Skill, Learning and Knowledge Transfer in Lithic Production as seen from LPPNB/FPPNB Ba‘ja, Southern Levant

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Abstract

This contribution summarizes the results of the research on household-level lithic production and knowledge transfer at Late and Final PPNB Ba‘ja, which is part of the current "Household and Death in Ba‘ja" – Project (2016-2021).

As no one is born a flintknapper, all knowledge and skills must be learned during lifetime. Most of this takes place during "childhood". Ethnographic studies suggest that learning in traditional societies and knowledge transfer often is informal and embedded within daily practise. When craft production is of concern, there is a strong relationship between apprenticeship and the *chaîne opératoire*, and apprenticeships are long-lasting episodes lasting years to decades.

Dumps of generalized household and specialized production contexts from various excavation areas (Areas A, B-North, C, D) have been included in the study, and were analysed for their technological composition, raw material use and quantity and quality of characteristic knapping errors (*i.e.* step/hinge termination and scars, presence of multiple error features). These knapping errors are analysed contextually, technologically, and diachronically to understand how and where learning behaviour and knowledge transfer took place. Our analysis shows that learning is omnipresent in most of the investigated samples and contributed considerably to the formation of the archaeological record.

Learning behaviour, apprentices, unskilled knapping, Early Neolithic, PPNB

1. Introduction

The Early Neolithic site of Ba‘ja is located some 70 km southeast of the Dead Sea in the remote setting of the rugged sandstone mountains there, some 10 km north of Wadi Musa (Fig. 1).

The site extends over a 1.2 to 1.5 ha large intra-montane plateau. After an initial sounding in 1984, large-scale excavations started in 1997 which exposed more than 800 m² of Neolithic architecture showing two major phases of occupation during the Late Pre-Pottery Neolithic B (LPPNB, generally 7500-6900 cal. BCE) and the Final Pre-Pottery Neolithic B (FPPNB)/Pre-Pottery Neolithic C (PPNC, 6900-6600 cal. BCE) (Gebel and Bienert 1997; Gebel *et al*. 2017, 2019, 2020). In 2016 a new project phase was launched focussing on the topic "Household & Death at Ba‘ja" (hereafter H&D). The

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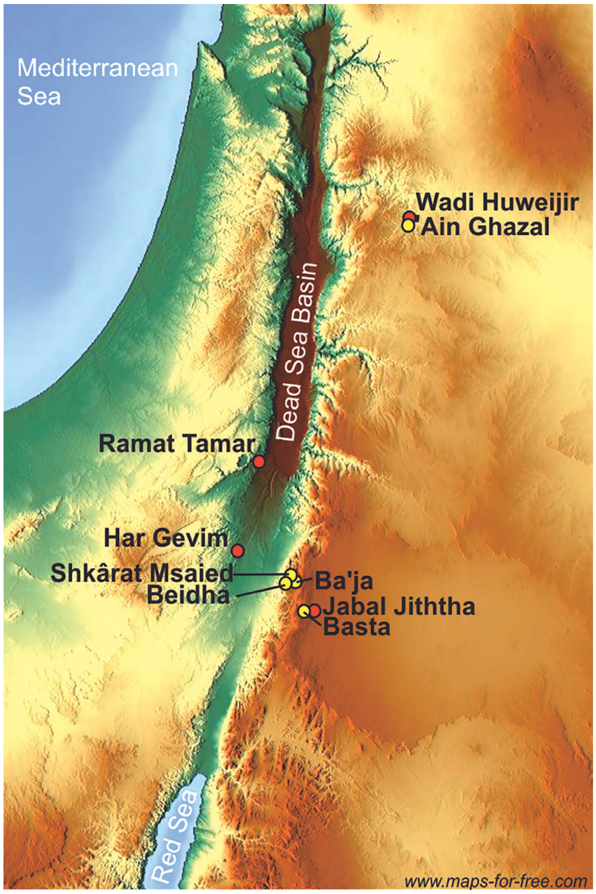

Fig. 1. Map of the southern Levant with PPNB sites (yellow) and chert quarries (red) mentioned in the text.

H&D-Project aims at investigating topics such as Neolithic household, sepulchral organization, commodification, cognition/identity, and territoriality from a holistic and transdisciplinary perspective, for which we are using Ba'ja as the material framework for understanding the local early Neolithic social evolution (Gebel *et al*. 2017). In our project we understand 'household' as the smallest socio-economic unit of subsistence which shares the basic principles of production, redistribution, reproduction, transmission, and co-residence. Though they often do, households are not necessarily circumscribed biologically by family or kin-group relations nor confined spatially to houses. Due to a general bias between insufficient biological data and rich artefactual data sets, archaeologists often focus on what households *do* rather than how they constitute biologically, which is also the perspective taken in this paper (*e.g.* Burke 2016, *cf.* also Wilk and Netting 1984).

The LPPNB lithic industry at Ba'ja can be described as a "dualistic lithic economy" which is very typical for the LPPNB mega-site phenomenon in the southern Levantine corridor (also referred to as "PPNB technological dualism" by Quintero 2010; *cf.* Gebel 2004, 2013; Purschwitz 2019b). The recent discovery of workshop dumps at the Ba'ja site periphery (Area A) demonstrates that specialized bidirectional blade producing workshops also existed and operated at LPPNB Ba'ja, though on a much smaller scale than attested at nearby Basta (Gebel *et al*. 2020). Much more commonly found at Ba'ja are modes of generalized household production which appear to be primarily self-sufficient and use predominantly expedient and opportunistic technologies. Such opportunistic lithic technologies, which receive increasing importance during the Late/Final PPNB transition, include less formalized blade core reduction (often prismatic blade cores), biface production (celt/adzes) and abundancy in flake core reduction. This dichotomy in technology also corresponds to different approaches to raw material. While generalized household production shows very opportunistic modes of chert procurement (often gathered from nearby wadi fills), the raw material procurement for specialized production is characterized by a clear preference for high-quality cherts from primary sources (Purschwitz 2017, 2019b; Parow-Souchon and Purschwitz 2020). In contrast, Final PPNB layers at Ba'ja show a general lack of bidirectional core technology (absence of core residues, very few CTE, little debitage). Bidirectional blades are still used in small numbers for tools, but are likely to have been scavenged from LPPNB deposits. Formal tools are still blade based, with blade blanks produced from single platform prismatic blade cores. Celt/adze production continues, while flake cores increase in number (*cf.* also Table 4). The abundance of flake cores (of all types) within domestic household dumps is more striking as flakes used as tool blanks are of insignificant importance (only 6% at Ba'ja, *cf.* Purschwitz 2017: Tab. 134). This raises the question as to the "authorship" and function of these cores. Are they really the result of expedient tool production or are they the residues of child play and leaning behaviour (as recently suggested by Purschwitz 2017: 289)?

This paper aims at investigating how technical knowledge was transmitted at Ba'ja. We particularly try to identify and analyse the material evidence, which is linked to learning behaviour, in order to understand where learning Ba'ja was practiced, who might be involved, and how formalized apprenticeships could be reconstructed.

2. Concepts of knowledge, learning, and apprenticeships

As we are aware, no one is born a flintknapper and we know that all knowledge and skills must been acquired. Knowledge is commonly divided into two major types: *knowing how* and *knowing what* (Pelegrin 1990; Bamforth and Finlay 2008). *Knowing how* depends on muscularly embodied memory. It is tacit knowledge that is primarily acquired through practical experience. However, *knowing* *what* includes knowledge which can be transferred from one person to another through language, by speech, signs, gestures, or other visual or sensory means. *Knowing what* is also central to planning and decision making in technological activities (such as flintknapping) as it enables the cognitive understanding of an activity or process. It is important for the abstraction of an action, and the anticipation of results. Neuropsychologically, *knowing how* corresponds to procedural memory which once acquired, is permanent and irreversible. *Knowing what* in contrast, represents declarative memory (which is further differentiated into semantic memory and episodic memory). Declarative memory can be manipulated, and become passive, inactive, or even lost. Once lost this memory must be learned anew.

All knowledge must be acquired or learned. Some knowledge we do acquire by ourselves, but most knowledge is transferred via human interaction (*cf.* Bamforth and Finlay 2008). Using a theoretical point of view d'Errico and Banks (2015) developed a heuristic approach to explore and describe learning processes and modes of knowledge transmission among non-human and human societies. They suggest investigating learning behaviour and knowledge transmission according to various dimensions (spatial, temporal, social). The spatial dimension characterizes the possible forms which interactions may take place between a practitioner and a learner, and their spatial distance during the transmission of knowledge. The interaction can be practical – via physical actions; and/or more theoretical – via communication/observation. The temporal dimension describes the time needed to transfer and to consolidate the knowledge. The knowledge necessary to accomplish a specific task may be transferred to a learner through a single information transfer event, or through multiple repetitive transfer sessions. For complex tasks various information transfer events might be necessary. However, this does not imply that the learner subsequently may be able to accomplish the task perfectly. It rather means that the learner has acquired all know-how necessary to increase his/her skill progressively through practice and repetitive trial and error. However, complex knowledge such as flintknapping requires multiple and repetitive sessions which usually last months to years (Bamforth and Finlay 2008; Quintero 2010; Stout 2002: 702; Whittaker 1994). A third dimension considers the social aspects of knowledge transmission which can occur *across* generations (vertical or parent-to-child transmission) or *between* generations (horizontal transmission). Vertical (parent-to-child) transmission is assumed to be more conservative and stable, while horizontal transmission (between children) may allow more space for experimentation and innovation (Cavalli-Sforza *et al.* 1982). Some authors also refer to oblique transmission, which is common for learning ceremonial practises and where older children teach younger ones (Lew-Levy *et al.* 2017: 370). The social dimension of learning also includes how much knowledge is shared: It can be public and available to everyone (generalized knowledge); or confined to specific members (selective knowledge).

