Miniaturized Late Pleistocene Lithic Technology From Alor Island Articulates with the Records of Flores and Timor Across Southern Wallacea

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ABSTRACT

Stone artifacts from Makpan cave on Alor island date from ~40 ka, filling a gap in the Marine Isotope Stage (MIS) 3-2 record of southern Wallacea between Liang Bua on Flores to the west, and Asitau Kuru on Timor to the east. Since Alor is a largely volcanic island, the Makpan stone artifacts are dominated by igneous materials, distinguishing them from other Late Pleistocene assemblages on neighboring islands. However, the Makpan lithics exhibit the same focus on imported fine-grained materials and the creation of small flakes (linked traits termed miniaturization) that characterize other MIS 3-2 Wallacean assemblages. Despite sometimes using similar reduction techniques, earlier assemblages from the region produced by extinct hominin species are not miniaturized as they do not feature a combined focus on imported fine-grained stone and the creation of small flakes. Unlike the lithics of extinct hominin species, those from Makpan and other MIS 3–2 sites are associated with subsistence on marine invertebrates, fish, and small mammals, as well as the use of red pigment. We suggest that miniaturization was part of an adaptation that facilitated widespread dispersal of *Homo sapiens* through Wallacea. Double patination on the flake scars of five distinctive artifacts suggests the possibility of an earlier industry on Alor, whose products were recycled during the occupation of Makpan.

INTRODUCTION

The Wallacean archipelago between Southeast Asia (Sunda) and Australasia (Sahul) is a major biogeographic boundary for diverse plant and animal taxa, including hominins. Lower Paleolithic hominins colonized its western islands from at least 1 Ma (Brumm et al. 2010a), but not its eastern ones (Louys et al. 2017; Shipton et al. 2021b). It was not until Marine Isotope Stage (MIS) 4, ~65 ka, that this barrier was crossed by hominins, with the earliest stone tools in Australia at the site of Madjedbebe (Clarkson et al. 2017). Understanding the timing and nature of dispersal through this island frontier is thus a key question for hominin biogeography.

At the cave of Liang Bua on Flores island it has been suggested there was continuity in knapping technology across the transition from *Homo floresiensis* to *Homo sapiens* (Moore et al. 2009). Renewed analysis featuring layers from 50–11 ka (Sutikna et al. 2016) that were not included

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in the original study, shows an abrupt transition in material selection from a focus on silicified tuff and andesite by *H. floresiensis*, to a focus on chert by *H. sapiens* at 50 ka (Sutikna et al. 2018). The silicified tuff is described by Moore et al. (2009: 507) as "fine- to medium-grained," while the chert is described as exclusively "fine-grained." Indeed this distinction is visible in Figure 1 in Moore et al. (2009) in which artifacts A, B, and C, associated with *H. sapiens*, are evidently fine-grained chert, while artifacts D, F, and H, associated with *H. floresiensis*, are evidently of the relatively coarser-grained silicified tuff. This transition in materials 50 ka at Liang Bua is penecontemporaneous with the earliest occupation on the south-eastern Wallacean island of Timor, at the sites of Laili, Lene Hara, and Asitau Kuru (Figure 1), which date from ~44 ka and all have chert dominated assemblages (Hawkins et al. 2017; O'Connor et al. 2010; Shipton et al. 2019). The focus on cryptocrystalline chert at Asitau Kuru occurs in conjunction with the small size of the flakes (<20mm), linked traits that have been termed miniaturization (Pargeter 2016). This phenomenon is recognized as being of wider importance in global trends in lithic technology (Pargeter and Shea 2019), including in distinguishing the Later from the Middle Stone Age in east Africa (Shipton et al. 2021a; Shipton et al. 2018).

Between Flores and Timor is the island of Alor where recent fieldwork has revealed the cave site of Makpan with an occupation record dating back to ~40 ka (Kealy et al. 2020). In this paper we examine the Pleistocene lithics from Makpan. This assemblages articulates with the MIS 3-2 lithic assemblages described for Liang Bua on Flores (Sutikna et al. 2018) and the lower levels of Asitau Kuru on Timor (Shipton et al. 2019) (see Figure 1), thereby allowing a fuller understanding of the southern Wallacean record and hominin dispersal in this region.

