Lithic production strategies during the late Middle Pleistocene at Dali, Shaanxi Province, China: implications for understanding late archaic humans

Hao Li[1,2], Matt G. Lotter[3]

[1] Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

[2] CAS Center for Excellence in Life and Paleoenvironment, Beijing, 100044, China

[3] Department of Anthropology and Archaeology, University of Pretoria, Lynnwood Road, Pretoria 0083, South Africa

Email address of Hao Li: wits_ivpp@hotmail.com;
Tel: 0086+15811376112;
ORCID: 0000-0001-5192-5458.

Abstract

The Dali hominid site is well known as it contains a human cranium associated with stone artefacts and animal bones. Dating efforts have provided an age range of ~ 300-247 ka for these remains. Renewed study of the cranium in recent years has revealed a mix of archaic traits in the neurocranium and derived features in the face, and thus this specimen may provide insight into our understanding of modern human evolution in China. However, the technological behaviour possessed by these people has remained unclear due to a lack of new and detailed research. In this paper we re-examine the lithic assemblages from Dali, originally excavated in 1978 and 1980, and for the first time we now provide a sound assemblage by removing those geofacts that have been used in past archaeological reports. Although the total number of artefacts is now smaller, our results show that core reduction strategies at Dali are primarily expedient, dominated by simple unifacial unidirectional flaking. In contrast, the formal tools exhibit relatively advanced technology, with artefacts that are diverse in type and characterized by a relatively standardized production strategy. In contrast to the widely accepted model for slow and conservative technological development in Chinese Palaeolithic technology, pre 40 ka, here, we suggest that there is evidence for gradual technological changes from the Early to Middle and early Late Pleistocene.

Key words Northwestern China, Dali cranium, late archaic humans, late Middle Pleistocene, lithic technology

Introduction

The latter half of the Middle Pleistocene (~ 450-128 ka) is a key evolutionary period in human history. In Africa, the transition from archaic to early modern (or near-modern) humans occurs, represented by the crania found at Herto (~ 160-154 ka) and Omo (~ 200-190 ka) in Ethiopia (White et al. 2003; McDougall et al. 2005, 2008),. and more recently at Jebel Irhoud in Morocco (weighted average age of 315 ±34 ka; Hublin et al. 2017; Richter et al. 2017). In western Eurasia, this transition is marked by the evolution of late *H. heidelbergensis* into Neanderthals (Hublin 2009; Arsuaga et al. 2014; Meyer et al. 2016). From a technological perspective, hominids living in Africa and western Eurasia developed a more advanced and sophisticated skillset during this period (i.e. transition to Middle Stone Age/Middle Paleolithic technologies) (Kuman et al. 1999; Clark et al. 2003; Monnier 2006; Shea 2008; Moncel et al. 2012; Adler et al. 2014; Richter et al. 2017). During these stages new tool types occur, some of which served as effective hunting tools once hafted (i.e., points; see Aterian, Lupemban and Still Bay Industries) (McBrearty 1988; Brooks et al. 2006; Wilkins et al. 2012; Scerri 2013). Wooden spears and bone tools are also documented at sites of this period, such as those from Schöningen (~ 300 ka) in Germany (Schoch et al. 2015; Kolfschoten et al. 2015).

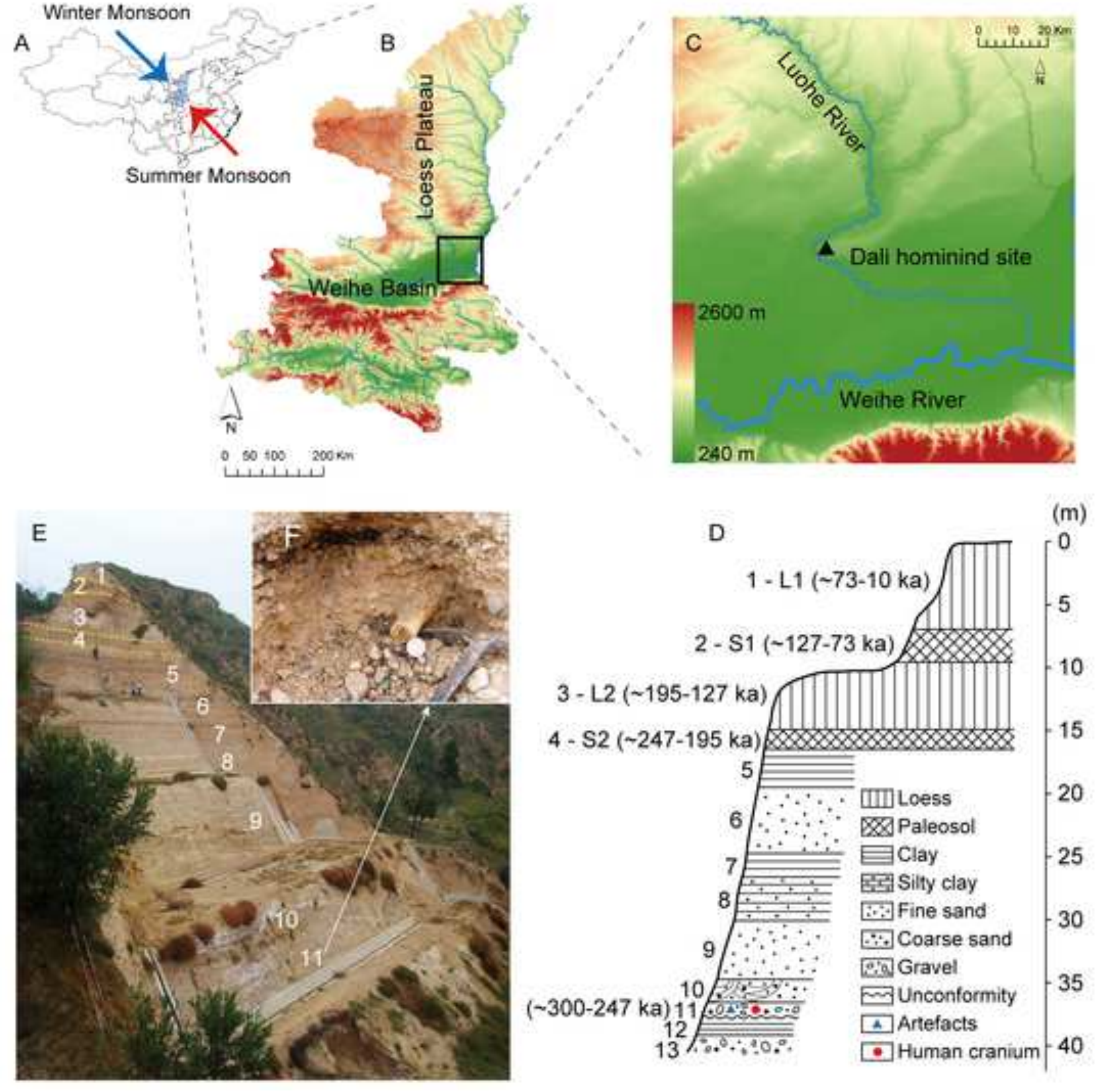
Compared with Africa and western Eurasia, human fossils in China also occur, such as those from Jinniushan (~ 260 ka), Hexian (~ -412-150 ka) and Maba (~ 300-130 ka) (Rosenberg et al. 2006; Lu et al. 2011; Cui and Wu 2015; Wu and Bruner 2016). However, due to the lack of or limited quantity of stone artefacts recovered from these sites, our understanding of the technological behaviours of ancient populations remains unclear. The site of Dali in Shaanxi Province, NW China, however, contains a relatively complete human cranium associated with stone artefacts in the same layer (Wang et al. 1979; Wu and You 1979; Zhang and Zhou 1984).