Though learning is omnipresent throughout an entire human life, without doubt the most intensive and fundamental period of learning cross-culturally occurs during childhood. It is important to note, that childhood and adolescence are cultural constructs, and also that psychological and cognitive child development across cultures is not universal (Molitor and Hsu 2019). Particularly, one's individual mental abilities are highly influenced by social and environmental settings (Lave and Wenger 1991; Vygotsky 1978; *cf.* also Bauer 2005; Bauer and Benz 2013; Gamble *et al.* 2015; Högberg and Gärdenförs 2015). However, while growing up, children undergo specific biological, physiological, and cognitive developments which follow predictable lines, and which often correlate to age-class specifics behaviour, and mental capacities (*cf.* Molitor and Hsu 2019; Högberg 2008; Lancy 2017). For instance, muscle power, motor skills, hand-eye coordination, the ability to understand and anticipate complex technologies, or to conceptualize problem solving strategies, continually develop with age during childhood (*cf.* Bamforth and Finlay 2008: 11).

Ethnographic studies of traditional and non-industrial societies suggest that learning and knowledge transfer is mostly informal, and embedded within daily practice (Lave and Wenger 1991; Lew-Levy *et al.* 2017; Stout 2002; Weedman Arthur 2018). Often children are forced to undertake specific household tasks and contribute to the family subsistence quite early in their lives (Ember and Cunnar 2015; Lancy 2015). Therefore, learning and knowledge transfer often is discontinuous and structured by daily or seasonal tasks and needs. A typical child-like approach to learning includes observation, participation, imitation, copying and emulation, learning by play and others (Högberg 2008; Lew-Levy *et al.* 2017; Riede *et al.* 2018; Tehrani and Riede 2008; Wendrich 2012). Playing and experimenting with other children of the same age class is important (Derricourt 2018; Montgomery 2009). Vertical transmission of knowledge and apprenticeships often are household specific and may include gender specific aspects (*e.g.* knowledge transfer from mothers to daughters, fathers to sons, or from peers of the same gender, Lew-Levy *et al.* 2017: 379; Shennan and Steele 1999). However, when craft and craft production is involved, there is generally a strong relationship between apprenticeship and the production process or *chaîne opératoire* (Bamforth and Finlay 2008; Wendrich 2012). Teaching and scaffolding often are present in the form of demonstration, commands, positive/negative feedback, and error-correction support (Bamforth and Finlay 2008; Lew-Lewy *et al*. 2017; Tehrani and Riede 2008). The age when a child may start an apprenticeship varies considerably, but usually it's not before middle childhood (6-12 years), and the learning process is shaped according to the physiological and cognitive capacities of the apprentice (Wendrich 2012). Beginners may start with supporting activities such as cleaning up and helping with preparations, and often practice on low-quality or discarded raw materials (Lave and Wenger 1991; Wendrich 2012). Usually, apprenticeships last from several months to years or even decades (Lew-Levy *et al*. 2017; Stout 2002; Weedman 2002; Weedman Arthur 2018; Wendrich 2012: 10). Apprenticeships involves more than simply mastering a technology or an activity. It provides the complete (socio-)ontological framework of how a craft is embedded in the culture (*e.g.* Weedman Arthur 2018; Wallaert 2012). Moreover, apprenticeships involve the construction of identity and enables social membership (Lave and Wenger 1991).

There are many approaches to investigate learning and knowledge transfer in archaeology, though there is some difficulty in identifying and interpreting evidence of learning behaviour from prehistoric periods. Among the concepts most often used are those studying the *chaîne opératoire,* and studying *skill*. *Skill* can be described as the interface between *knowing how* and *knowing what* – something acquired during life through practice – a learning process which is also referred to as *enskillment*. Therefore, skill is not a static phenomenon, but fluid and contingent and depending on age. From a biographical perspective skill develops between beginner, novice, practitioner, and expert, whereas the enskillment process is often linked to age or status. However, there are several factors which can temporarily or permanently impact skill. Short-term factors such as motivation or fatigue, illness, diseases, traumata or simply longer periods of non-use may result in *De-skillment*, which refers to a temporary reduction in skill-level (*e.g.* Bernbeck 2010). Moreover, factors such as aging and degenerative changes (*e.g.* impacting vision or motor skills), may result in a permanent loss of skill.

In lithic technology it might be also helpful to categorize skill as "artisanal skill" or "efficiency skill" as suggested by Andrews (2006). "Artisanal skill" refers to time-consuming, wasteful and risky production of ceremonial or prestigious items which transmit social information and tend to be highly individualized and aesthetic (such as bifacially flaked daggers or large points). In contrast, "efficiency skill" as related to the production of utilitarian items (such as blade blanks) is characterized by maximized output in spite of a minimal investment in time and raw materials. "Efficiency skills" promote standardization both in the production process and in the products that are produced. However, ethnographic studies warn us to confine skill to mere technological components, as the perception and assessment of skill can involve social and ethical aspects (*e.g.* Wallaert 2012; Weedman Arthur 2018). Among the Ethiopian Boreda Gamo, *skill* "is not defined by the morphological characteristics of the final product or by the evolution of nonknappers, but rather by the status of the practitioner within the community of knappers" (Weedman Arthur 2018: 12). Similarly, Stout (2002) reports, that the most acknowledged and experienced adze maker of the Irian Jaya (New Guinea) produced very crude adzes.

3. Skill, novices and beginners in lithic research

There is an increasing number of studies on flintknapping skills, although in archaeology there is still the tendency to focus more on the identification of experts, than on identification of novices or beginners (Bamforth and Finlay 2008: 5). This tends to ignore the impact of unskilled persons (or apprentices) on the formation of the archaeological record. Obviously, the mastering of complex lithic technologies (such as bidirectional blade technology) is quite time consuming and requires a lot of practice (*e.g.* Bamforth and Finlay 2008; Quintero 2010; Stout 2002; Whitaker 1994).

Many knapping features have been suggested to be indicators of unskilled knapping. According to replication studies, knapping experiments and by evidence from core and debitage analysis of archaeological assemblages, such knapping features could be: stacked step scars and hinge terminations, mis-hits and hammermarks on the core faces and platforms. Additionally, novice/beginners work is characterized by the inability to rejuvenate cores, by deviations from the expected *chaîne opèratoire*, by peripheral spatial knapping, and others (Barmforth and Finlay 2008: Tab. II with further references). Many researchers stress the wasteful and ineffective use of raw material among novices (*e.g.* Ferguson 2008; Milne 2012; Shelley 1990). They suggest that best evidence of novice flintknapping is found at places where raw material is abundant and can be obtained at a very low cost (Ferguson 2008; Goldstein 2019; Milne 2012). In contrast, where access to high-quality raw materials is restricted, novices and beginners may have practised on low-quality or discarded raw materials, and often under supervision (*e.g.* Ferguson 2008).

However, many researchers stress that beginners/novices do not necessarily need to be children (*e.g.* Ferguson 2008: 56; Milne 2012), particularly when knapping and chipping stones can be considered a dangerous activity (*cf.* Ferguson 2008: 55; Whitaker 1994) and that using raw materials to practice might be costly. Ferguson (2008: 62) also claims that children under 10 years of age are generally incapable of producing longer flakes and concludes that evidence of unskilled knapping generally is associated to older children, young adults or older persons. Ethnographic evidence may support this view. Among the Irian Jaya (New Guinea) adze makers apprenticeships do not start before the age of 12-13 years (Stout 2002), and among the Boredo Gamo (Ethiopia) leatherworker knapping is prohibited to boys until passing their puberty rites (taking place between 14-20 years, Weedman Arthur 2018). The female knapper of the Xauta (Ethiopa) hideworkers start their knapping activity around 14-16 years (Weedman Arthur 2010). However, these ethnographic examples refer to multi-staged apprenticeships, in which knapping is practiced in the later or latest stages (*cf.* also Ferguson 2008: 62-63). Modern experimental studies show that (if they have the chance to do so) 4 to 6 years old boys and girls playfully engage in stone tool "production", being able to flake stones, and while doing so producing a considerable amount of knapping debris (Ferguson 2008; Högberg 2008; Sternke and Sørensen 2009).

Experimental and replicative research is also very helpful in identifying typical beginner's mistakes and to differentiate between the behaviour of children and adult beginners (*e.g.* Ferguson 2008; Shelley 1990; Sternke and Sørensen 2009). According to Shelley (1990) beginners discard their cores more frequently (regardless of reduction strategy) due to multiple stacked step/hinge terminations. They also produce a higher number of debris than experienced knappers. In contrast, experienced knappers produce less frequently step or hinge terminations, and if they do, they are generally able to correct their errors and continue the core reduction. Their cores are rarely abandoned as result of knapping errors. Sternke and Sørensen (2009) conducted a behavioural replication study (Lejre experiment) in which six children (between 6 and 11) and two adult beginners performed simple flake core reduction and some tool production of typical Later Mesolithic tools (scraper, piercer, transverse arrowheads and a bifacial core axe). They observed fundamental differences between beginners, novice and skilled knapping performances which reflect both age- and know how-related differences in motor control and mental capacities. As also reported by Shelley (1990), beginners knapping resulted in high numbers of step/hinge terminations with a tendency to produce multiple hinge fractures. Platforms often showed multiple impact marks, and beginners were unable to thin bifacial products. Concept errors occurred frequently, particularly in complex reduction strategies (such as core axe production). Additionally, child knapping was characterized by bipolar knapping on anvils. Also, there was a preference for direct hard percussion (to overcome difficulties in motor control and hand-eye coordination). Hinge flake terminations occurred very frequently (up to 50%), which clearly showed a general lack of understanding fracture mechanics. Generally, children did not apply core maintenance and their knapping is rather two-dimensional, as they focussed on visual imitation of shape and morphology while ignoring concepts and technology. Finally, the absence of standardized products was very characteristic.

