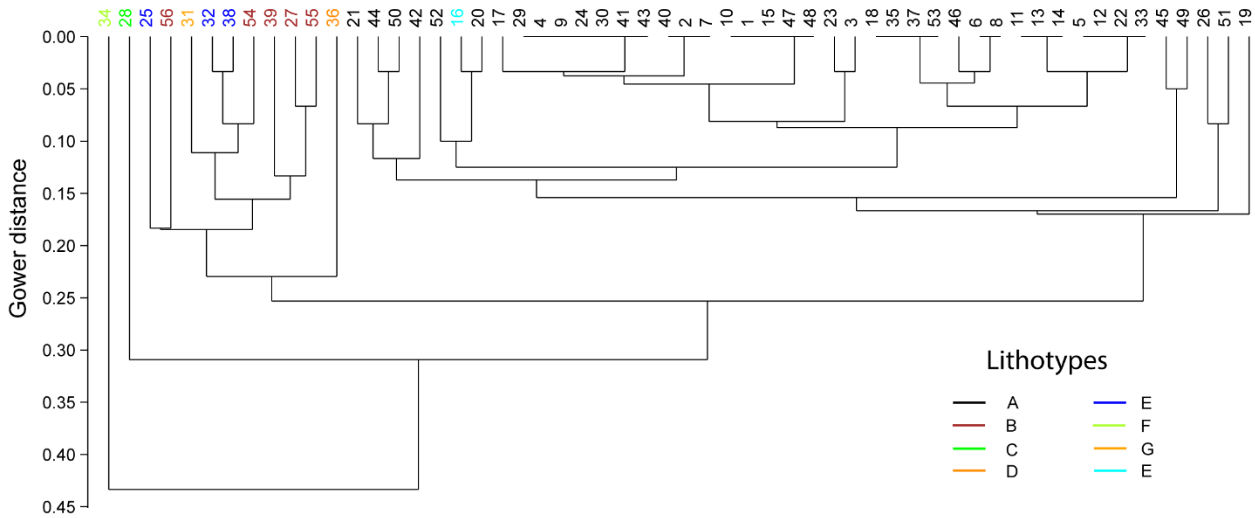


Fig. 8 Hierarchical dendrogram showing the results of the cluster analysis.

4.3.2. Microscopic description

Results from the microscopic description allowed to better distinguish the previously discussed lithotypes. Sorting, fraction, and micro-palaeontological content have been the discriminant variables allowing the distinction (Tab. 3). For what regards the texture, lithotype A features poorly-sorted textures with particle size more than 50%. The texture of lithotype B is moderately-sorted, occasionally well-sorted, with particle size more than 50%. Lithotypes C and H have similar sorting (poorly-sorted) but the fraction is different (less than 10% in the first, between 10% and 50% in the second). Lithotypes D-F exhibit moderately sorted textures with particle size between 10% and 50%. Finally, lithotype G shows well-sorted texture with particle size of more than 50%.

Micro-facies analysis allowed to recognise the importance of foraminifera, followed by sponge spicule, and algae within the lithotype A (Fig. 7, a; cp. Fig. 9, a, c, f). Lithotypes B-G differentiate from the former due to the presence of radiolarians (Fig. 7). They are associated with foraminifera and sponge spicule in lithotypes B-F, together with algae in lithotypes D-E. The presence of corals differentiates the lithotype C, as well as gastropods and ostracods in association with radiolarians in F. In addition, radiolarians constitute the only species observed in G, while H is characterised by the exclusive presence of foraminifera.

Using 8 ordinal variables, we performed cluster analysis, using the Paired Groups (UPGM) algorithm and the Gower Distance similarity index (Hammer et al. 2001), to statistically explore the results of the microscopic description and validate the differences found. Two variables are related to the texture (sorting, fraction), the remaining six provide the abundance of microfossil species (foraminifera, sponge spicule, algae, ostracods, gastropods, and radiolarians) within the samples studied.

Results highlight that several important correlations exist (Fig. 8). Looking at the dendrogram, from left to right, it is possible to note the separation of 4 groups at line 0.25. The samples belonging to lithotypes F (s. 34) and C (s. 28) constitute two separate groups. A third group is composed of samples belonging to lithotypes B, D, E, and G (this latter separating from the main cluster at line 0.23). Finally, the larger group is constituted by the lithotype A and the sample from H.

The absence of radiolarians and the relevance of foraminifera and sponge spicule in a poorly-sorted texture characterise the samples. The ramifications in the dendrogram might be explained as the effect of preferential chemical dissolution of the smallest fossils 'tests.

The group A characteristics find a direct match with the source of the Jebel Zawa, where the textures and the micro-palaeontological contents are quite homogeneous throughout the studied valleys. However, a certain degree of variability relates to some minor represented species, such as the alveolinids and the algae, differentiating the Old Sharya and a specific cluster in the Shik Hidir valley within the Pila Spi Formation.

As the case of some items within the group A, the presence of algae in association with foraminifera and low contents of sponge spiculae would lead us to exclude the Shik Hidir geological context, to find a match with the Old Sharya evidence. Indeed, two samples from Helawa (Fig. 9, a, c) are strictly correlatable with the samples coming from the Old Sharya valley (Fig. 9, b, d), suggesting that the blades might come from workshops located in the valley.

It is worth to mention that sample n.16, attributed to lithotype H, is also comprised within this large group and might effectively share the same provenance. As the dendrogram highlights, the differences among the other lithotypes are not perceptible by using exclusively these variables. In addition, it has been already shown that macroscopic variables, especially the colour coordinates, do not allow to operate a real distinction which will be discussed in the next paragraph.

4.3.3. Geochemistry

Results from the pXRF analysis considered the concentration of 8 elements: Sr, Ni, Fe, Ti, Mn, K, Ca, Ba. To compare the results obtained on the archaeological materials with the geochemical fingerprints of the Jebel Zawa source, Ca and Ti values have been excluded from the analysis (see chapter 6). Fe and K constitute the major elements revealed. On the base of the literature (Moroni and Petrelli 2005; Bradley 2017), we tested the hypothesis that Fe and K values can be interpreted as post-depositional enrichments occurred on the object's surfaces, in relation to different stages of patination. The graph reported in figure 10a, explores the correlation, per each sample, of Fe and K and compares their ratio with the geological samples. As evidenced, the content of Fe and K is strictly correlated and clearly separates the archaeological samples from the geological ones. Moreover, a further correlation seems to exist between the stages of patination, and consequent changes in colour, and the contents of Fe.