In this paper we re-examine the lithic assemblage from Dali, originally excavated and studied by Wu and You (1979) and Zhang and Zhou (1984), and present a detailed technological description of the artefacts dated to ~ 300-247 ka (Yin et al. 2001; Rits et al. 2017; Sun et al. 2017). Since detailed studies of the Dali cranium show that it aligns well with Middle Paleolithic/Middle Stone Age humans from Skhul, Qafzeh and Jebel Irhoud in the facial skeleton, and with Eastern Eurasian and African Middle Pleistocene *Homo* in the neurocranium, the Dali cranium may hence play an important role in the origin of early *Homo sapiens* in China, (Wu 2009, 2014; Wu and Athreya 2013; Athreya and Wu 2017). By documenting the lithic production strategies of Dali hominids we aim to provide a better understanding of the technological behaviours of these ancient populations, and furthermore, we aim to provide archaeological evidence that will aid in our understanding of the transitional processes to modern human biology in China.

Geological and chronostratigraphic context

The Dali site was found in 1978 in the Dali County, Shaanxi Province, NW China (34°52' N, 109°40' E). The Dali cranium was initially discovered in a gravel layer at the site (Wang et al. 1979; Wu 1981; Wu and Athreya 2013; Athreya and Wu 2017), and subsequent excavations in this layer yielded stone artefacts and animal fossils (Wu and You 1979; Zhang and Zhou 1984). Contextually, the site is located in the transitional area between the Loess Plateau and the lower Weihe Basin. The Luohe River, which is a tributary of the Weihe River, cuts through the Loess Plateau and flows into this basin (Figure 1:B,C). Dali is situated in the third terrace of the Luohe River and is 45-50 m above the present-day river. Regional palaeo- and current climatic data show this area to be an important converging point for summer (from the Pacific Ocean) and winter (from Siberia) monsoons (Figure 1A), therefore making it ‘climatically sensitive’. The study of fauna and pollens from Dali indicate it was formed during a warm period, which is suitable for human occupation (Ke et al. 1991).

Fig 1. A) location of Shaanxi Province (blue) in China; B) geomorphology of the Shaanxi Province, note that the study area is situated in the southeastern margin of the Loess Plateau; C) geographical setting of the Dali hominid site; D) stratigraphy of the site; E) picture of a section (identical with the Dali section) exposed ca. 70 m south of Dali; F) close observation of gravels in layer 11.



The stratigraphy at Dali comprises a ~ 42 m thick sequence, which is commonly divided into thirteen different layers (Figure 1D). This original stratigraphy, revealed in 1978 and 1980, has since been covered by more recent weathered deposits due to its long-term exposure. However, a section which is ~ 70 m away from this original profile has recently been exposed during construction (Figure 1E). This section is identical to the original Dali profile and is now used as a stratigraphic reference (see discussions and deposit comparisons by Hu et al. 2016; Rits et al. 2017). Early studies at Dali assigned incremental numbers to the stratigraphic layers, from the bottom to the top (Wang et al. 1979; Wu and You 1979), whereas the opposite is performed on these same layers in more recent studies (see Xue et al. 2000; Wu and Liu 2001; Hu et al. 2016); the latter system is followed here and is described below. Specifically, from the top, layers 1 to 4 comprise a ~ 17 m thick aeolian deposit of loess and palaeosol layers. From layer 5 to the basal layer 13, the sediments are characterized by fluvial-lacustrine deposits. Layers 5 to 10 are dominated by silty and sandy sediments, and the underlying layer 11 (equivalent to layer 3 in Wu and You 1979) consists of sands and gravels (Figure 1F). This layer 11 is ~ 37 m below the surface and it is from the upper part of this layer that the human fossil and stone artefacts were excavated. An unconformable contact has been identified between layer 11 and the underlying layer 12 (Wu and You 1979).