4. Methodology

4.1. Quantifying knapping errors and knapping skill performance

For our empirical study on the Ba'ja lithics we recorded the number of "typical" knapping errors and presumably "novice/beginners" mistakes such as hinge, or overshoot terminations for debitage products, and the number of dorsal preserved negatives showing previous step/hinge fractures on debitage products, cores or core-tools. Of particular interest were also artefacts showing multiple error-features and artefacts showing intentional error corrections (*e.g.* clean-up blades/flakes). Butts and core platforms were not systematically checked for impact marks, although various cores with multiple impact marks (miss-hits) were noted (*e.g.* Fig. 4: d-e).

To make the error frequencies and knapping performances comparable we analysed two variables. One of which is called "hinge ratio" which describes how often hinges and step terminations have been produced. The hinge ratio is calculated by taking the combined number of hinge terminations divided by the total number of preserved distals. The lower the hinge ratio, the higher the knapping skills.

The second variable is called "clean-up-failure ratio" and it describes the ability to correct knapping errors. The "clean-up failure ratio" is calculated per debitage class, and is derived by the number of failed clean-ups divided by the total number of artefacts with dorsal step or hinge negatives. The higher the "clean-up-failure ratio", the lower the ability to successfully correct step/hinge baulks.

In addition, we analysed the raw material use of cores. This included the raw material groupings (following the approach presented in Purschwitz 2019a; *cf.* Parow-Souchon and Purschwitz 2020), and the preserved characteristics of natural surfaces, which have been classified according to their qualities in primary cortex or secondary formed surfaces (natural clefts, battered, rolled, patinated, etc.). Both parameters serve as indicators for calculating the minimum distance of likely source areas, and also to reconstruct procurement modes (see Parow-Souchon and Purschwitz 2020 for methodology).

4.2. Samples

For our study we investigated 12,382 lithic artefacts from 148 Loci and 30 contexts (Table 1). 19 contexts (with a total number of 8085 lithic artefacts) were found in layers dated to the end of the LPPNB, while 11 contexts (4297 lithic

LPPNB	*Loci*	*Description /Interpretation*
Area A (*cf.* Gebel *et al.* 2020)		
S1	S1:10, S1:11, S1:12, S1:19, S1:21, S1:24, S1:28, S1:31, S1:32, S1:38, S1:39, S1:40, S1:41, S1:42, S1:43	Lithic dump of bidirectional blade production discarded in the site periphery, may also include some production waste of celt/adze manufacture
Area B-North (*cf.* Purschwitz/ Kinzel 2007; Purschwitz 2017)		
Pre-BNR17	BNR17:122=125, BNR17:126	Lithic dump below LPPNB-floors of BNR17
BNR17	BNR17:100, BNR17:102=109, BNR17:106=112=118, BNR17:111, BNR17:114, BNR17:116, BNR17:120, BNR17:121	Lithic dump in a terminated (burnt) LPPNB-building, includes production waste of non-bidirectional blade core reduction and celt/adze manufacture
BNR22/23	BNR22:100=BNR23:101, BNR23:100, BNR23:101, BNR23:102, BNR22:101= BNR23:103= 105, BNR22:102=BNR23:104=106, BNR23:111, BNR23:112	Lithic dump in an abandoned LPPNB-building, includes production waste of non-bidirectional blade core reduction and celt / adze manufacture
Area C (*cf.* Gebel *et al.* 2017, 2019, 2020)		
CR5/6	CR5:38, CR5:40, CR5:42, CR5:42a, CR5:43, CR5:44, CR5:45, CR5:47, CR6:14, CR6:16, CR6:17, CR6:18, CR6:19	Lithic dump in a collapsed* LPPNB building, room includes children subfloor burials and kitchen facilities
CR7	CR7:35, CR7:36, CR7:37, CR7:38	Lithic dump/terminated household in a collapsed* LPPNB building
CR17	CR17:124	Lithic dump in a collapsed* LPPNB building
CR22.1	C11:47	Lithic dump in a collapsed* LPPNB building
CR22.2	C11:43, C11:44	Lithic dump in a collapsed* LPPNB building
CR22	C11:34, C11:35, C11:36=38, C11:39, C11:40, C11:41, C11:42	Terminated LPPNB household discarded in Rooms CR22.1/ CR22.2
CR28.1	CR28:100, CR28:104	Lithic dump in a collapsed* LPPNB building
CR28.2	CR28:103, CR28:105, CR28:109	Lithic dump in a collapsed* LPPNB building; includes sub-floor burial
CR34	C10:118, C10:121	Lowermost fill upon floor in a collapsed* LPPNB building; building served in its final stage as burial ground.
CR35	C10:86, C10:88	Lowermost fill upon floor in a collapsed* LPPNB building; building served in its final stage as burial ground.
CR36.1	C1:20, C1:58	Lowermost fill upon floor in a collapsed* LPPNB building; building served in its final stage as burial ground.
CR36.3	C1:25, C1:28, C1:48	Lowermost fill upon floor in a collapsed* LPPNB building; building served in its final stage as burial ground.
CR37	C10:127, C10:130, C10:135, C10:140, C10:145, C10:151, C10:154, C10:157, C10:159	Lithic dump in a collapsed* LPPNB building
Area D (*cf.* Gebel *et al.* 2019, 2020)		
DR22	D32:56, D32:61, D32:62	Lithic dump below FPPNB floor in Room DR22
DR25	DR25:116	Lithic dump below FPPNB floor in Room DR25
FPPNB	*Loci*	*Description /Interpretation*
Area C (*cf.* Gebel *et al.* 2017, 2019, 2020)		
Buttress Bldg.	C10:2, C0:119, C0:121, C10:62, C10:92, C10:119, C10:125, C10:126	Lithic dump in an abandoned FPPNB building
CR5/6	C21:77, C21:81, C21:83, CR5:30, CR5:31, CR5:34, CR5:36, CR5:39, CR5:41; CR6:12, CR6:13	Lithic dump in an abandoned FPPNB building
CR7	CR7:34	Lithic dump in an abandoned FPPNB building
CR17	C11:37, C21:84, C21:85, CR17:106	Lithic dump in an abandoned FPPNB building
CR22.1	C10:87	Lithic dump in an abandoned FPPNB building
Area D (*cf.* Gebel *et al.* 2019, 2020)		
DR19	DR19:100, DR19:101, DR19:105	Lithic dump in an abandoned FPPNB building
DR22	D32:40	Lithic dump in an abandoned FPPNB building
DR25	D11/12/21/22:12, D11/12/21/22:13, D11/12/21/22:18, D11/12/21/22:24, DR25:100, DR25:101, DR25:105	Lithic dump in a collapsed building
DR26	D11/12/21/22:1, D11/12/21/22:2, D11/12/21/22:5, D11/12/21/22:14, D11/12/21/22:19, D11/12/21/22:20, D11/12/21/22:21, DR26:102, DR26:103, DR26:106, DR26:112	Lithic dump in a collapsed building, includes production remains of celt/adze manufacture
DR30	D32:39, D32:41, D32:42, D32:59	Lithic dump in an abandoned FPPNB building
D21:11	D21:11	Lithic dump of celt/adze manufacture

Table 1. Context description of samples included in the study. * Probably terminated by an earthquake (*cf.* Gebel *et al.* 2020).

artefacts) were included from FPPNB layers (for further context information including their location within the settlement see references provided in Table 1)

Most of the contexts have been interpreted as domestic dumps which often included lithic artefacts from a household level environment of lithic production (Table 2). This can be concluded by the context of deposition (usually in the context of abandoned or terminated architecture), composition of lithic dumps (predominantly informal and *ad hoc* technologies, heterogenous in raw material use, often including raw materials of secondary sources) and the association of other artifact classes (such as bones, sandstone bracelets, ground stone tools, etc.). However, there are three samples (*i.e.* Area A, S1; Area D, Loc. D21:11, and DR26), which differ in discard context and technological composition. Loc. D21:11 and DR26 represent the dumps of two celt-adze producing workshops. The dump in Loc. D21:11 is exclusively comprised of knapping debris of celt/adze production for which a very striking raw material group (FRMG 3b – a brecciated chert, *cf.* Purschwitz 2019a) was used. A cluster of 14 celt/adzes at all stages of production was discovered in DR26 (most of them in Loc. DR26:112, *cf.* Gebel *et al.* 2019). Their context and extreme homogeneity in raw material (predominantly high-quality chert in DR26 and brecciated chert in Loc. D21:11) clearly set them apart from the "ordinary" domestic dumps attested in most of the other contexts.

Area A, S1 represents a small sounding (1 m²) in the western site periphery, which was used as a dump area during the LPPNB. The lithic artefacts are very homogeneous in composition (almost exclusively comprised of debitage and production waste of bidirectional blade core technology) and predominantly include high quality chert raw materials (Gebel *et al.* 2020). In terms of composition and deposition context the dump is very similar to workshop dumps found at other PPNB sites of the region (such as MPPNB Shkârat Msaied, or LPPNB Basta) for which a specialized production has been suggested (Gebel 1996, Purschwitz 2019c).

5. Results

5.1. Error frequency and knapping skill performance (Tables 3-4, Figs. 2-4)

5.1.1. Bidirectional core technology

Bidirectional blade cores are found in small numbers (1-3) in almost half of the analysed LPPNB samples (8 out of 17), and generally are associated with hinge terminated or plunged blades. Such knapping errors were found in 10 out of 17 contexts (including all 8 contexts in which cores were found). The hinge ratios show a great variability, ranging between 0 and 0.500 (average value 0.118). The hinge ratio of the workshop dump found in S1 was among the lowest (0.059). Most of the domestic samples, in which bidirectional blade core reduction sporadically is in evidence (BNR17, BNR22/23, CR5/6, CR22), show two to four times higher hinge ratios (0.114-0.211) than attested in S1. Ten out of twelve core residues bear step/hinge scars on their reduction face, from which nine show multiple errors (two to six scars). All the cores with step/hinge scars have been found in domestic dumps. The clean-up failure ratios show a great variability too, ranging from 0.143 to 1.000. The lowest value is attested at S1 (0.143), while contexts of domestic production show much higher values (*e.g.* 0.667 for CR5/6, and 1.000 for the terminated household found in CR22).