MAKPAN

Makpan is a large lava tube cave, 8–20m in diameter and ~80m deep, located 386m from the modern shoreline on southwestern Alor (Kealy et al. 2020). Excavation of the cave deposit in 2016 revealed a 3.5m sequence with age estimates spanning from 500 to 40,000 years ago. The Pleistocene layers were excavated in a 1m x 1m deep-sounding, Square B, that comprised the north-eastern quadrant of the upper 2m x 2m excavation. The artifacts described in this paper derive from spits 32–68 of Square B, corresponding to Layers 11–18 of the entire sequence (Figure 2). Bayesian modelling of the 24 radiocarbon dates from this lower part of the sequence indicates that it can be divided into three occupation phases (Kealy et al. 2020): An initial Late Pleistocene sporadic occupation in Layer 18 (spits 59–68), with dates ranging from 40–15 ka; an intensive occupation in the thick Layer 17 (spits 37–58) at the terminal Pleistocene, with dates spanning from 14–12 ka; and a Pleistocene-Holocene transition shell midden in Layers 11–16 (spits 32–36), with dates spanning from 12–11 ka. This Pleistocene-Holocene transition phase then continues up into the main excavation (Spits 1–31).

Tectonic uplift for south-west Alor was calibrated using the archaeologically sterile basal beach deposits in the Makpan Square B excavation (Kealy et al. 2020). Modelling this uplift with sea-level fluctuations suggests that at 40 ka Alor was nearly joined to the neighboring island of Pantar to the west, with the crossing between the two only a few hundred meters (see Figure 1). During the Last Glacial Maximum and terminal Pleistocene, Makpan stood on the eastern side of the entrance to a large bay on the combined island of Alor-Pantar. This island then separated again into Alor and Pantar around 11 ka.

The stable isotope signature on a human tooth sample indicates both marine and terrestrial resources were consumed in the terminal Pleistocene, the latter likely including giant rats (Roberts et al. 2020). However, most of the anthropogenic food remains from Makpan are marine; comprised of mollusc shells, barnacle shells, sea urchin spines and shells, and fish bone (Kealy et al. 2020). Sea urchins and barnacles are particularly prominent in the late and terminal Pleistocene levels, while molluscs are dominant in the Pleistocene-Holocene transition. Shell fishhooks, including roughouts and preforms, were found in the terminal Pleistocene and Pleistocene-Holocene transition phases (Langley et al. forthcoming). Single and double holed *Nautilus* shell beads occur from the Late Pleistocene. Both these types of *Nautilus* bead, as well as fishhook manufacture, are documented in the occupation of Here Sorot Entapa on Kisar island ~250km to the east (O'Connor et al. 2019), indicating long-distance maritime connections in the terminal Pleistocene and early Holocene (see Figure 1).

METHOD

Stone artifacts were first classified and counted by material, with cobble manuports, grindstones, and anvils noted separately. For the second stage of data collection, flaked materials were assigned a technological class—core, flake, broken flake, retouched flake, or flaked piece. Non-burinated retouched flakes, which had multiple retouch scars whose axial length was at least 25% of their maximum dimension, were designated as cores-on-flakes and included with cores. Broken flakes and flaked pieces underwent no further analysis.

For the third stage of data collection, cores, complete flakes, and retouched flakes were assigned a typology, and their axial (box) length and medial width were measured. For flakes, their platform thickness was measured, while for cores and retouched flakes their medial thickness was measured. For flakes and retouched flakes, the number of dorsal scars were counted (not including retouch scars), and for cores, all scars >3mm long were counted. Platforms and dorsal scar patterns on flakes were assigned to a type and the presence of any platform preparation was noted. Two types of platform preparation were distinguished—multiple small *overhang removal* scars struck from the platform on to the dorsal surface, and multiple small *facetting* scars struck from the dorsal surface to strengthen the platform. The Scar Density Index (SDI) of reduction intensity (Clarkson 2013) was calculated on flakes by dividing the number of dorsal scars by flake area, estimated as the prod-