Wu and Liu (2001) and Xiao et al. (2002) have investigated the age of these deposits, through the application of magnetic susceptibility analysis of loess-paleosol deposits. Magnetic susceptibility analysis shows that layers 1 to 4 correspond to loess L1 (~ 73-10 ka), paleosol S1 (~ 127-73 ka), loess L2 (~ 195-127 ka) and paleosol S2 (~ 247-195 ka), respectively (Liu 1997). S2 (layer 4) in the loess-paleosol sequence has been securely dated to ~ 247 ka, corresponding with MIS 7 (Wu and Liu 2001). Since layer 11 occurs ~ 20 m below layer 4, and since we have no other dates for layers 5-10, we can therefore assign a minimal age of ~ 247 ka to both the human fossil and stone artefacts. Considering both the magnetic susceptibility data and the relationship of terracing processes with climatic conditions, Xiao et al. (2002) further suggest the age of layer 11 to be ~ 270 ka, equal to the age boundary from loess L3 to paleosol S3. Faunal evidence, such as species of *Palaeoloxodon*, *Equus*, *Rhinoceros*, *Megaloceros pachyosteus*, and *Pseudaxis* cf. *grayi*, also indicate a late Middle Pleistocene age for layer 11 (Zhang and Zhou 1984; Keates 2003). ESR dating applied to shells from this layer provide four age results: 282.5±116.6 ka, 279.5±110.7 ka, 267.1±72.2 ka and 246.6±65.6 ka (Yin et al. 2001), whereas U-series dating of a rhino tooth gives an age range of 349-258 ka (Yin et al. 2002; Yin et al. 2011). More recently, optically stimulated luminescence (OSL) dating, using the K-feldspar pIRIR$_{290}$ protocol, has narrowed the age range of Dali to between 267.7±13.9 ka and 258.3±14.2 ka (Sun et al. 2017). Based on these dating results discussed above it is therefore reasonable to estimate the age of layer 11 to ~ 250-300-247 ka. Both the artefacts and the fauna show a mix of fresh and more abraded conditions, which indicates that the alluvial deposit captured material from different sources (Zhang and Zhou 1984). Nevertheless, all finds have a minimum date of ~ 247 ka.

Lithic technology

Assemblage components and raw materials

To date only two excavations have been carried out at Dali. During the first excavation in 1978, 181 artefacts were recovered from layer 3 (i.e., layer 11 in this paper) where the Dali human cranium was discovered (Wu and You 1979). The second excavation in 1980 retrieved 384 artefacts from layer 3 and 17 artefacts from the overlying layers 4 (n= 4) and 5 (n= 13) (i.e., layers 10 and 9, respectively; Zhang and Zhou 1984). In total, 582 stone artefacts have been excavated, according to previous reports. However, as noted by Zhang and Zhou (1984), a large number of artefacts is abraded, clearly demonstrating the fluvial context of the site. It has thus been necessary to re-examine the sample, with the primary goal of removing geofacts produced by this fluvial action. For instance, in previous studies artefacts with a series of overlapping micro-scars were classified as tools with intentional retouch, but we

Table 1. Dali artefact types grouped by raw material. Misc. = miscellaneous.

	Quartzite	Quartz	Chert	Total	%
Cores	3	-	6	9	6.4
Complete flakes	38	2	33	73	52.1
Split flakes	5	-	4	9	6.4
Flake fragments	11	2	-	13	9.3
Chunks	6	2	1	9	6.4
Formal tools	15	7	3	25	17.9
Misc. retouched tools	1	1	-	2	1.4
Total	79	14	47	140	

now know these scars have been created by natural impact. Furthermore, our understanding of the types of raw materials utilized in artefact production, as well as the techniques employed in this production, have been misunderstood and thus a re-assessment is needed. Now, from our re-analysis, we provide a total of 140 artefacts – those bearing clear artefactual features – that were selected for this study (Table 1).

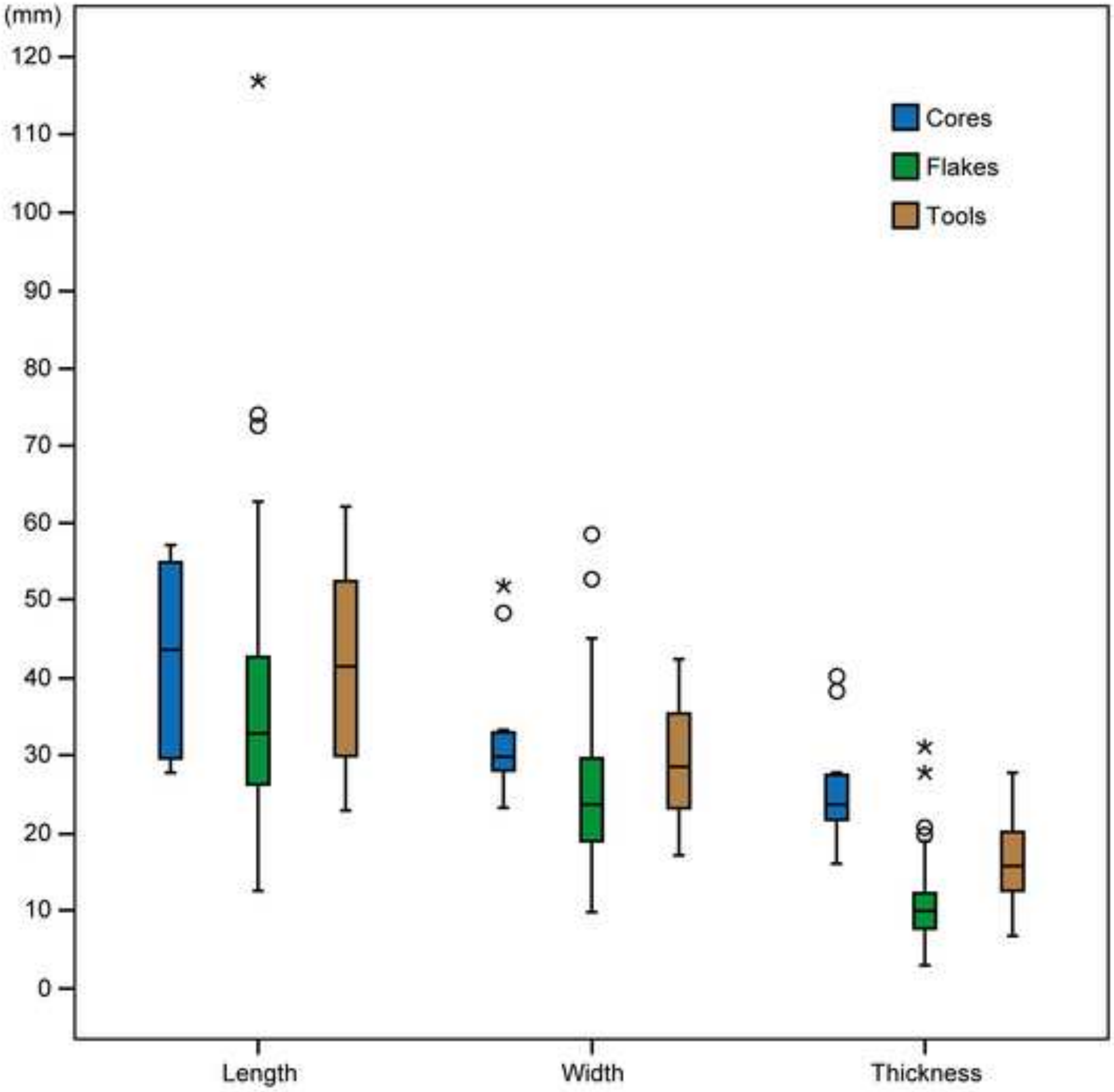
The artefact assemblage at Dali includes: nine cores (6.4%), 95 flakes (67.9%; including 73 complete flakes, nine split flakes and 13 flake fragments), nine chunks (6.4%), 25 formal tools (17.9%), and two miscellaneously retouched tools (1.4%). Quartzite is most favoured for artefact production (56.4%, n= 79), followed by chert (33.6%, n= 47) and quartz (10.0%, n= 14). Overall, the artefact sizes are small (Figure 2); average length, width and thickness dimensions are as follows: 42.5, 33.1 and 25.7 mm (cores), 36.5, 25.3 and 11.0 mm (complete flakes), and 42.6, 29.0 and 17.0 mm (tools), respectively.