A few overshoots (n=5) have been found in the S1 sample (as well as one example in CR22), which did not appear to be accidental, but intentionally knapped. All of these overshoots were struck along the lateral core face of (exhausted?) bidirectional blade cores in order to remove parts of the opposed platform, and to transform the bidirectional blade core into a single platform blade(let) core.

	Area A, S1	**Pre-BNR17**	**BNR17**	**BNR22/23**	**CR5/6**	**CR7**	**CR17**	**CR22**	**CR22.1**	**CR22.2**	**CR28.1**	**CR28.1**	**CR34**	**CR35**	**ACR36.1**
Chunks		2	56	41	16	2		4		2	2	1			
Debris	498	29	510	139	697	79	103	149	8	42	82	56		6	2
Indetermined		1	1		28	1		15	2	4	14	27		2	
Flake cores		1	25	7	9			15		4	4	1			
Non-bidir. bl. cores	2		3	2	7										
Bidir. blade cores	1		1	2	3	1		2				1			
Indet. cores			5	4	1			1		2					
Primary elments	34	3	67	53	20	4	4	19		3	5	4		3	
Non-bidir. CTE	5		5	6	3	3		4		1		1			
Bidir. CTE	194	1	25	21	18	4	1	9	1	1	4	1			
Indet. CTE	2		5												
BTF	61	3	27	23	59	1		7			1	2			
Chips	3		40			6									
Flakelets	154	17	569	199	127	58	15	29	8	12	16	11	1		
Flakes	275	18	360	262	212	74	15	86	2	26	18	14	2	14	2
Non-bidir. blades	18	15	357	224	46	17		6			9		5	2	
Bidir. blades	196	10	127	111	39	25	6	30	1	1	4	7	5	3	2
Indet. blades	114	7	88	56	40	15	11	17	1	4	5	3	1		1
Burin spall (prim.)	1	1	5	2	2										
Burin spall (sec.)					1	5									
Transvers. sp.(prim.)	3		2		1										
Transvers. sp. (sec.)				5	2			1							
TOTAL	**1561**	**108**	**2278**	**1157**	**1331**	**295**	**155**	**394**	**23**	**102**	**164**	**129**	**14**	**30**	**7**
Tool-share (in %)	6.7	5.6	4.2	8.2	7.6	16.9	2.6	14.5	21.7	7.8	17.7	25.6	35.7	20.0	28.6
Tools	104	6	95	95	101	50	4	57	5	8	29	33	5	6	2
Production evidence **x** – Specialized production (workshop evidence) x – Generalized household production (workshop evidence) (x) – Sporadic household production ? – Unclear prod. evidence															
Bidir. blade core	**x**		(x)	(x)	(x)	(x)		(x)			?	?			
Non-bidir. bl. core	(x)		x	x	x										
Celt/ adze prod.	(x)		x	x	x			(x)							

Table 2. Primary product tabulation and production evidence of Ba'ja LPPNB/FPPNB contexts. See provided reference on sample/context location within the site.

CR36.3	CR37	DR22	DR25	**Total LPPNB**	CR5/6	CR7	CR17	CR22.1	Buttress Bldg.	DR19	DR22	DR25	DR26	DR30	D21:11	**Total FPPNB**
		1		**127**	5	1	4		1			2	23		2	**38**
10	2	36	17	**2465**	398	16	80	10	38	7	4	271	595	23	35	**1478**
	9	8	4	**116**	4	4	2		6	3		17	27	2		**65**
			2	**68**	4	1	3		5			17	31	2	1	**64**
				14	4		1		1				1			**7**
	1			**12**												**0**
			1	**14**		1										**1**
	3	2	6	**230**	5		2	3	11	1	2	9	34		2	**70**
	1		1	**30**	6		1	1	10			1	9	4		**32**
	1	2	7	**290**	2		2		6			1	6	4		**21**
	1			**8**		1			2			1				**4**
1	4	17	23	**229**	10	3	6	1	13	1		13	43	5	26	**121**
				49								91	92		12	**195**
	7	13	11	**1247**	72	6	19	2	31	10	5	227	425	14	87	**899**
2	16	32	25	**1455**	109	17	20	9	141	12	5	95	350	31	89	**882**
	15	1	8	**723**	32	7	3	14	74	8	1	14	65	4	9	**233**
1	14	15	4	**601**	8	1	10		13	1		2	15			**50**
	6	5		**374**	20	3	13		21		1	16	32	2	3	**111**
	1			**12**		1			3			2	5			**11**
				6		1	1		2			1				**5**
1				**7**					1			1				**3**
				8	1	1	1		1			1	2			**7**
15	**81**	**132**	**109**	**8085**	**680**	**64**	**168**	**40**	**380**	**43**	**18**	**782**	**1755**	**91**	**266**	**4297**
.0	40.7	16.7	11.0	**8.2**	7.6	23.4	12.5	5.0	21.1	11.6	27.8	5.1	6.5	22.0	3.4	**8.5**
	33	22	12	**666**	52	15	21	2	80	5	5	40	114	20	9	**363**
					x				x				x			
		(x)	(x)		(x)				?			(x)	x		x	

	Area A, S1	Pre-BNR17	BNR17	BNR22/23	CR5/6	CR7	CR17	CR22	CR22.1	CR22.2	CR28.1	CR28.1	CR34	CR35	ACR36.1	CR36.3	CR37	DR22	DR25	Total LPPNB
Bidirectional blades total	**196**	**10**	**127**	**111**	**40**	**24**	**6**	**33**	**1**	**2**	**4**	**8**	**5**	**3**	**2**	**1**	**14**	**15**	**4**	**606**
Distals	118	5	76	79	24	20	4	27	1	2	1	7	1	1	1		10	3	2	**382**
Step/ hinge terminations	7	1	16	9	3	1						2					5	1		**45**
Overshoot terminations	5*		4	7				2		1*										**13**
Bl. with dorsal step/ hinge neg.	7	n/a	n/a	n/a	2	1		1				1					n/a		1	**13**
No. of dorsal step/ hinge neg.	9	n/a	n/a	n/a	2	1		1				1					n/a		2	**16**
Bl. with multiple error features	3	n/a	n/a	n/a	1			1									n/a		1	**6**
Failed clean-up blades	1	n/a	n/a	n/a	2			1									n/a			**4**
Successful clean-up blades	6	n/a	n/a	n/a	1	1						1					n/a		1	**10**
Hinge ratio	.059	n/a	.211	.114	.125	.050	n/a	.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.500	n/a	n/a	**.118**
Clean-up failure-ratio	.143	n/a	n/a	n/a	.667	.0	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**.286**
Non-bidir. blades total	**18**	**15**	**357**	**224**	**46**	**17**	**0**	**7**	**0**	**1**	**9**	**0**	**5**	**2**	**0**	**0**	**15**	**1**	**8**	**725**
Distals	17	10	278	183	36	16		6		1	8		3	2			10		7	**577**
Step/ hinge terminations		3	34	18	1	1					2						3			**62**
Overshoot terminations		2	23	9	1	1				1										**37**
Bl. with dorsal step/ hinge neg.	1	n/a	n/a	n/a	1			1		1							n/a		1	**5**
No. of dorsal step/ hinge neg.	1	n/a	n/a	n/a	1			3		4							n/a		1	**10**
Bl. with multiple error features		n/a	n/a	n/a				1		1							n/a			**2**
Failed clean-up blades		n/a	n/a	n/a													n/a			**0**
Successful clean-up blades	1	n/a	n/a	n/a	1			1		1							n/a		1	**5**
Hinge ratio	.0	.300	.122	098	.028	.063	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.300	n/a	n/a	**.107**
Clean-up failure-ratio	.0	n/a	n/a	n/a	.0	n/a	n/a	.0	n/a	.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.0	**.0**
BTF total	**61**	**3**	**27**	**23**	**61**	**1**	**0**	**7**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**1**	**4**	**17**	**23**	**231**
Distals	56	3	26	22	57	1		7			1	2				1	1	17	23	**217**
Step/ hinge terminations	3	1	4	2	2			1										3	4	**20**
Overshoot terminations			1		1															**2**
BTF with dorsal step/ hinge neg.	3	n/a	n/a	n/a	3												n/a		3	**9**
No. of dorsal step/ hinge neg.	3	n/a	n/a	n/a	7												n/a		4	**14**
BTF with multiple error features		n/a	n/a	n/a	3												n/a		1	**4**
Failed clean-up BTF		n/a	n/a	n/a	1												n/a			**1**
Successful clean-up BTF	3	n/a	n/a	n/a	2												n/a		3	**8**
Hinge ratio	.054	n/a	.154	.091	.035	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.176	.174	**.092**
Clean-up failure-ratio	.0	n/a	n/a	n/a	.333	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.0	**.111**
Flakes Total	**275**	**18**	**360**	**262**	**211**	**74**	**15**	**86**	**2**	**26**	**18**	**14**	**2**	**14**	**2**	**2**	**16**	**32**	**25**	**1454**
Distals	244	15	316	224	195	68	15	72	1	23	17	14	2	14	2	1	13	32	24	**1292**
Step/ hinge terminations	25	1	45	25	23	9		14		2		3		1			2	11	4	**165**
Overshoot terminations	3		6	3	1															**13**

	Area A, S1	Pre-BNR17	BNR17	BNR22/23	CR5/6	CR7	CR17	CR22	CR22.1	CR22.2	CR28.1	CR28.1	CR34	CR35	ACR36.1	CR36.3	CR37	DR22	DR25	Total LPPNB
Fl. with dorsal step/ hinge neg.	14	n/a	n/a	n/a	11	5	n/a	8		1							n/a		6	**45**
No. of dorsal step/ hinge neg.	17	n/a	n/a	n/a	20	5	n/a	11		2							n/a		10	**65**
Fl. with multiple error features	2	n/a	n/a	n/a	8	2	n/a	4		1							n/a		5	**25**
Failed clean-up flakes		n/a	n/a	n/a	1	2	n/a	2		1							n/a		2	**8**
Successful clean-up flakes	14	n/a	n/a	n/a	11	3	n/a	6									n/a		4	**38**
Hinge ratio	.102	.067	.142	.112	.118	.132	.0	.194	n/a	.087	.0	.214	n/a	.071	n/a	n/a	.154	.344	.167	**.128**
Clean-up failure ratio	.0	n/a	n/a	n/a	.091	.400	n/a	.250	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.333	**.178**

Table 3a. Error features and error frequency of Ba'ja's debitage products during the LPPNB. Note: Hinge-factors of small sample sizes (<10 distals) are not calculated. * Intentional overshoots.