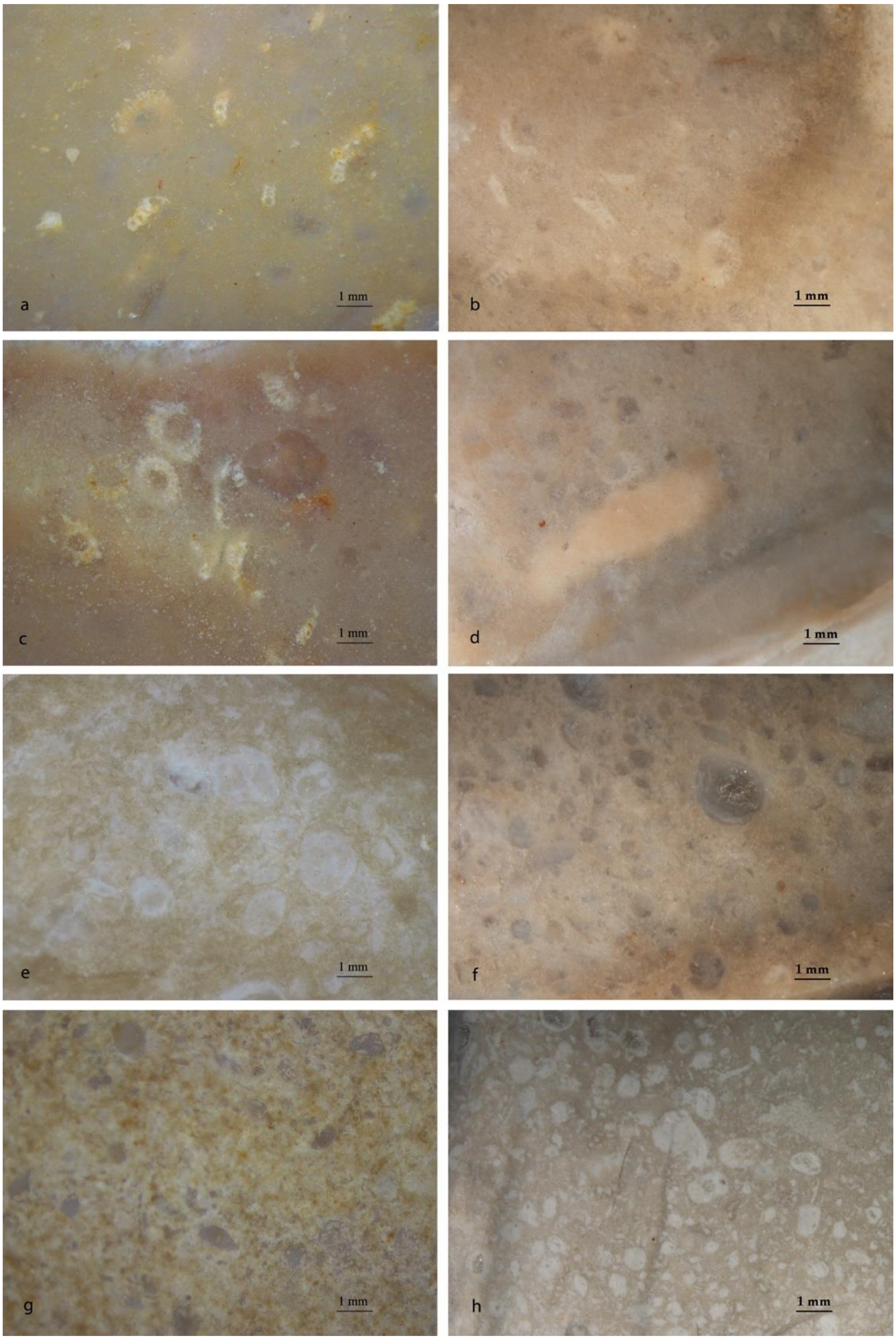


Fig. 9 Comparison of petrographic features between the archaeological artefacts (left column) and the geological samples (right column) (magnification 10x). Samples n. 51 (a) and n. 55 (c) from the site of Helawa; sample n. 10 from site 776 (e); sample n. 6 from site 48 exhibiting a patination stage 4 (g); geological samples from the Old Sharya valley of the Jebel Zawa (b, d, f, h).

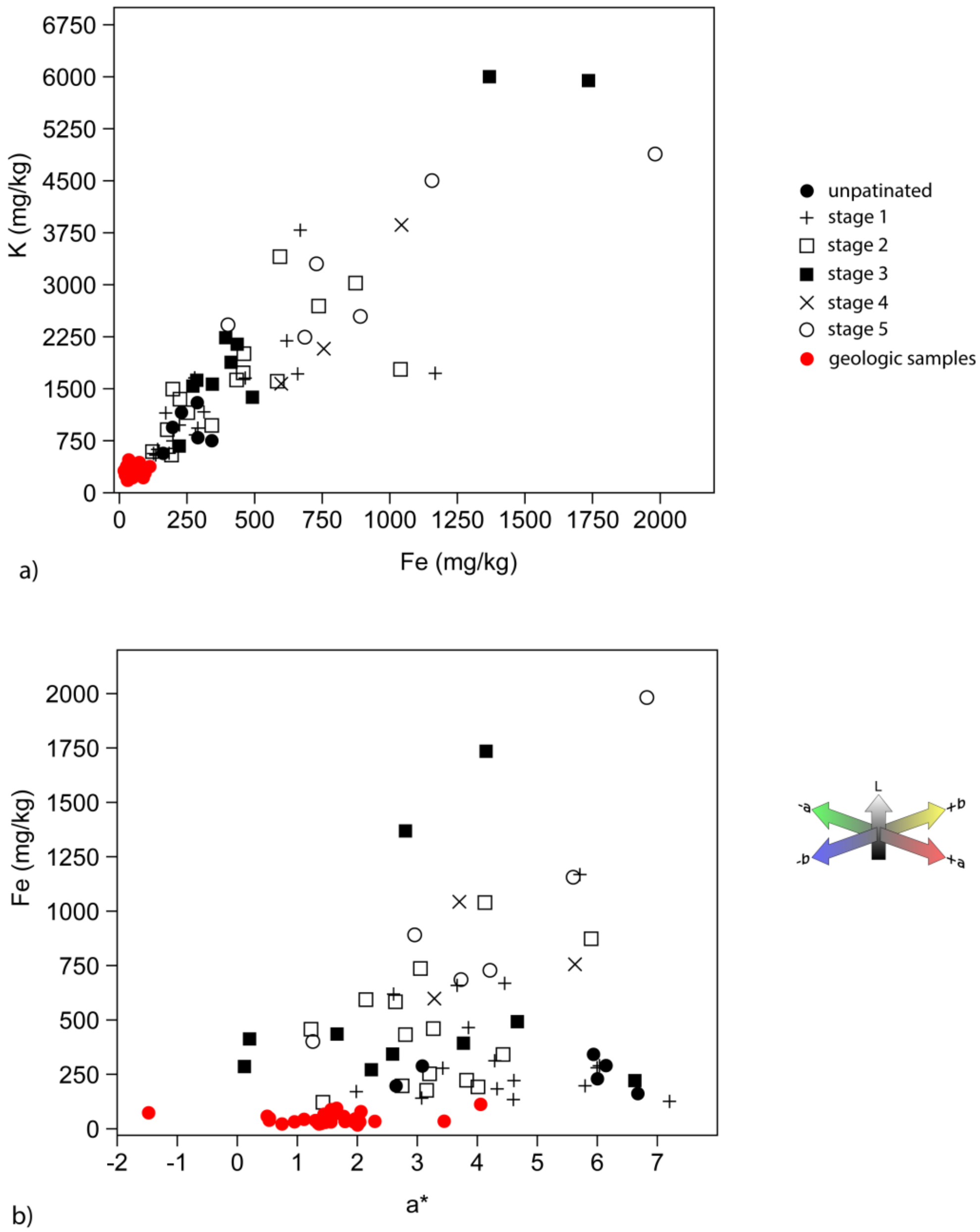
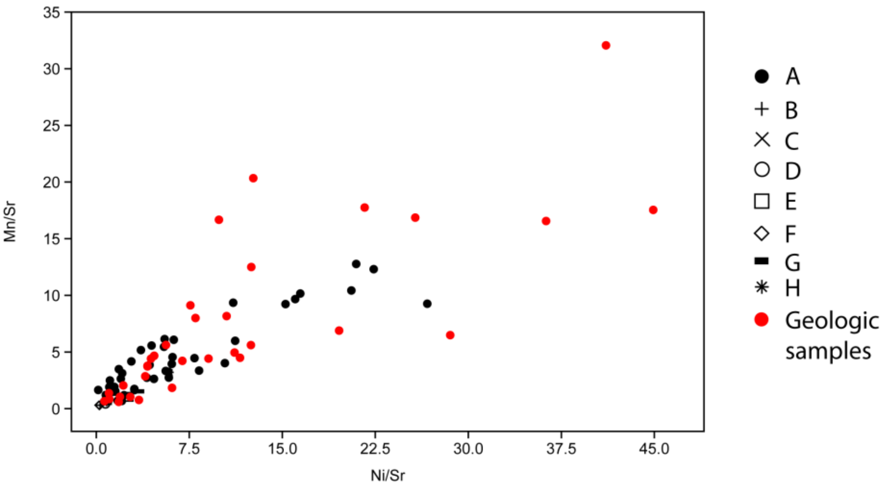
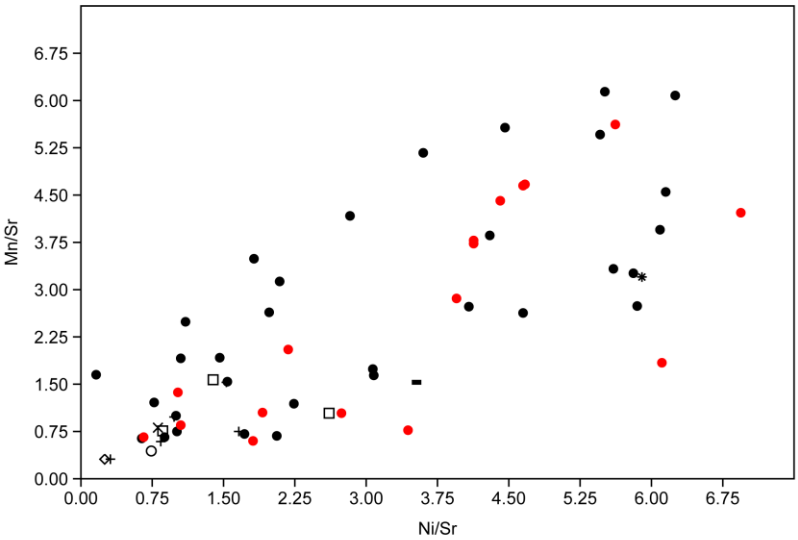