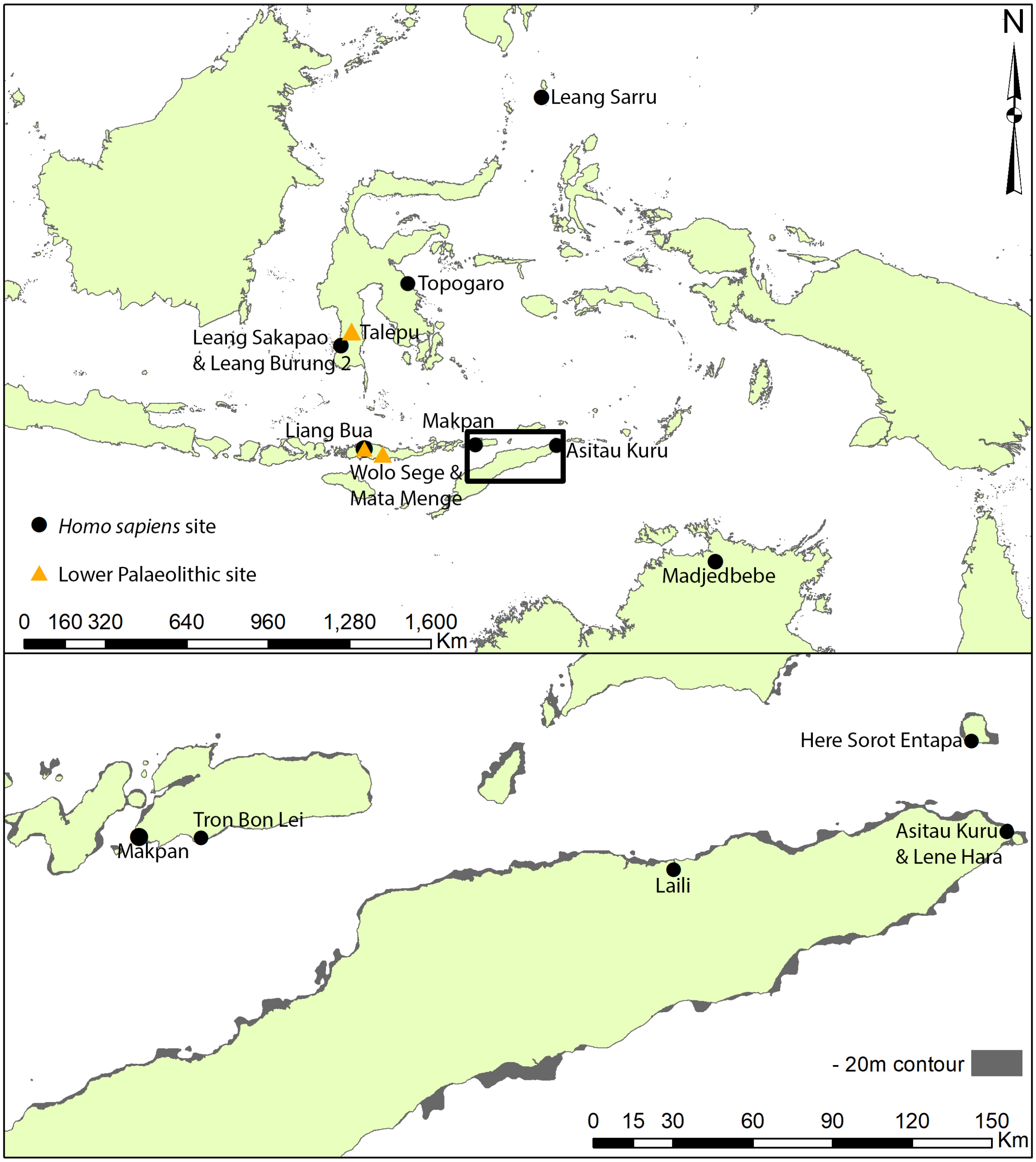

Figure 1. The location of Makpan and other sites mentioned in the text. The -20m contour represents the modelled sea-level at ~40 ka when the Makpan occupation begins.

uct of length and medial width (Dogandžić et al. 2015). SDI on cores was calculated by dividing the number of flake scars by area estimated using the formula for a cuboid. The utility of SDI is that it measures reduction intensity (defined as percent mass lost) independently of the size of the original clast, so that different materials can be directly compared (Clarkson 2013; Shipton and Clarkson 2015). The length of the largest complete scar on cores was measured to determine the point at which cores were discarded. For retouched flakes, the length of the edge that was retouched was measured and this was divided by the flake perimeter length, estimated as twice length plus medial width (Dogandžić et al. 2015), to give a measure of retouch proportion. If present and visible under low magnification, use-wear and residue were noted for all artifacts.