	CR5/6	CR7	CR17	CR22.1	Buttress Bldg.	DR19	DR22	DR25	DR26	DR30	D21:11	Total FPPNB
Bidirectional blades total	**11**	**1**	**10**	**0**	**13**	**1**	**0**	**2**	**15**	**0**	**0**	**53**
Distals	6	1	7		3			2	12			**31**
Step/ hinge terminations			1					1	1			**3**
Overshoot terminations	1				2							**3**
Bl. with dorsal step/ hinge neg.			n/a						3			**3**
No. of dorsal step/ hinge neg.			n/a						3			**3**
Bl. with multiple error features			n/a						1			**1**
Failed clean-up blades			n/a						2			**2**
Successful clean-up blades			n/a						1			**1**
Hinge ratio	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.083	n/a	n/a	**.097**
Clean-up failure-ratio	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.333	n/a	n/a	**.333**
Non-bidir. blades total	**39**	**7**	**3**	**14**	**76**	**8**	**1**	**14**	**65**	**4**	**9**	**243**
Distals	32	7	3	11	55	7	1	7	49	3	9	**187**
Step/ hinge terminations	4		1	2	6	1			5	1		**20**
Overshoot terminations				1	2	1						**4**
Bl. with dorsal step/ hinge neg.	4		n/a	1	3			1	3		1	**13**
No. of dorsal step/ hinge neg.	8		n/a	3	5			2	3		1	**22**
Bl. with multiple error features	4		n/a	1	2			1	1			**9**
Failed clean-up blades	1		n/a		1				1			**3**
Successful clean-up blades	3		n/a	1	2			1	5		1	**13**
Hinge ratio	.125	n/a	n/a	.182	.109	n/a	n/a	n/a	.102	n/a	n/a	**.107**
Clean-up failure-ratio	.25	n/a	n/a	.0	.333	n/a	n/a	n/a	.167	n/a	.0	**.188**
BTF total	**14**	**3**	**6**	**0**	**13**	**1**	**0**	**13**	**43**	**5**	**26**	**124**
Distals	11	3	3		12	1		13	43	4	26	**116**
Step/ hinge terminations	2							3	6		2	**13**
Overshoot terminations												**0**
BTF with dorsal step/ hinge neg.			n/a						6			**6**
No. of dorsal step/ hinge neg.			n/a						8			**8**
BTF with multiple error features			n/a						4			**4**

Table 3b. Error features and error frequency of Ba'ja's debitage products during the FPPNB. Note: Hinge-factors of small sample sizes (<10 distals) are not calculated. *Intentional overshoots.

	CR5/6	CR7	CR17	CR22.1	Buttress Bldg.	DR19	DR22	DR25	DR26	DR30	D21:11	Total FPPNB
Failed clean-up BTF			n/a						1			**1**
Successful clean-up BTF			n/a						7			**7**
Hinge ratio	.182	n/a	n/a	n/a	.0	n/a	n/a	.231	.140	n/a	.077	**.112**
Clean-up failure-ratio	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.167	n/a	n/a	**.167**
Flakes Total	**118**	**17**	**20**	**9**	**145**	**12**	**5**	**95**	**350**	**31**	**89**	**891**
Distals	99	17	17	9	124	12	5	85	339	29	77	**813**
Step/ hinge terminations	9	1	1	2	20	1		8	56	1	5	**104**
Overshoot terminations					1				1			**2**
Fl. with dorsal step/ hinge neg.	11		n/a		17	1		3	20	2	5	**59**
No. of dorsal step/ hinge neg.	14		n/a		24	1		4	38	4	10	**95**
Fl. with multiple error features	3		n/a		13			1	13	2	4	**36**
Failed clean-up flakes	2		n/a		9				7	1	3	**22**
Successful clean-up flakes	9		n/a		8	1		3	13	1	2	**37**
Hinge ratio	.091	.059	.059	n/a	.161	.083	n/a	.094	.165	.034	.065	**.128**
Clean-up failure ratio	.182	n/a	n/a	n/a	.529	1	n/a	.0	.350	.500	.600	**.373**

Table 3b. Continued.

	Late Pre-Pottery Neolithic B																			
	Area A, S1	**Pre-BNR17**	**BNR17**	**BNR22/23**	**CR5/6**	**CR7**	**CR17**	**CR22**	**CR22.1**	**CR22.2**	**CR28.1**	**CR28.1**	**CR34**	**CR35**	**ACR36.1**	**CR36.3**	**CR37**	**DR22**	**DR25**	**Total LPPNB**
Bidir. bl. cores total	**1**		**2**	**1**	**3**	**1**		**2**				**1**					**1**			**12**
No. of dors. step/ hinge neg.			8	3	9	1		4				3					n/a			28
Cores with error feature			2	1	3	1		2				1					n/a			10
Cores with mult. error feat.			2	1	2	0		1				3					n/a			9
*Mean err. feat. per core**	-	-	*4.0*	*3.0*	*3.0*	*1.0*	-	*2.0*	-	-	-	*3.0*	-	-	-	-	n/a	-	-	*2.8*
Non-bidir. bl. cores total	**2**		**3**	**1**	**7**															**13**
Count of dors. step/ hinge neg.	2		5		2															9
Cores with error feature	2		2		2															6
Cores with mult. error feat.			2		0															2
*Mean err. feat. per core**	*1.0*	-	*2.5*	-	*1.0*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*1.5*
Flake cores total		**1**	**25**	**5**	**9**			**15**		**4**	**4**	**1**							**2**	**66**
No. of dors. step/ hinge neg.		n/a	*15*	6	10			23		9	6	3							9	69
Cores with error feature		n/a	*9*	3	3			8		3	2	1							2	43
Cores with mult. error feat.		n/a	*5*	2	2			8		3	2	1							2	25
*Mean err. feat. per core**	-	n/a	*1.7*	*2.0*	*3.3*	-	-	*2.9*	-	*3.0*	*3.0*	*3.0*	-	-	-	-	-	-	*4.5*	*2.6*
Celts / adzes total			**11**	**17**	**4**	**1**		**6**		**1**	**1**	**5**		**1**			**1**	**1**	**2**	**51**
No. of dors. step/ hinge neg.			n/a	n/a	3			5						n/a			n/a		4	20
Celt/ adzes with error feat.			n/a	n/a	11			2						n/a			n/a		1	6
Celt/ adzes with mult. err. feat.			n/a	n/a	2			2						n/a			n/a		1	5
*Mean. err. feat. per celt/ adze**	-		n/a	n/a	*3.7*	-	-	*2.5*	-	-	-	-	-	n/a	-	-	n/a	-	*4.0*	*3.3*
Celt/ adze preforms			2																	2
Primary transversal spalls	3		2		1											1				7
Secondary transversal spalls				5	2			1												8

Table 4. Error features and error frequency of Ba'ja core types. *Only cores and celt/ adzes with step/ hinge negatives included.

5.1.2. Non-bidirectional blade core technology

Non-bidirectional blade core residues were found in small numbers in four LPPNB (4 out of 17) and FPPNB-samples (4 out of 11). Only the samples of CR5/6 provided higher core counts. It might be worth noting that during the LPPNB there seems to be a positive correlation between contexts of non-bidirectional and bidirectional blade core reduction (5 out of 6 production contexts of bidirectional blade production show evidence of non-bidirectional core reduction). The average hinge ratio (of both LPPNB and FPPNB assemblages) is 0.107, with values ranging from 0.028 (CR5/6) to 0.300 (each Pre-BNR17 and CR37) in the LPPNB, while those of the FPPNB samples show less variability (ranging between 0.102 and 0.182). Hinge ratios for contexts of regular or sporadic non-bidirectional blade core reduction generally have values below 0.125 (often also below average). Multiple errors have been found at 2 out of 13 LPPNB core residues (both from BNR17), and at 4 out of 8 FPPNB cores (CR5/6 and DR26) as well as on two LPPNB clean-up overshoots (each one from CR22, and CR22.2) and on 9 FPPNB blades (CR5/6, CR22.1, Buttress Building, DR26). Again, there is a positive correlation between the presence of multiple error features and evidence of non-bidirectional blade core reduction (5 out of 8 contexts). Clean-up failure rates are very low (0) for the LPPNB samples and moderate (between 0.167 and 0.333) in FPPNB core reduction context. Of particular interest might be two clean-up overshoots found in CR22.1/CR22.2, as both bear multiple step/hinge scars (3 and 4 scars), and may indicate error-correction support by an experienced knapper (*cf.* Fig. 4: a for another example of error correction support).