Fig. 10 Plot showing the relationship between Fe and K, compared with the geological samples (a); plot showing the correspondence between Fe and a*, compared with the geological samples.

The graph in figure 10b highlights this correlation and shows how the reddish coordinates of the CIELab spectrum (a* values) are influenced by the growing amount of Fe. Apart from few non- and low-patinated samples, that naturally exhibit reddish shades, higher degrees of patination (stages 4-5) are correlated with high amounts of Fe, due to the already cited textural changes that can occur. In addition, a separation already exists since low degrees of patination, indicating that the amount of Fe cannot be considered to reconstruct the provenance of the artefacts. Moreover, the geological samples show that a* values are not correlated with Fe content.



a)



b)

Fig. 11 Plot comparing the ratio between the concentrations of Ni/Sr and Mn/Sr of the archaeological and geological samples (a); enlargement of the previous graph up to 7.5 values for both the axes (b).

Since Ba content oscillates within the geological samples (see Chapter 6), and it has been not accurately revealed on the archaeological ones (half of the samples were under the limit of detection), we tested Sr, Ni, and Mn values to find a correlation in the light of the artefact's provenance. The hypothesis to verify was that the artefacts belonging to the lithotype A group, identified on a microscopic scale, correlate also from a geochemical point of view with the samples from the Jebel Zawa.

The ratio between the concentrations of Ni/Sr and Mn/Sr (Fig. 11, a-b) shows that the samples belonging to lithotype A correlate very well with the geological samples of the Jebel Zawa. In addition, sample n.16 (lith. H), as highlighted also by microscopic analysis, correlates with the geological samples, too. Some samples are spread through the centre of the graph, indicating similar content of Ni and higher values of Sr, which, however, is also reported for some geological samples. The other lithotypes (B-G) also find correlations with the geological samples. It should be considered that artefacts coming from different geographical sources might exhibit similar ratios between the concentrations of some elements – such as Ni, Sr and Mn – thus not suitable in the light of the artefact’s provenance in the region.

5. Discussion

Results from the application of NM-PCI on the archaeological artefacts, and the investigation of their provenance in light of the chert source of the Jebel Zawa, yielded good results only by operating a critical assessment of the data and combining the information collected over the different layers of analysis: macroscopic, microscopic and geochemical.

The present work represents the first absolute attempt to characterise a specific class of artefacts, widely spread in the Northern Mesopotamia and throughout the Near East, namely the Canaanean blades. As told earlier, to deal with such a class of materials, one should have to consider their complex biographies, including the possible physical and chemical diagenetic transformations that occur after their discard and can cause fractionament of the raw material properties.

The first stage of fractionament might already begin during the knapping of the chert nodules and involves their macroscopic features. Raw material selection strategies together with standardised methods and techniques of core reduction used (see chapter 3), certainly influenced the splitting up of the nodule original features (cortex, sub-cortical zones, type of structures) and their misrepresentation within the archaeological record, especially when the latter is relative to consumption sites where no other stages of the production are represented.

Another level of data disturbance is of socio-economic nature and relates to modalities and strategies of objects ‘use and management (segmentation, retouch, uses of glues involved in their hafting). A third layer is represented by the spatial and economic contexts in which they were introduced and discarded and regards not only anthropic factors but also the post-depositional agents affecting the site preservation.

The present work considered all the issues and focused on their effects providing a method to address the analysis accurately. The chert alterations observed on the artefact ‘surfaces were used to select the variables suitable to characterise them, providing elements of comparison with the geological samples to reconstruct their geographical provenance.

However, a series of limits in the application of the protocol have been found. These limits are probably represented not only by the weathering processes that affected the surfaces but also by the relative macroscopic homogeneity of the cherts circulating in the area. The presence of patinae certainly emphasized the difficulties, causing limitations in the systematic recording of several variables, such as fracture and structure. On the other hand, the similarities in chert colours, as recorded from unpatinated artefacts, yielded no significant results when compared with the variability of colours attested in the geological samples.

However, the microscopic features have been less affected by surface alterations. Unlike the recording of colour coordinates, the observation at the stereomicroscope was not limited by the geometry of the artefact 'surfaces. The absence of practical issues allowed to observe the chert features following the distribution of the best-preserved areas on the tool's surfaces. This circumstance was mediated also by an optimal knowledge of the geological samples, through an in-depth study of their features, which allowed to identify specific characteristics (micro-fossils, textures) even when the information was fragmentary (Fig. 9, d, h).

From a geochemical point of view, the state of preservation of the samples caused the mobility of some elements (Fe, K) and the depletion of others. Very few studies focused on the effects of patinae – or weathering at broader scale – on the geochemical provenance of archaeological lithic materials (Bradley 2017; Gautier and Burke 2011; Högberg et al. 2012; McLennan 1989). In the specific, the case study reported by Bradley (2017) is indicative of correctness of the method here adopted. Analysing the provenance of British cherts by using the XRF technique, the author found that patinated artefacts contained four times high contents of Fe than the geological samples, in recurrent association with "orange" patinae. He also claimed that different rates of Fe absorption, from the surrounding environment, can occur on the same sample. The statement is comparable to what has been observed in the present work[3], despite the evident geographical differences.

The advantage of adopting a multi-parametric protocol (nominal, ordinal and continuous variables) lies in the possibility to combine the results and establishing ratios of cause/effect by finding correlations between the variables. This was the case of the content of Fe and K, which were found to be enrichments due to post-depositional conditions. The relationship between reddish shades and the amount of Fe that occur at stages 4-5 of patination has been highlighted by plotting together the values of a* and Fe. This allowed us to avoid elements such as Fe and K, and focusing the analysis on those like Sr, Ni, and Mn that were found to be not affected by mobilisation.

The results of this work allowed to identify, on the base of the geochemical pXRF analysis, a correlation between lithotypes A and H with the geological source of the Jebel Zawa. This match is supported by the microscopic features, implying that all the Canaanean blades of the present groups resulted to be produced and distributed from the present source.

[3] A more detailed work regarding this issue is actually ongoing.

However, we must be cautious when asserting that the ratios between the concentrations of Ni/Sr and Mn/Sr constitute valid geochemical markers for this correlation. Future data will clarify this aspect when several other chert sources from the Tigris macro-region will be studied and compared. Some issues are evident when comparing the other identified lithotypes with the Zawa source. Despite they resulted to be incompatible from a microscopic point of view, they are quite similar from a geochemical point of view. The circumstance that distant sources could exhibit similar element ratios is known from the literature (Delage 2007; Moroni and Petrella 2005) and will deserve further attention in the future.

5.1. Assessing the geographic provenance of the samples

Results from this work allowed to obtain elements to assess the geographic provenance of the analysed archaeological samples. The lithotype A and H characteristics match with the Jebel Zawa chert, both at microscopic and chemical scales, while lithotypes B-G must be considered of non-local availability. This is highlighted by the distribution of the lithotypes within the analysed sites, in relation to their distance from the source of the Jebel Zawa (Fig. 12, a).