A size analysis of pebbles and cobbles in layer 11 shows that the average diameter of gravels is dominated by a range of 3-5 cm, with only few larger cobbles reaching 10 cm (note gravel size in Figure 1F). Since quartzite and chert are the prevalent raw materials, we suggest that the distinctive small size of artefacts is closely related to the local availability of the raw materials in these small sizes. The high preservation of cortex on artefacts, averaging 50% on cores, 20.9% on complete flakes, and 21.9% on tools, also indicates river gravel sourcing of raw materials. Artefact edge abrasion shows that the majority is in fresh condition (65%), while 32.1% of artefacts are slightly abraded and 2.9% are heavily abraded. From our contextual understanding of these deposits we can therefore conclude that the artefacts are of secondary context, having been transported some distance through fluvial/hydraulic processes.

Core reduction strategies

In total, nine cores were excavated from the site. Pebbles are the most favoured blank from which cores are produced (n= 6), followed by cobbles (n= 2) and a chunk. A technological classification of these cores, based on their reduction/flaking patterns,

Fig 2. Boxplots of the size profiles for cores, flakes and tools. Circles above the boxes mean the outlier values, while crosses mean the extreme values.



shows that five can be classified as casual cores, two as single-platform cores, one as a polyhedral core and one as a discoidal core (Figure 3:A,B). From this it is clear that the flaking pattern of cores is dominated by simple unifacial unidirectional flaking (n= 7), whereas the remaining two cores show multifacial and asymmetrical bifacial flaking patterns (see de la Torre 2011 for a detailed explanation of the core flaking patterns used in this study). The reduction intensity shown in the cores, as indicated by the total number of flake scars, is low at 3.4 scars, and it is the single discoidal core that illustrates the greatest intensity in reduction (n= 10 scars; Figure 3A). The proportion of cortex retained on cores is a valuable indicator for reduction intensity (Hiscock and Tabrett 2010), and the high average of 50% provides additional evidence for the low extent of core reduction at Dali. Overall, although the sample of cores is small, it is evident that core reduction strategies at Dali range from opportunistic to organized, and it is these opportunistic 'expedient' types that dominate. Prepared core technology does not occur at Dali.

Flakes are the most frequent artefact type in the Dali assemblage, comprising 67.9% of all lithics (n= 95), and three subtypes were identified, namely: complete flakes (n= 73; Figure 3:C-G), split flakes (n= 9) and flake fragments (n= 13). Several technological features of the complete flakes appear to be consistent with the core sample, based on flaking patterns and reduction intensity, and these include aspects of the flake platforms and dorsal scar data (pattern and number). With regard to the former, flake striking platforms are dominated by those that are completely cortical (57.5% of all platforms). Plain platforms are the second most abundant type, at 21.9%. Two-faceted (8.2%), linear (8.2%) and pointed (4.1%) platforms occur in relatively small proportions. Platform preparation, indicative of careful core preparation and maintenance during reduction (Van Peer 1992; Boëda 1995), is absent. With regard to the latter, dorsal scar counts highlight the generally low reduction intensity of cores, with the average scar number being two. Toth's (1985) classification of flakes considers both platforms (cortical and non-cortical) and dorsal faces (cortical, artificial, and partly artifacial) and six sub-types are identified (Figure 4A). At Dali types II (26.0%) and III (26.4%) are dominant, and these indicate the preliminary

Fig 3. Discoidal core with asymmetrical surfaces (A); single-platform core (B); and flakes (C-G; among them, E, F and G show triangular scars on the dorsal faces) from Dali. Red arrows show flaking directions on cores.