A few basalt flakes with a double patina were noted, so to systematically test this differential patination, color was measured on large basalt flakes using a colorimeter (FRU Precise Color Reader WR-10QC), with a reading taken on both patinas for the double patina artifacts and on cortex

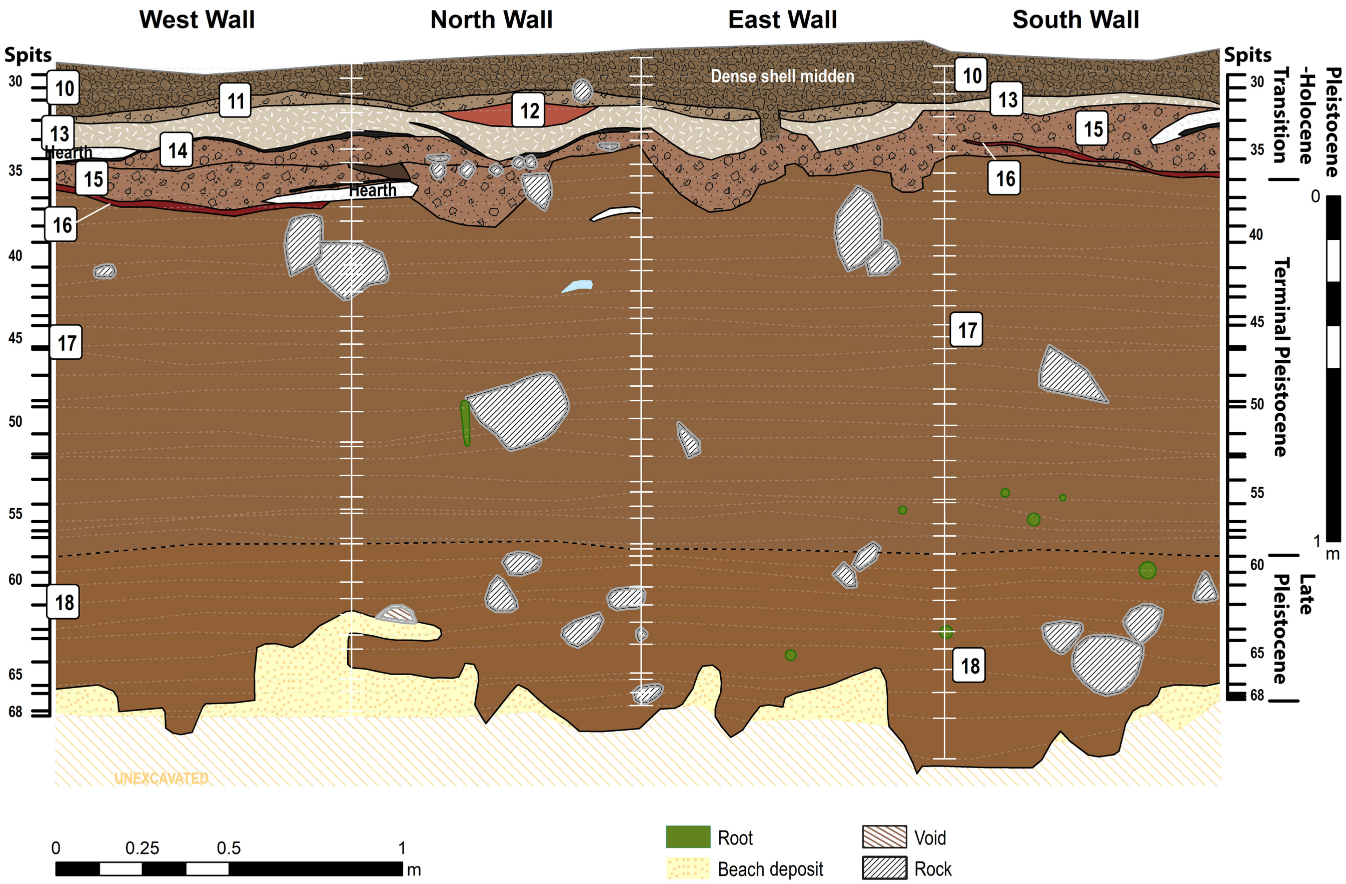

Figure 2. Stratigraphy of the Makpan Square B deep excavation (spits 30–68) showing layer numbers and phases.