The availability of suitable chert nodules within the upper part of the Pila Spi Fm observed in the Jebel Zawa (see chapter 6) assumes great importance in the whole Tigris region. Indeed, moving away from the territory of the chert mining district, the weight of other lithotypes, well separated from the local one, increases (Fig. 12, a). Results obtained on the Helawa samples support this assumption. Half of the samples have found to be produced and distributed from the Zawa source which dists about 120 km north. However, the weight of the B lithotype at the site is higher, indicating that no Eocene chert exploitation systems could have existed at the local exposures of the Pila Spi Fm, located west of the site and behind the city of Erbil.

This fact could be indicative of the exclusive geological setting of the Jebel Zawa in the light of the chert procurement and exploitation to produce the Canaanean blades on one hand, while, on the other, the existence of further networks of distribution is evident.

Although it is unknown at the present stage of the research the location of their distribution sources in the macro-region, results from the petrographic analysis indicates that these are represented by radiolarian cherts at all (Fig. 12, b). However, the lithotype B attested in Helawa is also diffused in the northern area (sites 728 and 888) indicating that the Canaanaean blades made from this type were distributed over long-distance, similarly to what has been observed for the Zawa blades.

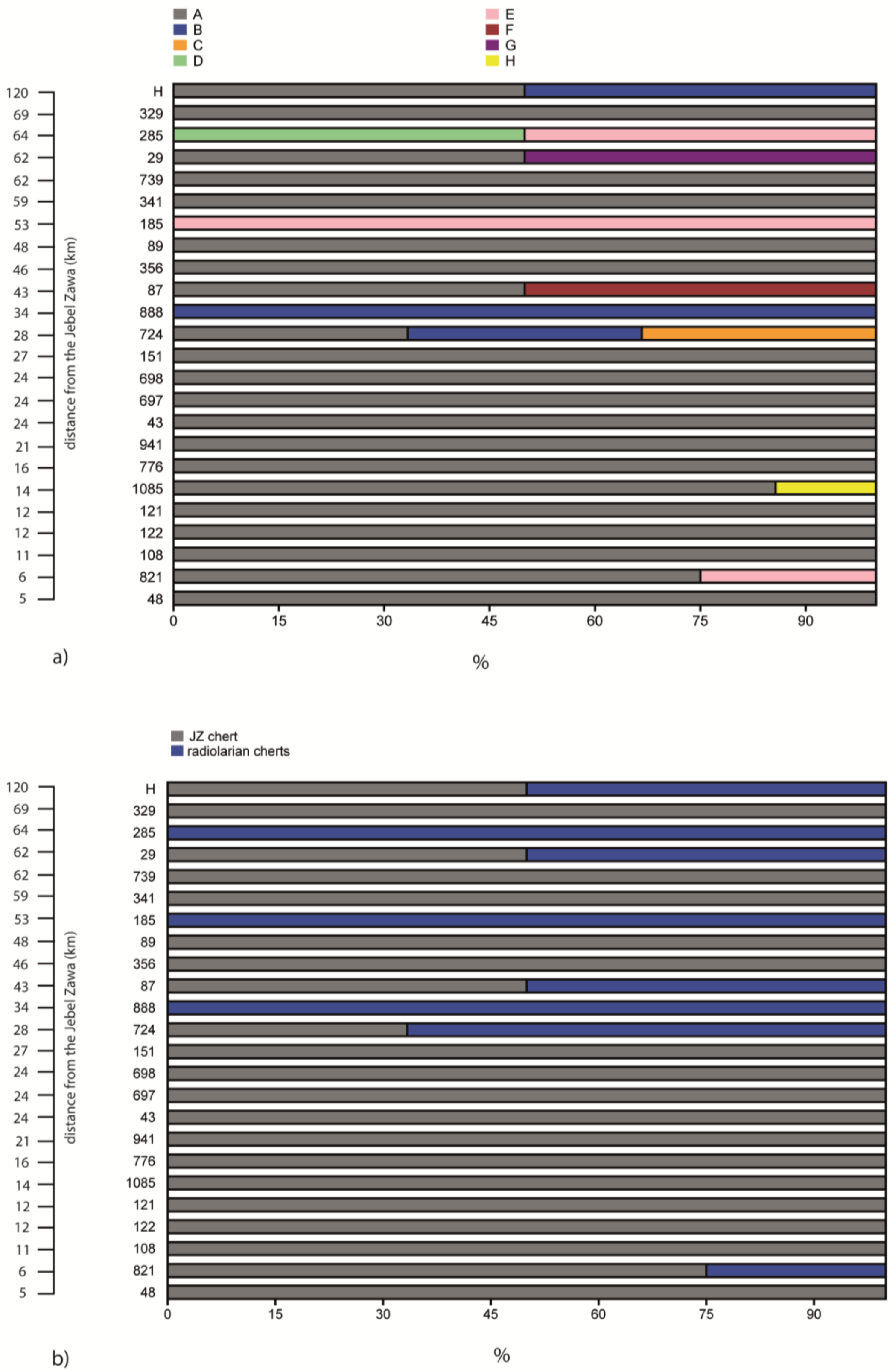


Fig. 12 Percentuals of the chert types identified in the sites in relation to the distance as the crow flies from the source of the Jebel Zawa. Distribution of the different lithotypes (a); distribution of the Jebel Zawa chert and radiolarian cherts (b).

It is also worth to mention that the local secondary deposits in the Jebel Zawa region are characterised by a massive presence of radiolarian cherts, especially those pertaining to the course of the Tigris River, which might have been eroded and transported from more ancient geological formations located in the upper course of the river (present-day Turkey).

5.2. The Canaanean blades 'procurement/distribution networks

From an archaeological point of view, the results of the provenance analysis allowed us to define distribution areas by which the presence of blades manufactured with the Jebel Zawa chert in the sites is discussed both in relation with their absolute distance from the source and the compresence of other lithotypes. Several ranges have been considered from a central point represented by the chert mines (Figs. 12-13). These ranges have been arbitrary traced out on a regular growing distance of 10 km from the mines and graphically represented using circles (buffers). Specifically, we identified a Jebel Zawa chert predominance area (0-20 km), a proximal area (20-30 km) where other networks are emerging, a regional area (30-70 km) where the weight of the radiolarian cherts assumes significance, and finally an extra-regional area (70-150 km) indicating the present-stage maximum extension of the distribution of the Jebel Zawa blades.

Within the closest range of 10 km to the mines (Fig. 12), all the Canaanean blades analysed are related to the exploitation of the Zawa chert, apart 1 artifact from site 821 resulted to be of non-local origin. The existence of a system of settlements potentially connected to the extractive and productive activities carried out at the mines strongly supports the evidence.

At 20 km from the mines, the data suggest that the procurement of Canaanean blades was carried out on a local scale. Within the range are comprised the sites located on the Mosul Dam and one site from the Dohuk Plain. In addition, the evidence from the Late Chalcolithic 5 and Early Bronze age site of Tell Karrana 3 indicates that the whole Canaanean blades production might be reconducted to a single chert type, defined as light to dark grey and believed to be locally available[4] (Brautlecht 1993). The technological analysis of the lithic production at Tell Karrana 3 also showed that blade extraction was carried out on-site from prepared cores (Brautlecht 1993).

In addition, from a geological point of view, the only one formation bearing chert is the mid-late Eocene Pila Spi and the availability of suitable nodules is recorded only at mines despite chert nodules have been also recorded at other localities (Fig. 13). Thus, the range of 20 km indicates that the area is placed in a circum-local sphere of the territory where the small communities settled in the area might have had direct access to the chert raw materials.

[4] Brautlecht (1993) indicates that an economy of chert raw materials existed at Tell Karrana 3. Fine-textured cherts were used to produce ad-hoc tools, while the large blades were produced using a coarse-textured and nodular chert of regional availability.

Different procurement patterns are hypothesized for the sites placed in the range of 20-30 km from the source (Fig. 12). While in the north-western area, site 941 attests a relationship with the mines, the lithic inventories from the sites located in Ba'dreh area reveal that radiolarian chert types begin to appear in the area along with the local one.