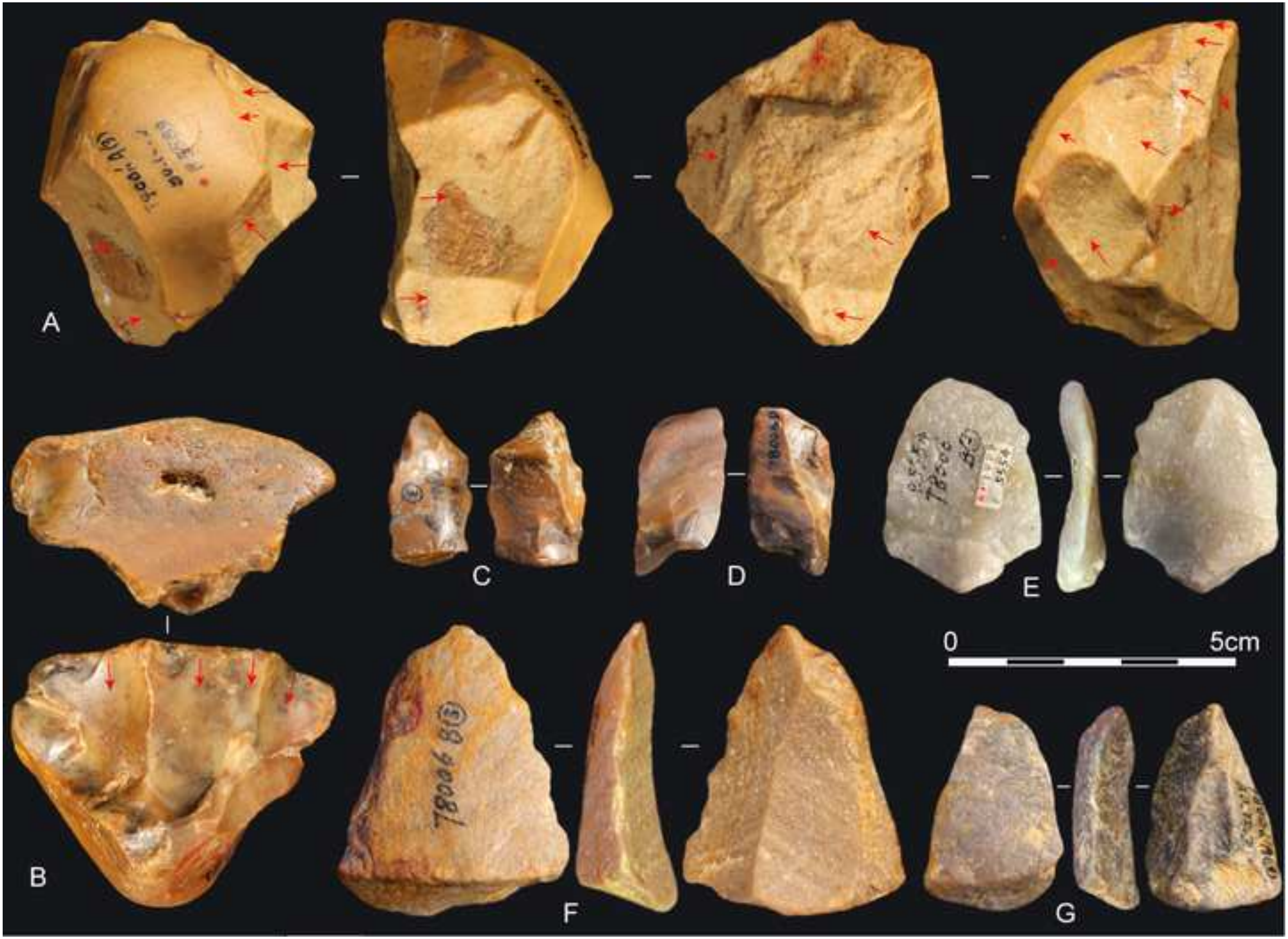
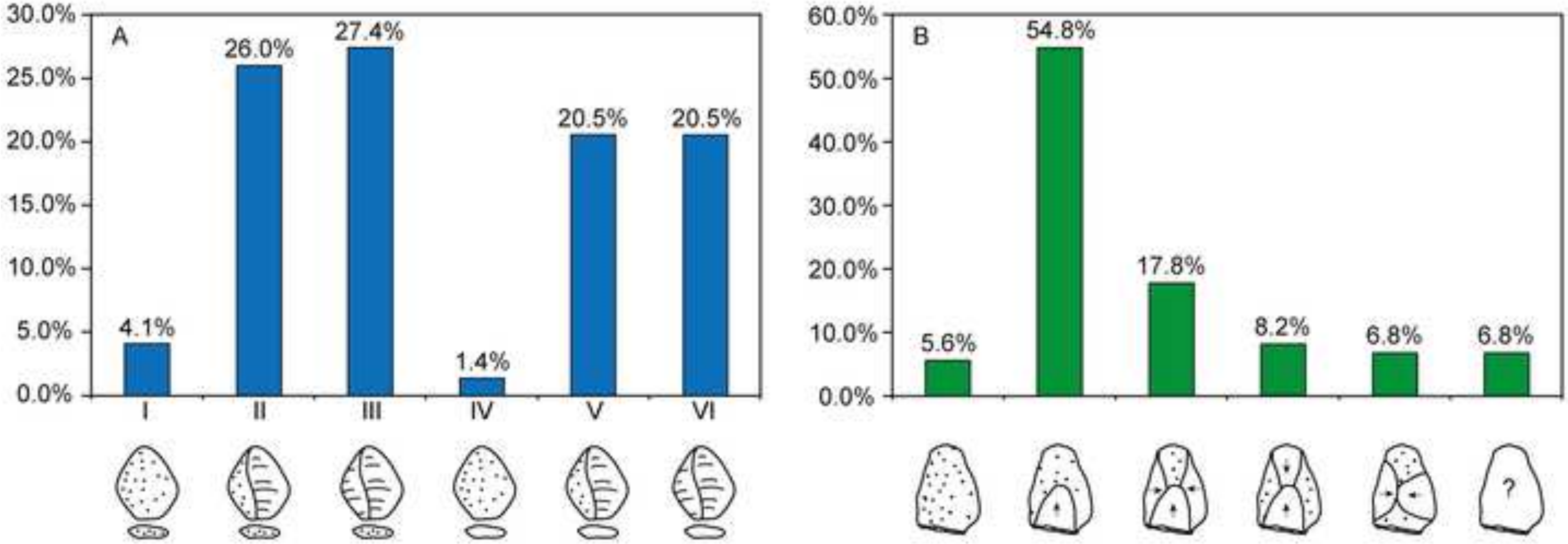


Fig 4. Classification of flakes according to Toth's (1985) typological system (A), and dorsal flake scar directions (B).