and fresh flake scars for other artifacts. Measurements were taken by placing the colorimeter aperture over a low relief area of the artifact that was at least 1.5cm^2 in area (the aperture of the colorimeter is 7.5mm in diameter). Statistical analysis of the colorimeter data and flake metrics was undertaken in SPSS (IBM Corp 2017).

RESULTS

NON-FLAKED ARTIFACTS

Six unmodified cobbles, five grindstones, an anvil, and a hammerstone were recovered from the deep excavation in Square B. All were of local igneous rock—basalt and andesite, except for a small pebble from the Pleistocene-Holocene transition (Spit 35) that is likely limestone. The deepest of these artifacts with clear evidence of use, was a muller from the Late Pleistocene (Spit 64) with a polished lower surface (Figure 3). From the terminal Pleistocene a (lower) grindstone with a red patina was further stained red in places through grinding ochre (Spit 44) (see Figure 3). A polished muller (top stone) with ochre staining and patches of battering was found from the Pleistocene-Holocene transition (Spit 35) (see Figure 3), while a flake from a cobble with ochre staining on its surface was also found in this phase (Spit 36). A hammerstone from the terminal Pleistocene (Spit 42) has battering on its edges as well as in its center (Figure 4). Two small elongate tabular artifacts were recovered from the terminal Pleistocene (Spit 38) and the Pleistocene-Holocene transition (Spit 34). The older of these has battering marks suggesting its use as an anvil, however, it also has a long groove running along it (see Figure 4). The younger piece has several elongate striations on one surface and a deep groove on the other (see Figure 4). We hypothesize that the unusual grooves on these artifacts may have been used to grind the outer edges of the shell fishhooks that were being produced at Makpan.

LITHIC PROVISIONING

Four principal material types were used to create sharp-edged tools at Makpan—chert, relatively coarse blue basalt, fine dark grey basalt, and obsidian (Figure 5). In addition, chalcedony, shell, and a glossy pale brownish green stone of unknown type (possibly chert) were flaked in small quantities (see Figure 5D; Figure 6).

The volcanic activity that formed Alor is thought to date from the Late Miocene to the Pliocene (Honthaas et al. 1998; Koesoemadinata and Noya 1989), with the formation of igneous rocks used for knapping and indeed lava tubes such as Makpan, having long since ceased prior to MIS 3. However, sea-level fall may have exposed fringing coastal rocks of both igneous and sedimentary varieties during MIS 2 that are not currently accessible.