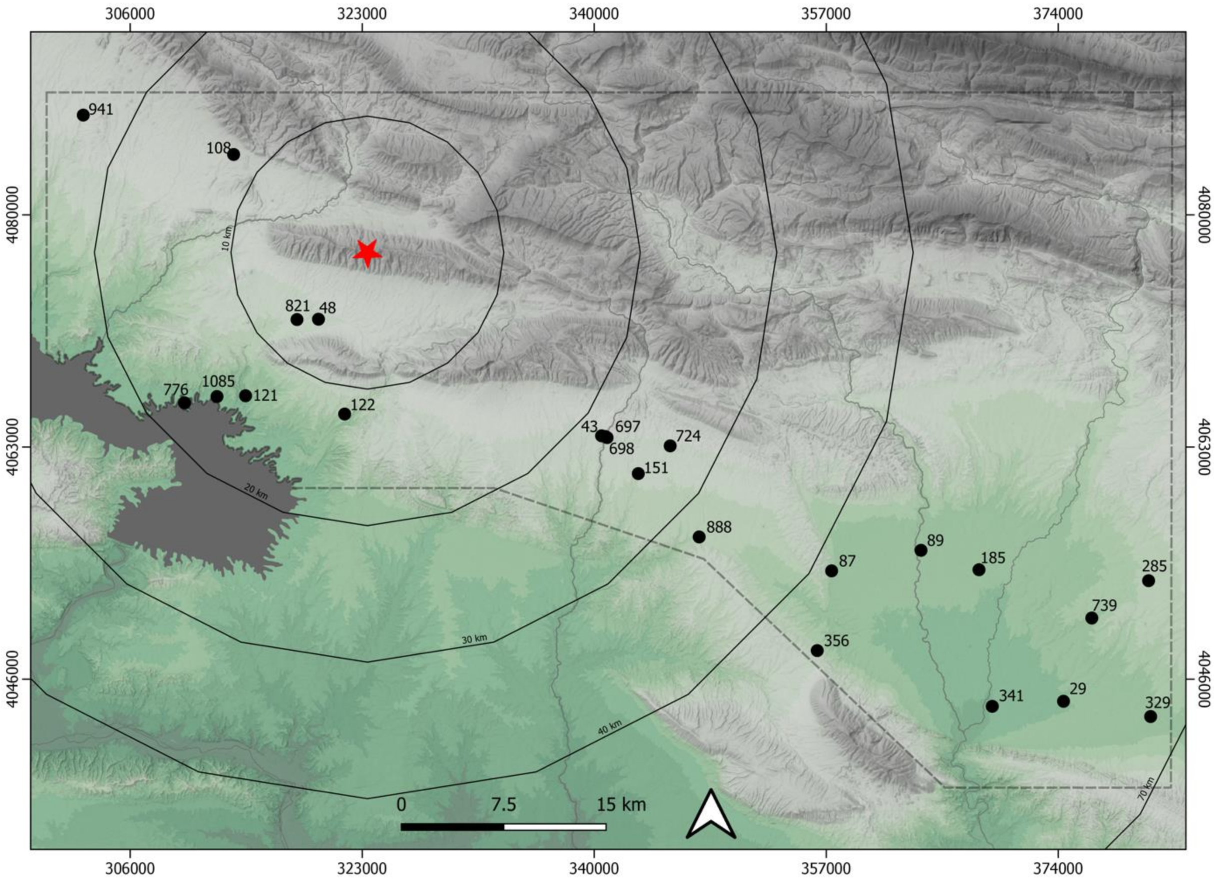


Fig. 12 The distributional areas of the Jebel Zawa chert within the LoNAP area.

The integration of the toolkits, through contacts and exchanges on a wider scale, of non-local produced blades seems to be the most affordable hypothesis for these sites. However, as discussed in the previous paragraph, we must consider that within the range of 70 km from the mines, several other geological formations of mid-late Mesozoic age are attested, when entering in the domain of the High Folded Zone (HFZ) of the Zagros Thrust Belt. Although these areas, located north and north-east, are fairly unexplored from a chert availability perspective, we cannot exclude that several other chert sources[5] were exploited to produce Canaanean blades at a regional scale.

[5] The only other known chert source, located at the northern border of the 70 km range, is that of the "black chert" present within the middle Jurassic Sargelu Formation, which consists of a succession of dolomitic limestons containing chert lists in the upper part of the sequence. The raw material features high contents of radiolarians, and it is reported to be highly fractured (Sherwani and Balaky 2006). However, this specific type has been not encountered for the moment in the region.

Within the range of 70 km from the source, the Zawa chert is spread along the south-eastern vector in the Navkur Plain. The current documentation does not allow to formulate hypotheses about the nature of the procurement from the source. However, it is possible to highlight that a crested blade produced in a non-local material is present in the surface record of site 739, indicating that a potential variability of chert procurement strategies might be revealed through systematic excavations at the sites of the area. For these reasons, the lithic materials unearthed from the excavations at Gir-e-Gomel and Asingrian will certainly contribute with new data to the discussion.

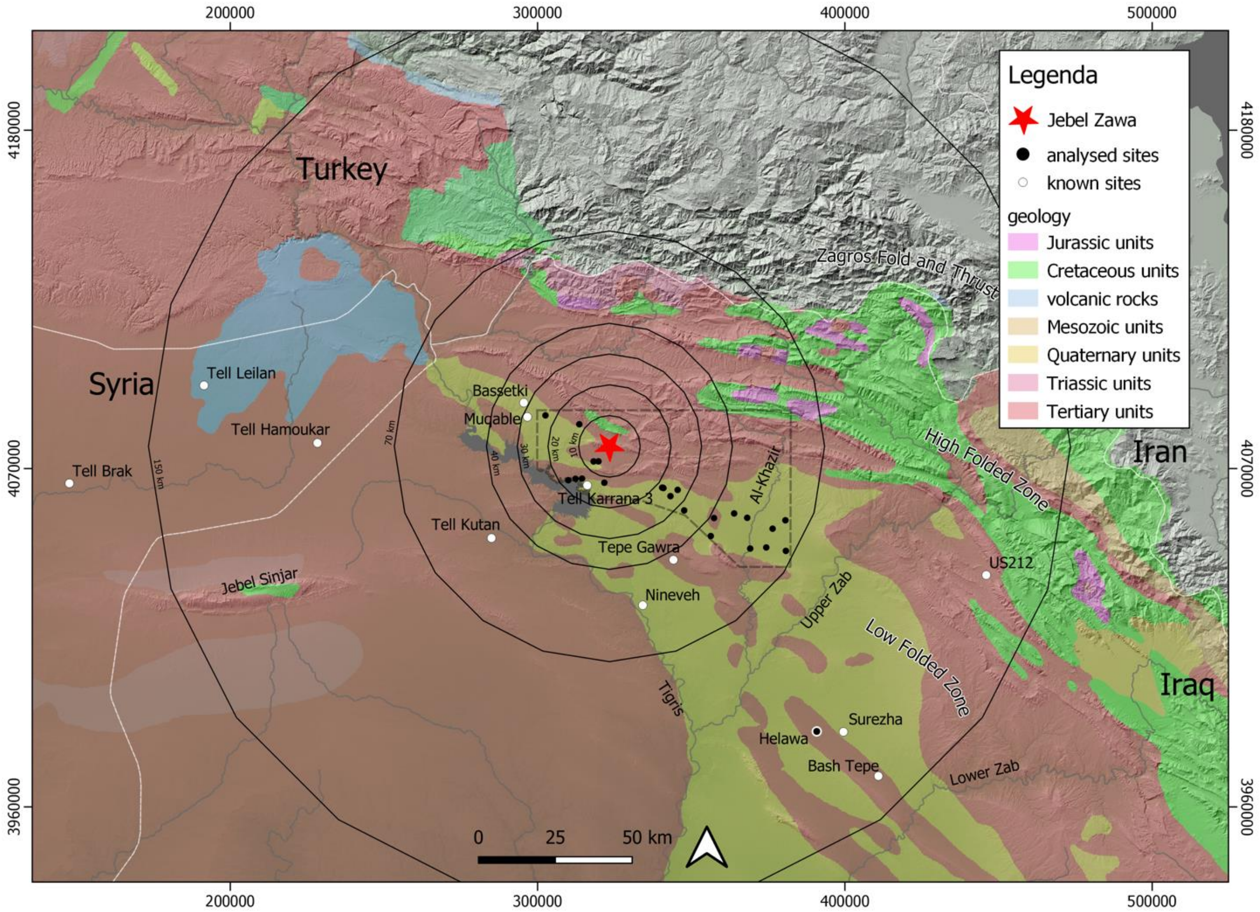


Fig. 13 The distributional areas within the north-eastern Mesopotamian LC-EBA framework.