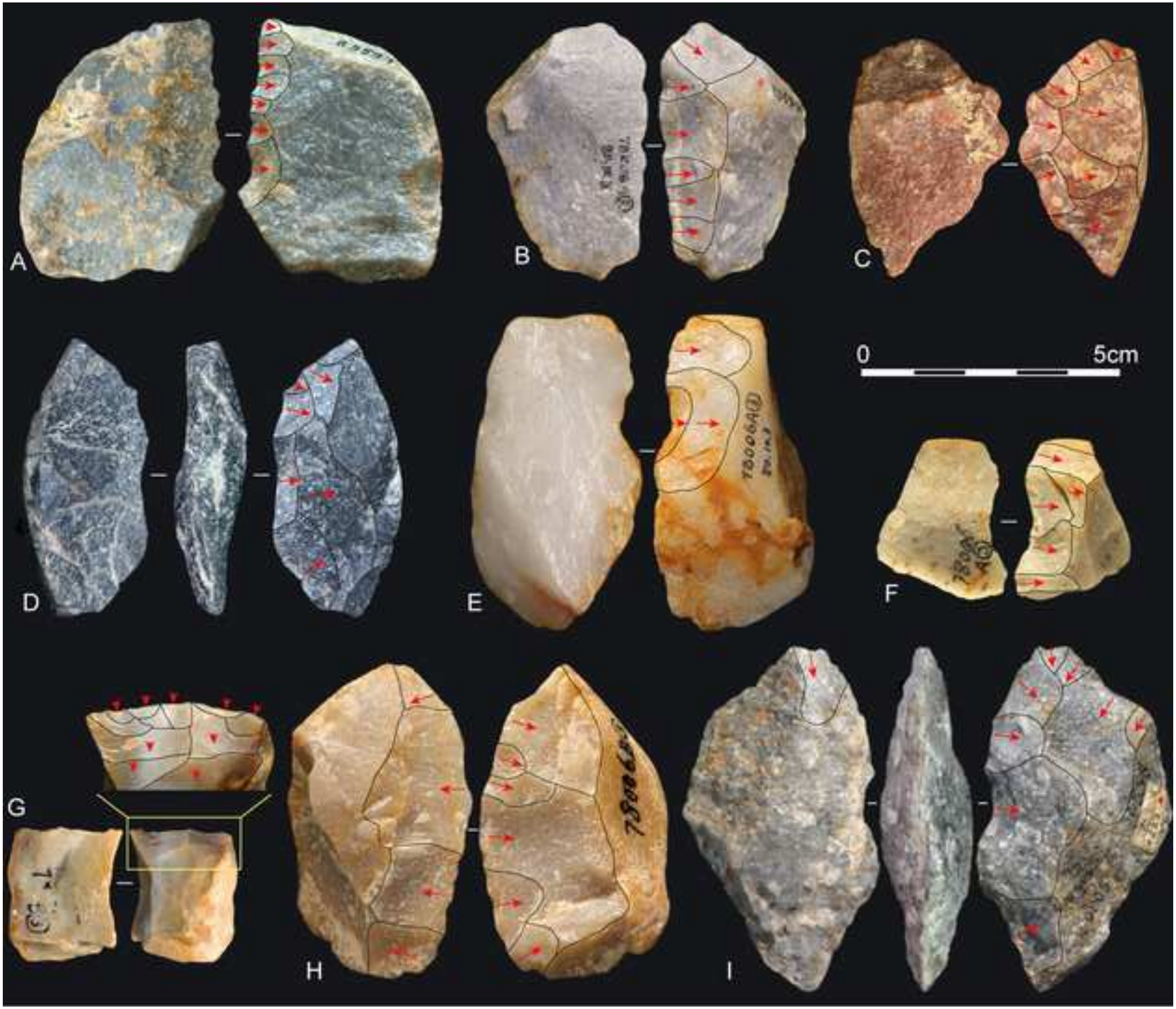


stages of flaking/core reduction. Dorsal scar directions reveal a multitude of flaking patterns, but it is the unidirectional flaking pattern, from the proximal end, that is predominant (54.8%); this is consistent with the unidirectional flaking pattern of the cores (Figure 4B). Other dorsal scar patterns include: flaking from both the proximal end and either one or two sides of a flake (17.8%), flaking from both the proximal and distal ends (8.2%), and flaking from the sides (6.8%). Flake bulbs of percussion show that 28.8% have relatively weak bulbs, whereas 71.2% have clear well-developed bulbs, indicating the extensive use of freehand hard hammer percussion for knapping (Cotterell and Kamminga 1987), which is consistent with the flaking technique used on cores.

Tool typology and production

Twenty-seven tools were identified in the assemblage and a sample of these is illustrated in Figure 5. In particular, there are 14 (51.9%) denticulates, five (18.5%) notches, five (18.5%) scrapers and one point (3.7%). In addition, two (7.4%) casually retouched specimens are grouped into the miscellaneous type. Although the total number of tools is relatively small, tool types at Dali show a varied nature. Denticulates in the assemblage exhibit clear serrated edges formed by a series of continuous notched scars (Figure 5:A-D). The average number of shaping scars for denticulates is 4.4. According to Bordes' typology (Debénath and Dibble 1994), notches at Dali consist mainly of the ordinary or complex type (n= 4), whose hollow edges are formed by a series of small continuous removals (Figure 5:E,F); there is only one notch where the edge is formed by a single blow. Scrapers at Dali generally have smooth edges that are produced by shallow retouch scars (Figure 5:G,H). The average scar number for scrapers is 4.0. The only point identified from the site has two converging retouched edges (Figure 5:I), and it is different from the Levallois points that are made on prepared flake blanks at sites elsewhere (e.g., Qafzeh Cave in the Levant; Hovers 2009). The point at Dali is similar to the Mousterian type of point, for which the distal summit is formed by deliberate retouch and the blank for making points can be any kind of flake (Debénath and Dibble 1994). Regarding the

Fig 5. Denticulates (A-D), notches (E and F), scrapers (G and H) and a point (I) from Dali. Red arrows show retouching removals on tools and the black lines indicate the boundaries of these removals.



functionality of the point, Hughes (1998) and Shea (2006) propose the 'tip cross-sectional area (TCSA) index', which is calculated in mm by multiplying values 0.5 × maximum width × maximum thickness. This provides a quantitative differentiation between projectile points, hand-cast spear points and arrowhead points. The point at Dali has a width of 18.0 mm and a thickness of 36.8 mm, thus providing a TCSA value of 331.2 mm^2, which falls in the upper end of the range (392-50 mm^2, mean= 168 mm^2) for thrusting spear points (Hughes 1998; Shea 2006).