5.1.3. Celt/adze production and flake technology

Celt/adzes and flake cores are abundant during both periods, and occur in most contexts (13 out of 17 during the LPPNB; 8 out of 11 during the FPPNB). Among the samples there is great variability in number: 11 out of 17 LPPNB and 7 out of 11 FPPNB contexts have less than 3 celt/adzes or flake cores. However, some contexts have up to 33 flake cores (DR26) and up to 17 celt/adzes (BNR22/23). There is a strong correlation between the abundant co-occurrence of celt/adzes and flake cores (particularly BNR17; BNR22/23; CR5/6, CR7 during the LPPNB; CR5/6, Buttress Bldg., DR25, DR26 during the FPPNB).

The average hinge ratio for Biface Thinning Flakes (BTF) is 0.092 during the LPPNB and 0.112 during the FPPNB samples, with a maximum range between 0.035 and 0.231. Two quite compact clusters of hinge values can be seen in the context of celt/adze production activity: low hinge ratios are represented in S1 (0.054), BNR22/23 (0.091), CR/5/6 (all LPPNB, 0.035), and Loc. D21:11 (FPPNB, 0.077), while higher ratios are found at BNR17 (0.154), DR22 (0.176), DR25 (all LPPNB, 0.174), and CR5/6 (0.182), DR25 (0.231) and DR26 (all FPPNB, 0.140). Flakes, which in majority might also derive out of celt/adze production, show a slightly higher average hinge ratio (0.128), with a similar compactness (general range: 0.034 to 0.214, with one outlier at 0.344). There are also two clusters with lower values (<0.120) and higher hinge ratios (>0.154), which show a strong correlation to the hinge clusters observed for BTF (*i.e.* samples with low hinge ratios for flakes show also a low hinge ratio for BTF and vice versa).

Most LPPNB (13 out of 15) and FPPNB samples (6 out of 11) include evidence of multiple errors. Multiple errors occur much more frequently on flakes (n=58) and flake cores (n=46) than on BTF (n=8) or celt/adzes (n=9). Again, there is a positive correlation between the presence of multiple errors and attested or assumed contexts of celt/adze production. The average clean-up failure ratio for BTF is low (0.111 to 0.167), although the sample size is small. For flakes, the clean-up ratios show a variability ranging between 0 (S1, *i.e.* all clean-up's successful) and 1.000 (CR22.2, DR19, *i.e.* all clean-ups failed). The average

Final Pre-Pottery Neolithic B											
CR5/6	**CR7**	**CR17**	**CR22.1**	**Buttress Bldg.**	**DR19**	**DR22**	**DR25**	**DR26**	**DR30**	**D21:11**	**Total FPPNB**
											0
-	-	-	-	-	-	-	-	-	-	-	-
5		**1**		**1**				**1**			**8**
7		1						2			10
3		1						1			5
3								1			4
2.3	-	*1.0*	-	-	-	-	-	*2.0*	-	-	*2.0*
5	**1**	**3**		**6**			**17**	**33**	**2**	**1**	**68**
7		3		7			10	58		3	88
3		3		4			7	18		1	36
1				2			2	15		1	21
2.3	-	*1.0*	-	*1.8*	-	-	*1.4*	*3.2*	-	*3.0*	*2.4*
1	**1**						**5**	**14**		**2**	**22**
4	3						3	5			15
1	1						1	2			5
1	1						1	1			4
4.0	*3.0*	-	-	-	-	-	*3.0*	*2.5*	-	-	*3.0*
								9		2	11
1				1			1				3
2		1		1			1	2			7

	Flint Raw Material Group in % (FRMG, *cf*. Purschwitz 2019a; Parow-Souchon / Purschwitz 2020)																Min. distance to closest sourcea in %			Information on nat. surfaces		
	Count	**FRMG 1**	**FRMG 2**	**FRMG 3b**	**FRMG 3d/g**	**FRMG 4**	**FRMG 5a**	**FRMG 5b**	**FRMG 6**	**FRMG 7**	**FRMG 8**	**FRMG 9**	**FRMG 10**	**FRMG 11**	**FRMG 25**	**FRMG 45**	**5-10 Min**	**4-5 h**	**<10 h**	**Count**	**Prim. Cortex (%)**	**Sec. surfaces (%)**
Bidir. bl. cores	**9**		11.1		33.3	11.1	11.1		11.1	11.1						11.1	33.3	11.1	55.6	**7**	85.7	14.3
Non-bidir. bl. cores	**19**	5.3			94.7												94.7		5.3	**13**	23.1	76.9
Flake cores	**118**	0.8	4.2	8.5	69.5			0.8	1.7		1.7	2.5	1.7	1.7	2.5	2.5	79.7	5.9	14.4	**58**	17.2	82.8
Celt/ adzes (without DR26)	**67**		1.5	3.0	71.6	1.5	3.0		1.5		1.5	7.5	1.5	3.0	0.0	4.5	71.8	12.7	9.9	**20**	25.0	75.0
Celt/ adzes (only DR26)	**14**				92.9											7.1	14.3[b]	78.6[b]	7.1	**12**	78.6	21.3

Table 5. Chert raw material selection, information on natural surfaces, and minimum distance analysis. [a] On methodology and time estimation see Parow-Souchon/Purschwitz 2020. [b] The closest primary source areas for FRMG 3d are in 2 h walking distance, more abundant primary source areas can be found within 4-5 h distance (Purschwitz 2017).

ratio is 0.178 during the LPPNB and 0.373 (!) during the FPPNB. The skill of successfully correcting knapping errors on flakes was much higher during the LPPNB than during the FPPNB: 4 out of 6 LPPNB samples have ratios below 0.251, while 4 out of 7 FPPNB samples show ratios of 0.500 or even higher. This development is also supported by the absolute counts: while during the LPPNB only 8 clean-ups failed (out of 46), 22 failed clean-ups are represented among the FPPNB-samples (out of 59).

5.2. Skill performance and raw material use

The characteristics of raw material use show a clear technological correlation between raw material quality and procurement efforts. As the core sample shows no major differences in raw material use between the Late and Final PPNB (except for the absence of bidirectional cores among the Final PPNB contexts) the data has not been presented separately (Table 5).

Bidirectional core technology at Ba'ja is practiced on a broad spectrum of high-quality raw materials (including FRMG 2, 3d/g, 4, 5a, 6, 7, and 45). This high investment in procurement is demonstrated by a predominance of primary cortex residues (>83% of all cores bear remnants of primary cortex, which indicates the use of primary sources). Additionally, more than 55% of the raw materials are not available within the 10 h site catchment. Though the core number is small, this trend is confirmed by other more extensive raw material studies which also analysed core trimming elements and all types of debitage products (Purschwitz 2017, 2019b, in prep.; Parow-Souchon and Purschwitz 2020). Among the core residues, there is only one core showing battered surfaces, which (accidental or not) is the core with the highest number of step/hinge fractures (n=6).

In contrast, the raw material use attested for non-bidirectional blade core technology and among flake cores is characterized by local chert types of the immediate site vicinity (FRMG 3d/g, local cherts comprise of almost 79.7-94.7%). This low investment in raw material procurement is also seen by high proportions (76.9-82.8%) of secondary surface residues on the cores, which indicate the raw material procurement from Wadis (such as the nearby Siq al-Ba'ja). However, there is a significant difference in raw material use between LPPNB and FPPNB non-bidirectional blade cores. Eight of 12 LPPNB non-bidirectional blade cores have deliberately been tempered, while tempering is quite rarely found in the FPPNB core sample (7 out of 76 cores were tempered, all of which are small exhausted flake cores, which probably represent recycled blade cores).

Adzes/celts show a similar raw material use as non-bidirectional blade and flake cores, with the exception being the celt/adze cluster found in DR26. This cluster is characterized by an extreme homogeneity in raw material choice (92.3% FRMG 3d), which (in contrast to the other celt/adze finds) is overwhelmingly characterized by primary cortex residues.

5.3. Diachronic trends

Diachronic analysis shows significant differences, but also continuities in the frequency of knapping errors. The hinge ratio remains remarkably stable, and does not show any chronological difference between LPPNB and FPPNB samples for non-bidirectional blades (0.107) and