It is possible to define the present range as the limit of the regional area, which also includes the presence of other well-known sites, such as Tell Kutan, placed at the south-western border of the area, Tepe Gawra and Nineveh to the south.

The first two sites are small villages, while Nineveh represents the biggest settlement (about 40 ha) of the whole area. For what concerns Kutan, little information is available for the chert raw materials attested on the Canaanean blades fragments used as tools[6] that might find a potential match with the Jebel Zawa. The lithic assemblages from the other two sites remain unpublished[7].

Further widening the range to 150 km from the source of the Jebel Zawa, several other areas exhibiting must be added in the discussion. From east to south-east, the territories related to the Great Zab fluvial basin and the contiguous Erbil Plain, while to the west, the eastern part of the Syrian-Iraqi Jezirah and that of Jebel Sinjar (Fig. 13).

The Zab River Plain shows a settlement pattern evolution very similar to the nearby Navkur Plain. The number of settlements increases during the Late Chalcolithic, forming a dense network of villages that do not exceed 1-5 ha in size. Only one site grows up to 40 ha in size, showing the character of a typical Southern Uruk pottery production (Kolinski 2018). During the Ninevite 5 period, however, the settlements, although more numerous, are more dispersed throughout the territory (Kolinski 2018). It is interesting to note that during this latter period, site US212 revealed the presence of a lithic workshop to produce large blades that might have had served the whole area (see chapter 4).

Although chert availability is not yet known in the Zab region, the presence of suitable nodules within the local Pila Spi Fm represents an element to verify with future research, as well as the suitability of the radiolarian chert sources located more inland in the High Folded Zone (Karim *pers. comm.*).

Further south, the 5th to 3rd millennia BC occupation of the Erbil Plain shows different settlement trajectories. During the early Late Chalcolithic period, several villages coexisted in the plain (Peyronel and Vacca 2015). Although some sites are abandoned during the 4th millennium BC, no site emerged as an urban centre (Peyronel and Vacca 2015). On the contrary, during the Early Bronze age two larges settlement developed in the region: Tell Baqtra (80 ha) and Qasr Shemamok (40 ha). Unfortunately, the lithic assemblages from the two sites are not reported nor published.

However, the results obtained from the Helawa archaeological samples are of great relevance within the local picture. The three Canaanean blades manufactured with the Jebel Zawa chert testify that during the maximum extension of the settlement (about 8 ha), occurred during the late LC3 period, the site was connected within the network of circulation of the Jebel Zawa chert. However, the analysis of the lithic assemblages (see chapter 5) indicates the preponderance of several other distribution networks of Canaanean blades in the Erbil Plain. This is confirmed by the Canaanean blades assemblages of the Late Chalcolithic/Early Bronze age neighbouring site of Bash Tepe

[6] Within the small Ninevite 5 village of Tell Kutan, a medium-coarse textured chert of grey colour is reported to be the raw material attested on the Canaanean blades fragments. Moreover, no stages connected with their production are attested at the site (Inizan and Anderson 1994).

[7] Angevin (2018) reports two colour photos of some blade cores from the LC 2-3 layers of Tepe Gawra, reduced by the lever pressure system or the indirect percussion. However, no additional informations are available. Iamoni (2017) reports a colour photo of a Canaanean blade proximal fragment from the prehistoric layers of Nineveh, whose chert type appears to be very similar to the Jebel Zawa one.

(Angevin 2013), where some similarities with chert raw materials represented at Helawa can be highlighted from a macroscopic scale.
The appearance of a large blade component within the lithic assemblages in the Erbil region dates to LC3 period at Helawa and fits perfectly within the Surezha evidence (Stein 2018). However, the distribution of the Jebel Zawa chert in the northern area suggests that knapping workshops might have been active since the very early beginnings of the Late Chalcolithic period. The precocity of the processes occurred around the source of the Jebel Zawa constitutes a further element concerning the absence of suitable chert sources in the southern area.
In the area west of the Tigris River, the occupation of the territory seems to be very different. As early as LC2, the biggest settlements of the area – Tell Brak, Hamoukar, Tell Leilan, Tell Al-Hawa – expand and reach enormous dimensions. No published data about the lithic assemblages are available (Thomalski 2019). Regarding the supply of Canaanean blades, some scholars agree that these settlements were mostly related to the Euphrates and Anatolian worlds (Chabot and Eid 2003; Chabot and Pelegrin 2012).

6. Summary

Using the NM-PCI protocol, we analysed a set of 56 Canaanean blades selected from LC-EBA sites within the north-western Kurdistan Region of Iraq. Results of the work highlighted a correlation between specific groups of artefacts (lithotypes A-H) and the geological samples from the Jebel Zawa mines, suggesting the provenance of such blades from the lithic workshops identified at mines. The correlation is strongly supported by petrographic analyses and, from a geochemical point of view, by the comparison between the elemental concentrations of Ni/Sr and Mn/Sr.
The work also demonstrated that chert post-depositional alterations – such as patinae – do not constitute an unsolvable problem for chert characterisation. On the contrary, they have been used to explain colour and textural modifications, as well as chemical elements mobilisation by identifying the diagenetic changes and selecting the idoneous variables to conduct the study in a correct form.
From an archaeological perspective, the distribution of the Jebel Zawa Canaanean blades occurred within the regional territory. An absolute prevalence of the Zawa chert is recorded within the Canaanean blades assemblages within the range of 20 km from the mines. As far as the distance grows from the core area (from 30 to 70 km), the weight of radiolarian cherts is significative of different distribution networks occurring in the region. During the late LC3, the supply of the Jebel Zawa products occurred over a long distance at the site of Helawa where off-site produced Canaanean blades constituted the exclusive laminar component within the lithic assemblages starting from this

period. Several other chert types constituted the largest part of the Canaanean blades evidence, thus supporting the existence of other networks of distribution in the area.

8. Conclusions

1. General remarks

The results of this work are important from two points of view: the methodological framework adopted and the archaeological implications. As regards the first aspect, it was the first time that a relevant issue – the Canaanean blades – is addressed through field-research, technological analysis of production sites, use and discard contexts and laboratory analyses. Indeed, a fundamental part of the research focused on identifying the sources on the territory and their characterisation.

Although this approach is now widely applied to the study of the circulation of stone artefacts from sources to destination sites to reconstruct mobility patterns and interactions between ancient human groups, it represents an absolute novelty for what concerns the standardised chert productions of the Near Eastern late prehistory where similar studies are only applied on obsidian.

Therefore this project constitutes a pilot study for both the Kurdistan Region of Iraq and the northern Mesopotamia as a whole, which over time is being enriched with stratigraphic and chronological data. The stratigraphic sequences are now being defined thanks to the numerous excavations in the area which will provide radiocarbon dates for a precise definition of the periods, and on the other hand, lithic assemblages from secure contexts that will contribute to a detailed scan of the events under discussion. For these reasons, we took into account the lithic documentation available from the intensive surveys on *tell* sites. Thanks to the data collected and made available by the LoNAP team, it was possible to trace the evolution of the sites over the long term, establishing a relative chronology for the finds in their contexts. Since all the teams active in the area (LoNAP, EHAS, UGZAR, EPAS and MAIPE) have adopted the same pottery typology (Ball et al. 1989, Ur 2010; Wilkinson and Tucker 1995), the periodisations carried out in the various areas are perfectly comparable and this constituted an undoubted advantage for comparisons and assessments on the interregional settlement.