Several tools at Dali are made on flakes (n= 17; 63.0%), seven on chunks, two on pebbles and one is indeterminate. The small pebble tools clearly show the skillful exploitation of small raw material blanks, for retouching. Tool edges are dominated by acute angles (n= 19), whereas abrupt and semi-abrupt angles are equally as common (n= 4). Marginal retouch dominates (n= 19), while the remaining eight tools are relatively invasively retouched. Unifacial retouching is the most favoured (n= 26; 96.3%). With regard to the position of retouch on tools (Inizan et al. 1999), 22 specimens show direct placement, two are inverse, one is alternating, and two are indeterminate.

Discussion and conclusions

Characteristics of the Dali assemblage and its comparison with 'Mode 1'

The lithic assemblage at Dali provides us with significant materials that can be used to discuss the technological behaviour of ancient populations in China ~ 300-247 ka. In summary, the Dali assemblage shows the following key features: first, the size of artefacts is small, with the average length and width smaller than 5 cm; second, core reduction strategies are dominated by simple unifacial unidirectional flaking, but also include a single asymmetrical discoidal core; third, formal tools are relatively prominent (17.9%) and the tool types are varied, including denticulates, scrapers, notches and a point, all produced through intentional, relatively refined and continuous retouch.

Reviewing archaeological evidence from sites in China, between 300-40 ka, Gao (2013) suggests that there are no remarkable technological changes for the Chinese Paleolithic during this period, and that the term 'Mode 1' can still be used to describe assemblages that developed slowly and conservatively. In particular, Gao (1999, 2013) and Gao and Norton (2002) argue for four criteria that demonstrate Chinese Paleolithic Mode 1 technology between 300-40 ka, when compared to those earlier assemblages pre-300 ka. These include: one, the lack of exotic raw materials; two, simple and casual core reduction; three, irregular modification of tools; and four, the lack of clear diversity in tool types. These criteria could also be applied to those Oldowan lithic assemblages from DK, FLK *Zinjanthropus* and FLK North Levels 1-6 from Bed I of Olduvai Gorge. Débitage dominates these assemblages (i.e., broken and complete flakes and angular fragments), and an extremely low percentage of these have irregular retouch that lacks typological diversity (de la Torre and Mora 2005; Barsky 2009). Nevertheless, our analysis here shows that, compared with the standard Mode 1 technology described above, advancements are evident in the Dali tools in both the representation of discrete retouched types and the relatively refined nature of this retouch.

Comparison of Dali with Early and Middle Pleistocene sites in northern and central China

Since Dali occurs at a key period in the late Middle Pleistocene, the lithic assemblage here can undoubtedly contribute to our understanding of the technological changes of Paleolithic materials in China, although the number of artefacts is small. According to current evidence, small-sized tools already appear in sites in northern China during the Early Pleistocene [e.g., sites in the Nihewan Basin, namely Xiaochangliang (~ 1.36 Ma; Figure 6:D), Feiliang (~ 1.2 Ma) and Cenjiawan (~ 1.1 Ma) (Zhu et al. 2001; Deng et al. 2007; Wang et al. 2005, 2006; Yang et al. 2016; Pei et al. 2017)]. However, in contrast to the tools at Dali, these small tools are often simply and casually modified, without clear diversity in types (Shen and Chen 2003; Gao et al. 2005; Shen et al. 2010; Pei et al. 2017). In addition to this, core reduction

Fig 6. Technological evolution of small-sized tools at sites from Early to Middle, and to early Late Pleistocene (bottom to top, respectively). Retouched pieces at Xiaochangliang (D); Denticulates and points (including one with basal retouch) from Zhoukoudian Locality 1 (C); Denticulates (upper row) and two classic discoidal cores (lower row) from Lingjing (B); and denticulates (upper row) and three pyramidal cores (lower row) from Xujiayao-Houjiayao (A).

strategies are primarily simple and casual. One exception in this time period is the site of Donggutuo, which is also located in the Nihewan Basin and has been dated to ~ 1.1 Ma (Wang et al. 2005). A re-examination of the lithic assemblage by Yang et al., (2017) shows that core shapes are pre-determined (this core technology is still highly debated, see Keates 2010 and Wei 2014) and the tools are relatively finely retouched. These innovative technologies exhibited at Donggutuo suggest that technological progress was already occurring, likely on a regional scale, at an earlier time.

In the Middle Pleistocene, the well-documented sequence at Zhoukoudian Locality 1 (~ 700-300 ka) in Beijing (Figure 6:C), along with other contemporary sites, begins to show changes in small tools when compared with the Early Pleistocene sites. The deep cultural deposits at Zhoukoudian Locality 1 serve as a good example to illustrate these changes; three cultural phases, namely an Early Phase (lower levels 8-10), a Middle Phase (middle levels 6-7) and a Late Phase (upper levels 1-5), have been identified at this site, and there are clear observable differences between them, especially between the Late Phase and the earlier two Phases. To be specific, in the Late Phase small flake tools (e.g., scrapers, notches, denticulates and points) are more diverse and have greater standardization in retouch. In addition to this, the use of good quality local raw materials, like chert, becomes more popular (Shen et al. 2016). The age of the Dali lithic assemblage studied here is close to that of the upper levels of Zhoukoudian Locality 1. Importantly, both sites show advancements in the lithic technologies of ancient populations.