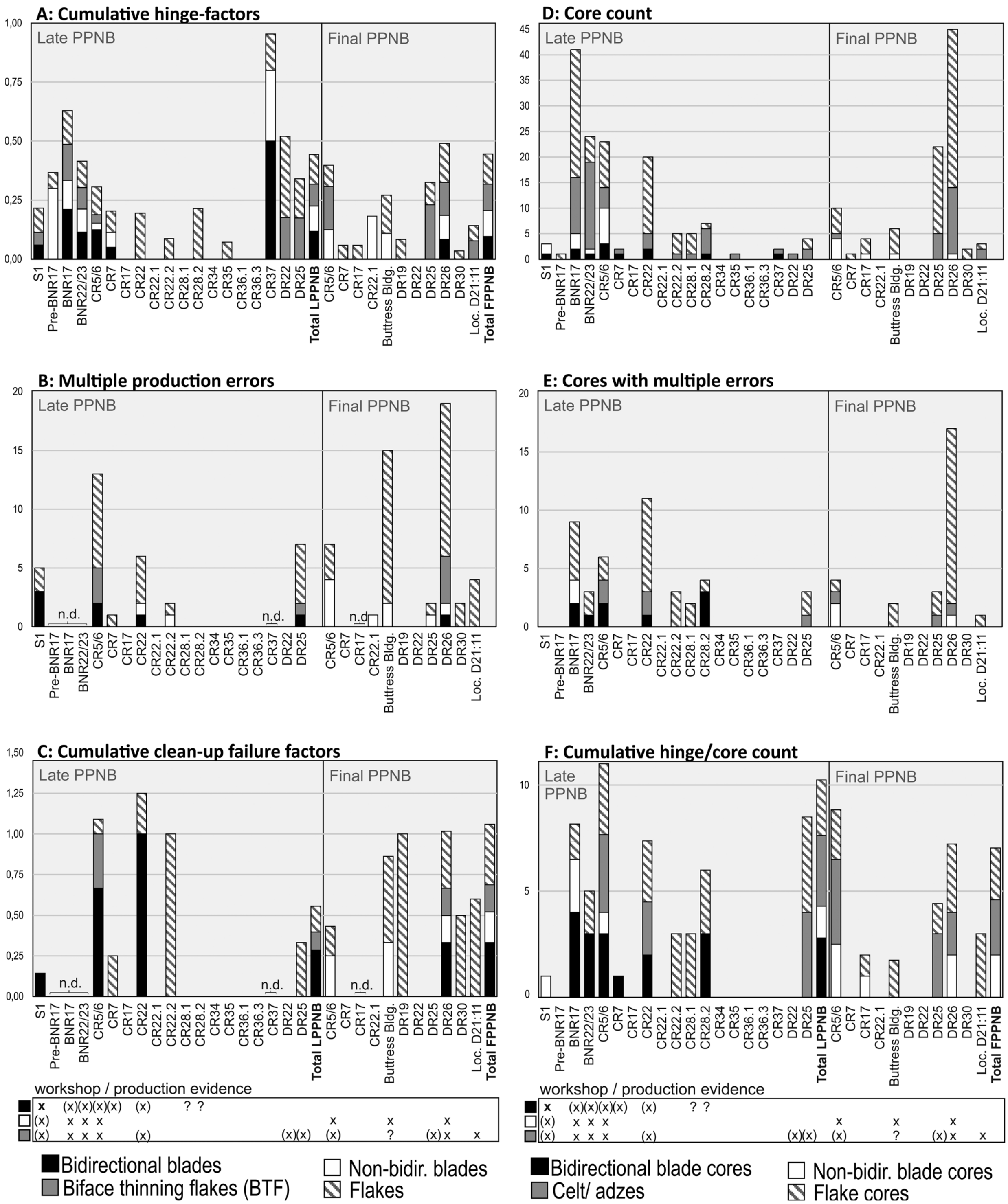

Fig. 2. Diagrams of Ba'ja error frequencies on debitage products (a-c) and cores & celt/adzes (d-f).

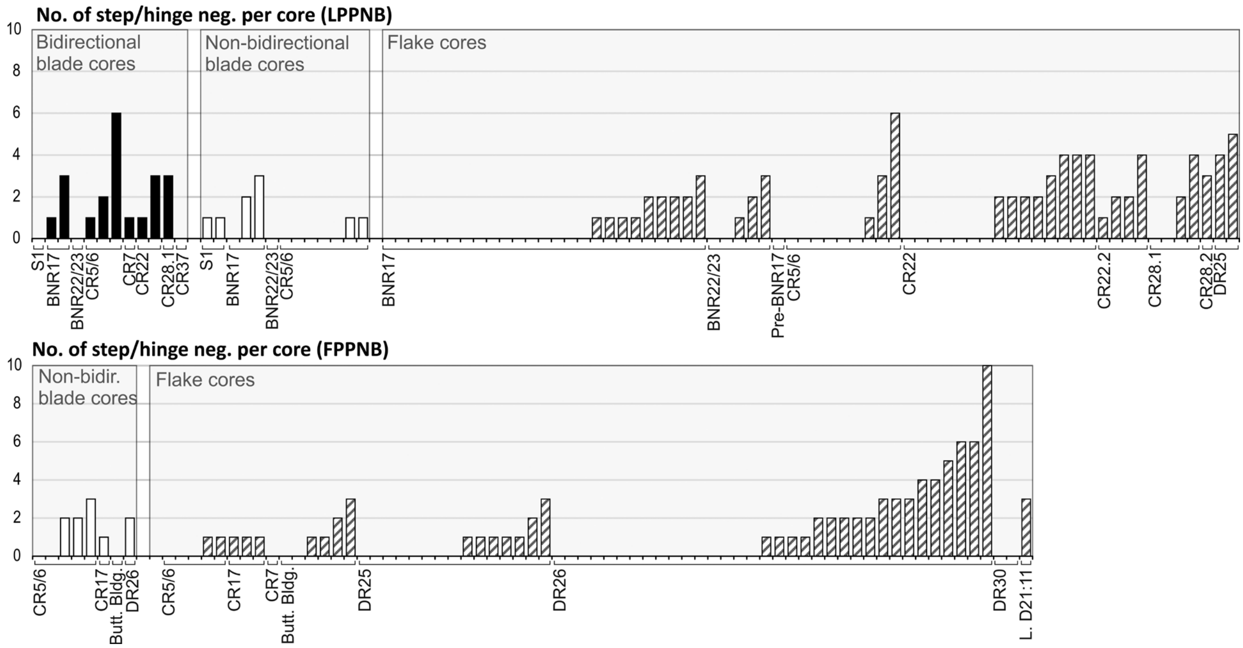

Fig. 3. Number of step/hinge scars per core according to technology and period (LPPNB upper chart; FPPNB lower chart).

flakes (0.128). There are minor differences for BTF's and bidirectional blades. The hinge ratio for BTF's slightly increases from 0.092 in the LPPNB to 0.112 in the FPPNB, while the hinge ratio attested for bidirectional blades develops *vice versa* (decreasing from 0.118 during the LPPNB to 0.097 in the FPPNB). Both developments might be explained by the general abandonment of bidirectional blade core technology in Ba'ja after the LPPNB. The lower hinge ratio of bidirectional blades probably is the result of scavenging, and one can assume that feathered blades were preferably collected. The lower hinge ratio for BTF's during the LPPNB is caused by BTF's resulting from bidirectional core trimming (cresting) which is caried out by very skilled knappers. However, bifacial thinning of celts/adzes generally causes a higher frequency of step/hinge terminations, which also can be produced purposefully to thin bifacial tools faster (*cf.* Sternke and Sørensen 2009: 723). This interpretation is supported by the ratio of step/hinge scars on celt/adzes which remains constant (3.3 during the LPPNB vs. 3.0 during the FPPNB). This holds also true for flake cores and non-bidirectional blade core residues showing constant error frequencies per core (2.6 vs. 2.4 for flake cores; 1.5 vs. 2.0 for non-bidirectional blade cores). Similar diachronic error frequencies correspond to a constant diachronic occurrence of celt/adzes and non-bidirectional blade core residues among the lithic finds, which may indicate a similar economic importance, and continuity in knapping practise for these technologies during the FPPNB. In contrast, flake cores increase from 0.8% to 1.6% in the FPPNB. There is also a massive increase in clean-up failure for flakes (from 0.178 to 0.373), BTF's (0.111 to 0.167), and non-bidirectional blades (0 to 0.189) in the FPPNB assemblage, which shows a clear decrease in the know how to correct knapping errors.

6. Discussion and conclusions

It is important to emphasize that knapping errors are not unique to beginners and novices, and that beginners and novices should not automatically be equated with children. Knapping errors can and do occur to anyone knapping chert – independent of his/her gender, skill, or age, and errors may occur to even expert knappers. However, as has been shown by experimental research (Ferguson 2008; Shelley 1990; Sternke and Sørensen 2009) some error features (*e.g.* multiple step/hinge fractures, and a high hinge-ratio) are very characteristic for unskilled knapping performances, as the unskilled knappers lack the know-how to properly anticipate fracture mechanics. They also tend to repeat their errors.

The abundance and omnipresence of lithic finds all over the site clearly suggest, that knapping chert at Ba'ja was a normal activity of daily-life and which was practiced by many (if not most) community members. The frequent occurrence of multiple and repetitive knapping errors both on core residues and debitage products, highly suggests that unskilled knapping is very likely associated to beginners and novices. The great variability of knapping errors and knapping performances among the various contexts shows a broad skill spectrum and various skill levels (beginners, novices, practitioners, and experts). It