2. Effectiveness of the method

The advantages deriving from the application of the methodology in this work were many. The single operator who carried out the entire workflow was able to personally evaluate the aspects related to all stages of the research, contextualising the issues related to both archaeological aspects and the raw materials used. In this way, a continuum was created between the identification and recognition of an economy of lithic raw materials and *débitage* products (Perlès 1991) and the subsequent choices over the characterisation of geological sources and archaeological artefacts.

This “global” and "systemic" approach made it possible to visualise all the components of the cultural and natural landscape, the availability of local resources and human behaviours in a single framework, proceeding from particular to the general. The relationships between technological choices and socio-economic organisation of societies (Conati Barbaro 2005; Lemonnier 1986, 2010), dictated by cultural needs and factors, have been related to each other providing a dynamic picture in which the different networks activated (Conati Barbaro and Manfredini 2006; Smith and Harvey 2018).

2.1 The NM-PCI protocol

The NM-PCI protocol (Delluniversità et al. 2019) was applied to answer specific questions in a geographic area totally different from the one on which it was first formalised and published, namely the Kurdistan Region of Iraq.

For this reason, the present work actively contributed to the development and refinement of the present protocol. First, the macroscopic variables were integrated with the morphometric data relating to the nodules, collected directly in the field, to solve questions regarding the availability of blocks suitable to produce large blades. Secondly, the recording of the position (with a margin of error due to the GPS instrument adopted) of the sampled nodules allowed the elaboration of distribution maps of selected variables to understand, not only the behaviour of single characteristics within different populations of samples (SK-SK2-GK-OS groups of Jebel Zawa) but also to highlight spatial differences to effectively grasp the differences and use the data in terms of provenance of archaeological samples.

A further element of enhancement was the inclusion of variables relating to the state of preservation of archaeological artefacts. The recognition, study and distribution of patinae on the objects ‘surfaces allowed us to address and point out aspects not previously outlined, such as the incidence of post-depositional agents on the recognition of macroscopic, microscopic, and chemical characteristics.

Further analyses are currently underway to face and evaluate such a difficult issue, considered as taboo by many researchers and leading to partial analyses or drastic recalibrations of strategies to characterise archaeological lithic artefacts.

For all these reasons, we believe that this protocol, although still susceptible to changes over time depending on the contexts in which it will be applied, still has an enormous margin for growth and improvement. The advantage of working with many variables allows to consciously select them based on of their weight within the intrinsic characteristics of chert (e.g. bulk, surface and chemical features) and depending on the research theme. An interesting perspective could be that of experimenting techniques for automating data collection by exploiting modern data acquisition techniques (high-resolution microscopy, 3D imaging and processing) which would allow reducing the degree of

subjectivity that stays in the adoption of ordinal variables, in favour of continuous variables to conduct more detailed statistical processing.
Finally, the application of the NM-PCI protocol highlights the need to implement the microscopic description, recognised as being a very important factor to differentiate geological sources in the present region. One of the future goals will be to establish collaborations with micropaleontology experts and improving the method through post-doctoral projects.

2.2. The geological reference collection, aims and future perspectives

A further result of this work lies in having built up the basis for a *litotheque* of the western Zagros region. This tool is open access to all those interested in the subject (Moscone et al. 2020, *suppl. materials*). The reference collection is also accompanied by a series of practical examples of description, intended as a small useful guide for understanding the criteria for recognition and descriptions of the various aspects (see also the annexes of this work).
One of the objectives to be pursued soon is the integration of this database by publishing the chemical data. The integration of this dataset with the study of secondary deposits represents a further goal, useful for answering different questions and building detailed cartography for the area in conjunction with the publication of the new updated geological map of the area (Forti et al. *forth*).
This tool could also prove to be a collaborative basis with other researchers to enhance its breadth and develop research on neighbouring territories in the context of broader projects and on different topics.

3. Identifying a lithic production and exchange network

The results of this work allow us to recognize in Jebel Zawa the nuclear area of a network of production and distribution of Canaanean blades over two millennia. Similarly, this circuit intersects several other networks departing from unknown sources. The technological analysis applied to the study of the Jebel Zawa large blade workshops made it possible to identify their specific characters, the organization of production sequences at the chert mines. The whole sequence was aimed at obtaining blades of considerable and very regular dimensions – through a conscious and targeted extraction of nodules suitable for the purpose – which were exported to be distributed outside the mining context.
The distinctive features of the Jebel Zawa productions reside in the use of the pressure technique with a lever (or similar device, e.g. small lever) with a metal tip to produce long and regular blanks, thus bypassing variable mechanical properties of the raw material (see chapter 6). The core reduction process allowed to produce even smaller blades, as a result of a continuous knapping strategy, that

were also exported as an integral part of the production. This latter fact is of importance in the recognition of the variability in size and morphology of Canaanean blades productions from different areas.

The characters of this process seem to be homogeneous from a technical point of view. Similarities are highlighted with the neighbouring areas of the Jezirah in the morphology of the butts – dihedral and/or convex preparations – which also reveal the use of metal tips to enhance the blade detachment. The use of pressure for the extraction of these large blades represents a cultural marker that certainly finds comparison with the coeval contexts of eastern Anatolia, Caucasus area and middle-upper Euphrates and Jezirah regions (see chapter 1). Although the current state of knowledge allows us to grasp differences in our area only in terms of raw materials, the scarcity of proximal elements at Helawa site does not allow to in-depth characterise the blades 'morpho-technical aspects to highlight technological differences between raw materials and sites.

Moreover, due to the lack of excavated contexts and published assemblages we cannot even reconstruct evolutive dynamics of blade *débitage* traditions in the whole Tigris region. However, it is possible to carry out some considerations to set a starting point for future studies.

Helawa's evidence (see chapter 5) suggests that pressure (modes 2-3, *sensu* Pelegrin 2012b) represents an integral part of the technical packages of the Late Chalcolithic communities settled in the Erbil area, while it is not clearly recorded in the late Ubaid periods at the site. The presence of knappers able to produce bladelets using the pressure technique is testified on obsidian raw materials during the LC1 period, while only sporadically appears on cherts which are fully used to produce flakes. However, during this phase, larger obsidian blades (mode 4) appear to be the result of imports of finished products acquired through exchange dynamics. We cannot exclude that this trend began during the earlier periods of site occupation (7th-6th millennia BC), due to the limited extension and preservation of the excavated area.

During the LC 1-2 periods, differentiated behaviours were adopted in the productive areas of the site by exploiting and selecting local lithic raw materials (e.g. flint, diapers, limestone and quartzite) to produce both flakes and bladelets, some of them produced by pressure (modes 3).

Socio-economic strategies at the site undergo significant changes starting from LC 2/3 period. Blades and bladelets produced by pressure using crutches are attested on local raw materials and coexists with off-site produced blades with modules on the limit between modes 4 and 5. Before the abandonment of the site (late LC3), the imported blades attested at the site are attributable to the exclusive adoption of the lever system (mode 5).

This local evolution of the technical systems at the site might be representative of the Erbil plain picture and differs from what is observed in the Jebel Zawa region, where the presence of a suitable

chert source certainly boosted the emergence of large blades specialised productions since the beginnings of the Late Chalcolithic period.
Unfortunately, little is known about the characters of lithic productions in the Tigris region before the 5th millennium BC, even if the pressure technique characterises the blade assemblages both on chert and obsidian raw materials since the Early Neolithic (see chapter 1). All these gaps must necessarily be filled for a better understanding and scanning of the events according to a historical and cultural perspective to fine-tune the reciprocal relationships between contiguous areas often interpreted as different entities based only on pottery analyses.