An Acheulean techno-complex, characterized by large cutting tools (handaxes, picks and cleavers), has also been identified in the Chinese Middle Pleistocene not far from Dali, at Luonan, Dingcun and the Danjiangkou Reservoir Region (DRR) (Wang 2005; Kuman et al. 2014; Li et al. 2014a,b,c; Yang et al. 2014; Wang and Lu 2017; Li et al. 2018). The latter two have Acheulean sites that are contemporary with Dali (Yang et al. 2014; Li et al. 2014c; Pei et al. 2015), while those at Luonan have been dated to younger than ~ 250 ka (Lu et al. 2011, 2012; Wang and Lu 2017). The co-existence of these two distinct techno-complexes clearly shows the behavioural diversity of hominids during this period. Is this the result of two different populations with divergent traditions or, simply due to raw material adaptations based on their local availability or, other reasons? These are questions that need further investigation.

Significance of Dali for our understanding of the morphological evolution of humans in the late Middle Pleistocene

When viewing contemporary sites in the West, which are often characterized by the advent of sophisticated core reduction (e.g., blade production and the Levallois technique) and a diverse range of tools (Bar-Yosef and Kuhn 1999; McBrearty and Tryon 2006; Kuhn 2013; Adler et al. 2014), we acknowledge that lithic technology at Dali is different, as described above. Therefore, we suggest that the advancement of small tool production in the Chinese Middle Pleistocene likely indicates a regionally continuous development without clear interruption or influence from outside. One merit of Dali is the discovery of a human cranium, which provides us with a rare opportunity to discuss the relationship between technological developments and morphological evolution of late Middle Pleistocene humans.

The emergence of the Middle Stone Age in Africa and the Middle Paleolithic in western Eurasia at around 400-200 ka are often associated with the origins of early modern humans and Neanderthals, respectively (McDougall et al. 2005; Hublin 2009; Adler et al. 2014). Jebel Irhoud in Morocco provides the earliest known association of *H. sapiens* with artefacts from the Middle Stone Age at ~ 350-280 ka (Hublin et al. 2017; Richter et al. 2017; Stringer and Galway-Witham 2017). A recent reassessment of the Dali cranium morphology, through a multivariate approach, shows that the facial skeleton is clearly more derived and it aligns well with Middle Stone Age/ Middle Paleolithic *H. sapiens* from Jebel Irhoud, Skhul and Qafzeh (Athreya and Wu 2017). The neurocranial shape, however, is more archaic and similar to African and eastern Eurasian Middle Pleistocene *Homo* (Athreya and Wu 2017). This combined morphology highlights the uniqueness of the Dali cranium, which makes it distinct from any known Middle Pleistocene specimens and reflects the diverse morphological patterns of hominids in different regions. In this paper we use a general designation of late archaic human for the Dali specimen as it retains archaic traits in the shape of the braincase, e.g., the low neurocranial vault. The two early Late Pleistocene (~ 125-105 ka) human crania excavated at Lingjing, which share these features, have also been classified as late archaic humans (Li et al. 2017). The lack of sophisticated prepared core-flake products in the Dali assemblage exhibits a distinct technological trajectory when compared with those assemblages in the West. A recent study of the early Middle Paleolithic site of Attirampakkam in India (around 385-172 ka) further confirms this distinction, where Levallois flakes and points, produced by a range of strategies, have been found. Both the Dali and Attirampakkam assemblages though have a predominance of various types of small tools (Akhilesh et al. 2018). Therefore, we suggest that variation existed in both the behavioural and anatomical aspects of populations living in China, West Eurasia and Africa during the late Middle Pleistocene.

Comparison of Dali with Late Pleistocene sites in northern China

For the sites younger than Dali (e.g., Zhoukoudian Locality 15, Lingjing, Salawusu, Xujiayao-Houjiayao, Banjiangzi and Xinmiaozhuang, all of which are generally dated to the early Late Pleistocene; Figure 6:A,B), small tools show more diversified types and sophisticated retouch (Jia et al. 1979; Gao 2001; Xie 2006; Li 2007, 2010; Hou et al. 2013; Guo et al. 2016). In addition, standardized discoidal cores begin to occupy a relatively higher percentage of core reduction strategies, when compared with the earlier stages (Chen and Qu 2016). Although Levallois technology is still unusual at these sites, the term ‘Middle Paleolithic’ has been applied to them by some scholars, considering that the small tools are well-made and that ‘classic discoidal cores’ occur (Wang 2005; Qiu 2009; Yee 2012; Bar-Yosef and Wang 2012). We agree with this point of view, and we further suggest that, from the Early Pleistocene to the early Late Pleistocene, there is a gradual technological change exhibited in both the types of small-sized tools and their method of retouch. The continuous appearance of small tools is either related to a long-lasting cultural tradition or, more simply, to small locally available raw materials in these different areas. However, detailed studies of raw material availability and quality have not yet been performed, so the latter needs to become a priority in future studies.

In addition to the Middle Paleolithic assemblages featuring small tool production, it is also noteworthy that several new studies have identified Mousterian lithic assemblages, in Inner Mongolia and Xinjiang in northern China, comprising typical Levallois cores, Levallois points and Quina scrapers. The earliest appearance of these assemblages has been dated to ~ 50-40 ka, the second half of the Late Pleistocene (Yu and He 2017; Shan et al. 2017; Li et al. 2018). At Jinsitai, the Mousterian assemblage appeared there at least 47-42 ka and detailed typological and technological data are provided by Li et al. (2018). These suggest that the occurrence of the assemblage is likely related to either population dispersal or technological diffusion from the Altai Mountains of Siberia, since similar earlier lithic assemblages have been found and dated there (Li et al. 2018). According to this current evidence we propose that there are thus two Middle Paleolithic variants during the Late Pleistocene in China, and it is possible that even more variants will be uncovered when more sites are investigated.

For comparative purposes here we have referred to the better known sites in northern China, but in the future more research will hopefully provide larger assemblages and more robust data from which we can either strengthen or modify these conclusions, and further, refine our understanding of technological strategies and processes during the Early and Middle Paleolithic in China.

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