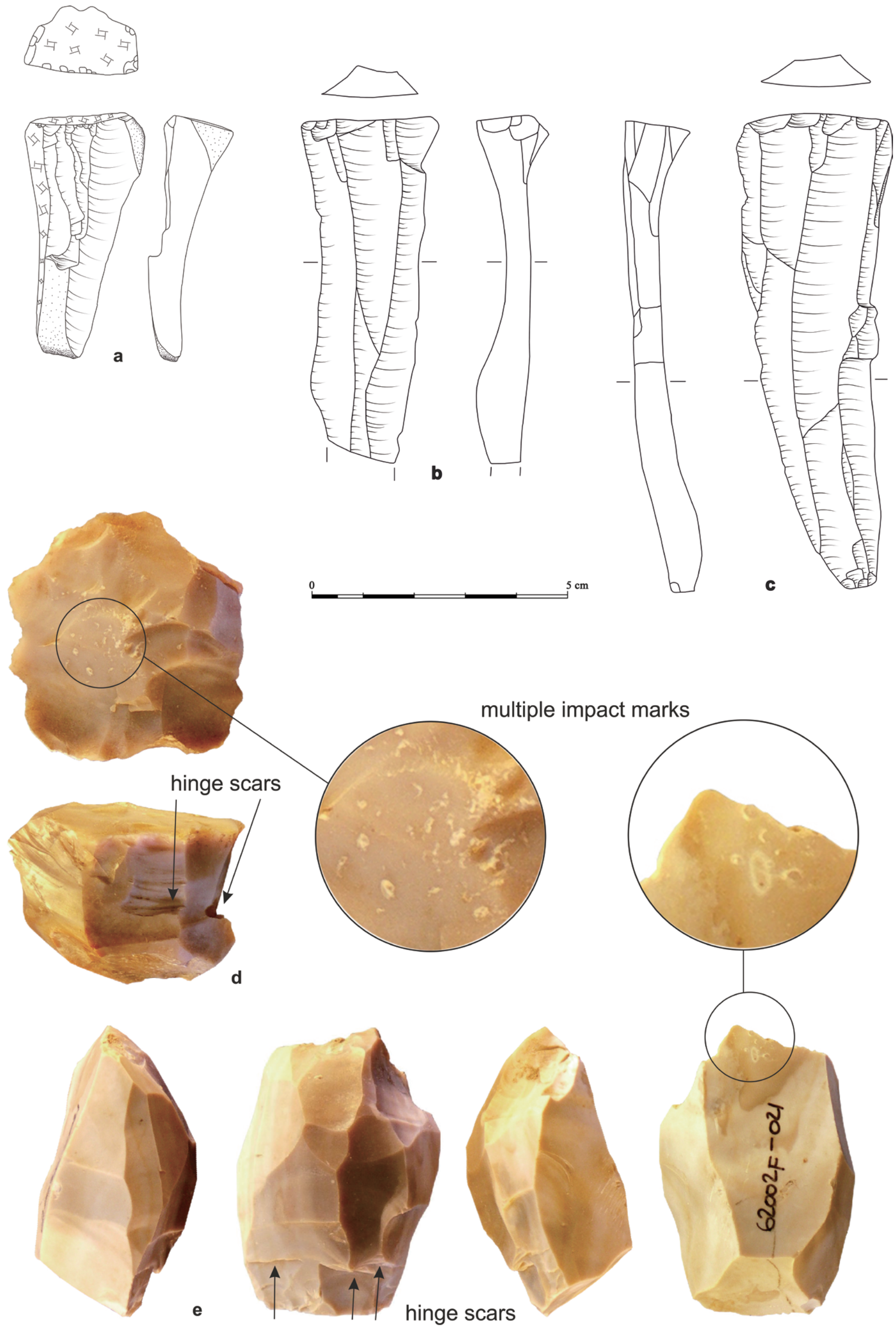

Fig. 4. a) BJ22265 (Loc. D11/12/21/22:13): Clean-up blade on single platform blade core, b) BJ62036-008 (Loc. BNR23:111): Unintended overshoot from bidirectional core reduction, c) BJ62002f-075 (Loc. BNR17:106) Plunged clean-up blade from bidirectional core reduction showing two dorsal hinge scars, d) BJ6291-034 (Loc. BNR23:112) Single platform flake core with multiple step/hinge scars and central battering's (mis-hits?) on the striking platform, e) BJ62002f-002 (Loc. BNR17:106) Exhausted bidirectional blade core with multiple step/hinge scars, Note the mis-hits on the striking platform (all drawings and photographs by the author).

also shows that most stages of flintknapping learning took place on-site.

Considering the spatial and temporal dimension of learning, we suggest that the household functioned as a central place for knowledge transfer. This is attested by the material evidence of learning behaviour (such as [multiple] step/hinge terminations or scars, and error correction support), which is found in the Ba'ja household dumps. This evidence includes all practiced technologies and includes bidirectional blade technology during the LPPNB. Often, many different *chaîne opératoires* are found associated within the same dump. How learning situations and knowledge transfer was exactly configured within these household settings is difficult to reconstruct. Successful clean-ups with multiple dorsal error scars are common, and may indicate regular interactions (such as scaffolding) between practitioners/experts and the learners. The association of various technologies and skill levels within the same contexts (*e.g.* BNR17; BNR22/23, CR5/6, DR26) may also support such interactions, and demonstrates that knappers of various skill levels shared the same working space (within one house[hold]). Concerning the social dimension, we may expect that all forms of horizontal, oblique, and vertical knowledge transmission occurred. Vertical transmission may have predominated among celt/adze production and among the blade technologies, while horizontal and oblique transmission may have prevailed in the expedient/"ad hoc" industry. The expedient/ad hoc" industry at Ba'ja is characterized by an abundancy in flake cores of great morphological variance and an extraordinary high error rate (hinge ratio, clean-up-failure ratio).

The complexity and high degree of standardization within some *chaînes opératoires*, such as bidirectional blade technology (and probably of celt/adze production and of non-bidirectional blade technology too), must have required multiple, repetitive transfer sessions which also included formal teachings and can be assumed to have involved long lasting, multi-staged apprenticeships. Children lack appropriate muscle power, motor-skills, hand-eye coordination, and cognitive capacities (needed for the understanding of this complex technology, to anticipate knapping results, or to conceptualize appropriate problem-solving strategies) to properly perform bidirectional blade technology or to produce skilled celt/adzes. Therefore, it appears very unlikely that children (below an age of 10-12 years) may have been able to practise bidirectional blade technology to its full extent. The material evidence of an apprentice's work may have been found in BNR17. The composition of bidirectional blade debitage at BNR17 clearly shows that core reduction took place on-site by using (excellently) prepared cores. Although the knapper (or knappers?) was obviously able to open the platforms, to reduce the core and to produce blades, he/she obviously was unable to rejuvenate the platforms nor the core face, and produced a large number of knapping errors (unintended overshoots, hinged blades) (Purschwitz 2017: 261-263; *cf.* also Table 3). Other evidence of learning behaviour at BNR17 is also found on an exhausted bidirectional blade core showing numerous mis hits on one of the platforms and several step/hinge scars (Fig. 4: e).

However, younger children must have been omnipresent at Ba'ja, and child burials show that children received much attention and care (Benz *et al.* 2020). There is no reason to assume that the children at Ba'ja did not interact with the adult world. They imitated what they observed within their daily play. Therefore, it seems very likely, that also children younger than 10 years left their lithic 'fingerprints' on the archaeological record. Their testimony might be seen in the abundancy of crudely knapped flake cores which generally are characterized by multiple errors and miss hits (*e.g.* Fig. 4: d), and we suggest considering (at least some of) these flake cores as 'imitations' of other core technologies.

We should hesitate to think that all agents and places of learning and knowledge transfer are equally represented among the Ba'ja findings, and that we should be aware of some aspects being less visible or even invisible to us. For instance, the specialized workshop dump of S1 is generally characterized by a very homogeneous and advanced skill level, which should not compellingly indicate the absence of apprentices. As has been demonstrated, the raw material processed within this workshop is mostly non-local, and clearly hints to more distant areas of chert procurement. Therefore, training may have been carried out at the extraction locales, and novice errors therefore might be underrepresented within the S1 sample. This is an important point, as we have good evidence of PPNB chert mining sites (such as Jabal Jiththa, Wadi Huweijir, Ramat Tamar, Har Gevim and others, *cf.* Purschwitz 2019a; Quintero 2010; Schyle 2007), all of which are located some distance from the settlements (*cf.* Fig. 1). At Ramat Tamar (the only quarry site where a systematic investigation was carried out and from where data has been published) hinge terminations and overpasses are abundantly represented (19% to 35% of debitage products, Schyle 2007: Table 3.13). This demonstrates the presence of unskilled knappers, among which we assume to include beginners and novices. Within the settlements apprentices of bidirectional blade technology may have undertaken other tasks (such as cleaning), or may have practised on discarded bidirectional cores (perhaps even at different locations), or have trained on single platform blade(let) cores (which are attested in small numbers at S1, and which indeed show knapping errors).

Another aspect of the social dimension involves the availability of technological knowledge. Evidence of learning behaviour is evenly distributed among the household dumps and includes examples of all lithic technologies (including bidirectional blade production). This indicates that (on a household level) technological lithic knowledge was rather public and generalized than private, although there probably were differences related to age, gender, or status. However, many researchers convincingly argue, that some households became specialized on specific crafts and produced beyond self-sufficiency (*e.g.* Barzilai 2010; Gebel 1996; Purschwitz 2017, 2019b, 2019c; Quintero 2010). Though this may sound contradictory, there may be another explanation for the formation of specialized (surplus) producing workshops, such as attested at Basta (Gebel 1996), 'Ain Ghazal (Quintero 2010) or to a smaller extent also in Ba'ja S1. Characteristic of these workshop dumps is some exclusiveness in raw material use. Often one or two raw materials of high-quality were preferred, showing quite a high investment in procurement (from primary resource areas, often extracted through mining). As Gebel (2014) has suggested "territoriality develops when social units or individuals establish themselves in an area by claiming resources through use", which makes it likely that high resource investment within the socio-economic settings of densely occupied LPPNB mega-sites (such as Basta or 'Ain Ghazal) led to territorial claims on physical properties (*cf.* also Gebel 2010).

The role of horizontal knowledge transmission may have increased during the LPPNB/FPPNB-transition, if the rise in flake core density and the extraordinary increase in clean-up failures are correctly interpreted. If so, lessened ability to correct errors may hint to a reduction in support from experienced knappers, or to a more autonomous way of learning. Though highly speculative, the decline and abandonment of bidirectional blade technology at the same time – probably as a result of major social transformation which prevented the continuation of this long-lasting learning tradition – may represent the other side of the same coin. However, much more research is needed to better understand the social processes which shaped and triggered this major period of transformation.

7. Perspectives

While the understanding of the role and impact of children and learning behaviour in the formation of lithic assemblages has received increasing awareness among lithic researchers, such a perspective is rarely incorporated into Southwest Asian lithic research. This paper illustrates the benefits for understanding lithic production and technology if approaches to investigating knowledge transmission, child behaviour and apprentice(ships) are included. Even though many aspects of learning and knowledge transfer among the PPNB community of Ba'ja are discussed here, it also became obvious that our state of knowledge is insufficient. For the future more studies are needed, and such research should consider (among others) the following aspects: necessity to include more contexts and dumps of specialized production (including evidence of procurement sites), which may allow a better understanding of how knowledge transfer within this very complex and standardized technological tradition took place. Particularly important would also be to investigate how knowledge transfer and learning processes of bidirectional blade technology differed from self-sufficient household lithic technologies, and of course which similarities can be seen. Such studies would benefit highly from experimental research on PPNB-lithic technologies by considering the learning capacities and strategies applied by younger knappers (including children and teenagers). Moreover, diachronic and multi-site approaches may allow us to better understand period- and site-specific aspects of knowledge transmission.

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