3.1. The Jebel Zawa region

The Jebel Zawa chert has been exploited starting from very ancient periods as evidenced by the surface finds in this mountain (see chapter 3). However, a real cultural and anthropic landscape emerged in the area from the Late Chalcolithic period. On the one hand, the exploitation of open-air outcrops, and, on the other, the excavation of karst cavities for the extraction of nodules, the accumulation of excavation debris and knapping waste piles contributed to the modification of the natural landscape, as a result of prolonged use of the area (see chapter 3).
All these activities occurred in the central valleys of the Jebel, where a greater availability of chert has been recorded. Nevertheless, specific choices were carried out by selecting raw blocks based on the size of the blanks to be obtained within a wide range of macroscopic and morphometric characteristics of the nodules. Large and regular blocks were preferred to set the core surfaces: a single striking/pressure platform, a main blade extraction surface in relation to lateral ones where approaching to manage the different reduction stages.
The settlements in the valley of the mines testify that arrangements have existed over time and evolved in relation to the Late Chalcolithic and Early Bronze age population of the region. Some of the sites were directly connected to the mines due to elements connected with pressure blade *débitage* activities. Other sites coexisted alongside them, with functions currently unknown (see chapter 5).
During the final stages of the Early Bronze age (half of the 3rd millennium BC), some of the sites placed along the access roads to the valley might have developed specific functions over time (mines control?) as they reached larger dimensions (approx. 5 ha).
In this changing context, the evidence of specialised workshops found along the central valleys of the Jebel might be discussed considering their position within the valleys and techno-economic features of the productions. In chapter 3, we already stressed about the importance of exploiting open and flat spaces to carry out systematic knapping activities within the Jebel area, highlighting how such choices were affected by the morphology of the valley's flanks. Although it is not possible to reconstruct how

intense was the production within most of these sites due to preservation problems, the evidence provided by site 980 gives some clues to address its interpretation.
Within the site, greater physical (e.g. transport of the nodules from the quarries) and technical (e.g. quantity of processed nodules and produced blades) investments are highlighted. This strategy could be indicative of a completely different structural organisation: a workshop placed at the beginning of the valley leads to the advantage of exploiting at the same time more quarries and convey the extracted nodules in a single place to be managed. Thus, in the light of these observations, we assume that the high intensity of produced blades by the artisans was not only aimed at obtaining their own kits but also finalised at originating a surplus to be distributed or exchanged as procurement activities mediated by stable relationships of cooperation between the communities living in the area and the artisans themselves, which were part of the communities. While the studied cores have been found widely exploited, the general scarcity of cores at the site suggests that some items might have been exported as rough preforms alongside complete blades.
This procurement model constitutes a plausible hypothesis to verify by researching clues about the social status of the artisans operating at the mines and in the surrounding sites of the region. As an example, the archaeological documentation from the LC5/EBA site of Tell Karrana 3 and the EBA site 1085 support the hypothesis of itinerant knapper artisans in the region at the onset of the 3rd millennium BC, as both the sites revealed evidence of on-site produced Canaanean blades using the Jebel Zawa chert raw material (see chapters 4 and 7).
This phenomenon might have been emphasized by the widespread ruralisation of the landscape occurred during the Early Bronze age in the area, where a strongly based farming life might have caused a growing demand for blades to be employed in everyday life activities.

3.2. Social dynamics and distribution networks

The distribution of the blades from the Zawa workshops occurred along all directions on the territory. Due to the limits imposed by the study area, we can detail the south and south-east directions. Thus, it is unknown whether the Tigris River represented a real border for their diffusion or, on the contrary, a relevant north to south vector for the spreading of such products.
Based on the data in our possession, it is possible to recognise in the Jebel Zawa the only chert source suitable to produce large blades connected with the Pila Spi Fm throughout the Tigris area. In fact, moving away from the source, the impact of radiolarian cherts apparently increases in the sites.
If the Neolithic could represent a crucial period for understanding the social and cultural dynamics associated with the formation of technical traditions based on pressure techniques, the Late Chalcolithic is a fundamental phase for understanding how socio-political and economic changes

have led to the creation and/or consolidation of chert production and distribution networks. The current knowledge about obsidian trading in northern Mesopotamia indicates that the procurement of such volcanic rock was carried out already over long-distance during very ancient periods. However, widespread evidence of obsidian consumption is strengthened by the number of imports testified in the sites of the entire Fertile Crescent area during the Neolithic, together with clear proofs of specialised workshops nearby the sources (see chapter 1). It is only during the Late Chalcolithic 1-2 that the circulation of obsidian reached its peak probably due to higher demand by the communities and consolidated relationships between source regions (Cappadocia, southern Caucasus, Lake Van area, northwestern Iran) and consumption territories. High-intensity workshops are testified in some bigger sites, indicating the presence of specialised artisans within the sedentary sphere (see chapter 1).

The end of the 5th and the beginning of the 4th millennia BC represent periods of demographic growth and increasing social complexities that testify a growing demand for utilitarian or prestige goods and raw materials. The emerging new craft specializations and the subsequent dislocation of skilled knappers out of the household sphere can be considered as a reflection of such changing social structure which is adapting to an evolving economy and a consequent switching interest towards specialised chert productions as well.

In Helawa this process is visible during the Late Chalcolithic 2/3. The presence of a monumental building with administrative functions placed in the highest part of the mound can relate to these developments. All this occurs in conjunction with a wider phenomenon of shrinking Late Chalcolithic settlements in the Erbil Plain. Many LC 1-2 sites are abandoned, while others enlarged. During the LC3, Helawa reached 10 ha in size and is currently one of the largest and interesting Late Chalcolithic settlements of the region. The settlement was subsequently abandoned, and the residential nucleus might have moved away, testifying that the sudden socio-political changes taking place in the area might have had a huge impact on the local communities' economic strategies.

The procurement of Canaanean blades made from several chert sources suggests that the site of Helawa was distally placed respect different lithic production and distribution networks and these objects might have been imported through trade, rather than a periodic relationship with groups of itinerant artisans.

If this will be supported through new excavations and prospections in the Erbil Plain, it will be possible to confirm different dynamics from the northern area; a procurement therefore not enhanced by direct relationships between mining areas, specialised artisans and local communities, but rather due to medium-long distance exchanges which supplied the local markets.

4. Towards a multi-regional model

The original characteristics of the Tigris area revealed several systems in continuous evolution and registered substantial differences according to the regions forming the Tigris macro-area. Rather than a single model for the production and distribution of Canaanean blades during the Late Chalcolithic and the Early Bronze age, a new perspective emerges aimed at reasoning no longer over large areas but from particular to general, considering all the elements forming the system and comparing them to find common traits and differences.

A determining factor is the presence of chert sources on the territories which are an impulse to the birth or consolidation of technical traditions, craft specialisations, distribution systems and exchange circuits. A second element to consider lies in the characteristics of the population on a regional basis. It is undeniable that the reciprocal relationship between settlement strategies and socio-economic choices pursued by the communities are based the on resources immediately available or their integration by participating in exchanges networks.

These networks should have to be investigated from two different perspectives: (1) the producers, who managed the supply and production stages and, possibly, the distribution of such items; (2) the consumers, who integrated their toolkits with resources not directly available in their subsistence territory and were involved with their use and maintenance.

The procurement of goods must therefore be mediated by establishing contacts with other populations or groups of people who directly managed those resources and have experienced and developed over time the necessary skills to transform raw materials into utilitarian goods. On the other hand, economic needs can determine new technical solutions and represent a factor towards the increasing the demand of specific goods, while, from the opposite part, an incentive to their production and distribution, as the case of Helawa seems to suggest.

This model can be certainly conceivable for the Late Chalcolithic period. Further research is needed and revisions of old assemblages from northern Mesopotamian sites are necessary to validate or not the hypothesis. However, clear signs of a different socio-economic setting are available only for the Early Bronze Age of the middle Euphrates where the urban centre of Titris Hoyuk shows original features due to the presence of an artisanal quartier located in the lower city outside the fortified upper town (see chapter 1). This area was involved in creating a surplus to satisfy the demand of the whole city, where the producers (e.g. the knappers) were "embedded" in the city structure and encouraged by emerging opportunities that this social reorganisation produced in terms of separation of expertise. On the contrary, the socio-political setting of the investigated area is indicative of different trajectories, especially in the Jebel Zawa region. The dynamics of labour organisation at the mines and the lithic workshops might have followed original trajectories dictated by the lack of settlements with a strong centralising impact and control over the territory, favouring the self-maintenance of the lithic artisans through time.

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