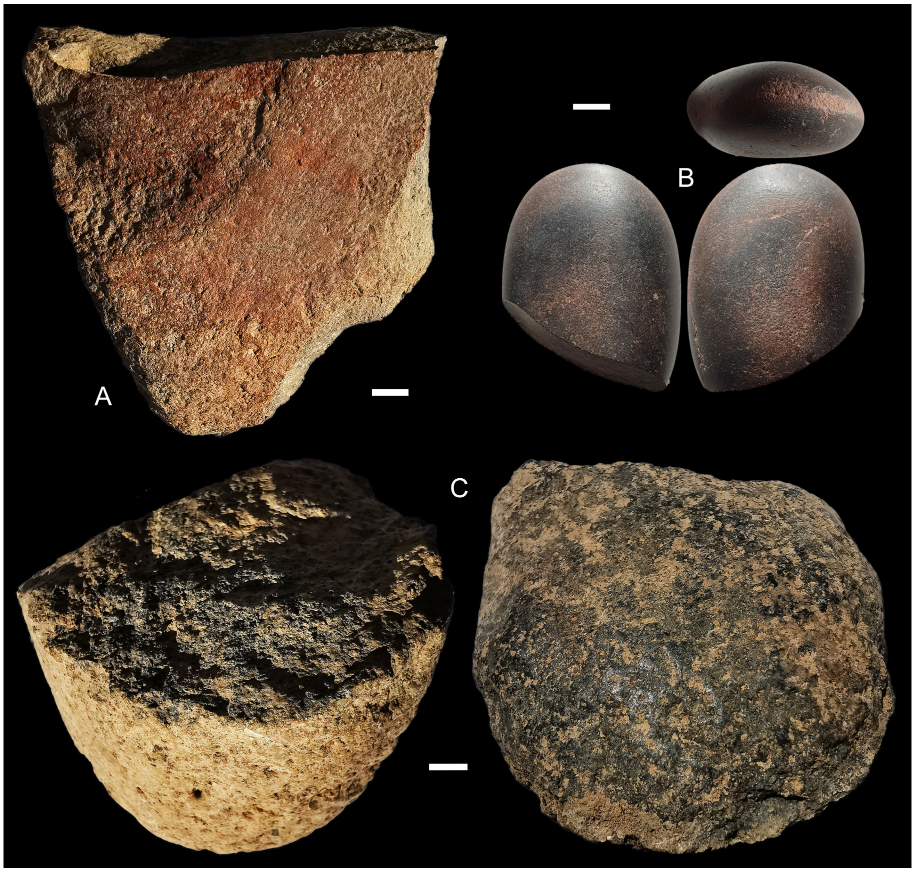

Figure 3. Three grindstones from Makpan. A is a basalt slab bottom stone from Spit 44 (terminal Pleistocene) with probable ochre staining, though the patina is also red with the unworked underside of the piece also this color. Note that it has more recent breaks which do not share this red patina on the right and top edges. B is a fine-grained basalt muller and hammerstone with ochre staining from Spit 35 (Pleistocene-Holocene transition). C is a basalt muller with polish on the lower (right) surface, but no ochre staining from Spit 64 (Late Pleistocene). The rounded cortical surface makes a good grip for the heel of the hand, while the non-cortical surface makes a good grip for the fingers (scale bars are 1cm long).

The fine dark grey basalt includes both a matt black variety and a glossy lighter grey variety (see Figure 5A and C), but as it was sometimes difficult to tell the difference between these two, they have been grouped together as fine basalt. In the Late Pleistocene there were approximately equal proportions of obsidian, fine basalt, coarse basalt, and chert, with occasional chalcedony (Table 1). In the terminal Pleistocene, the proportion of chert increases at the expense of both coarse and fine basalt, while the glossy green stone and flaked shell appear in the sequence (see Table 1). Then, in the Pleistocene-Holocene transition, the proportion of chert and basalt reduces, and there is a focus on obsidian, with a notable increase in chalcedony (see Table 1). Of the thirteen Pleistocene-Holocene transition retouched artifacts, four are chalcedony, indicating the rejuvenation of this exotic material.

The coarse basalt is available on the beach <500m away from Makpan in boulder sized clasts (Figure 7). Systematic survey of the Alor coast identified a probable source for the fine black basalt at a beach called Airpanas ~10km east of Makpan, with the basalt pebbles forming part of the beach between 8°25.39′ 124°31.401′ and 8°25.351′ 124°31.464′ (Figure 8). Black basalt xenoliths occur in the coastal cliff and underlying rock shelf of the beach, from where they are eroded out of their ultramafic matrix and rounded through wave action (see Figure 7). Available clasts of this basalt are typically ~10cm in maximum dimension or smaller. Because this rock is exposed here today and occurs throughout the Makpan sequence it is presumed this source was available throughout the Late Pleistocene. It is uncertain if Airpanas was also the source of the very fine dark grey igneous rock. As the region is volcanic, chert is presumed to be non-local, with this material rare (3.1% of Square B assemblage) at the site of Tron Bon Lei ~20km east (see Figure 1) where basalt and obsidian dominate (Maloney et al. 2018). The chert was mostly red in color, as at Asitau Kuru, but there are likely sources of chert in the limestone areas on the fringes of northern and eastern Alor (see Figure 8). It is also possible that now submerged chert sources were exposed in the channel between Alor and Pantar during the terminal Pleistocene sea-level low-stand when there is a peak in chert proportions.

The obsidian source of Kulunan is located on an extinct volcano in south-central Alor, ~35km east of Makpan

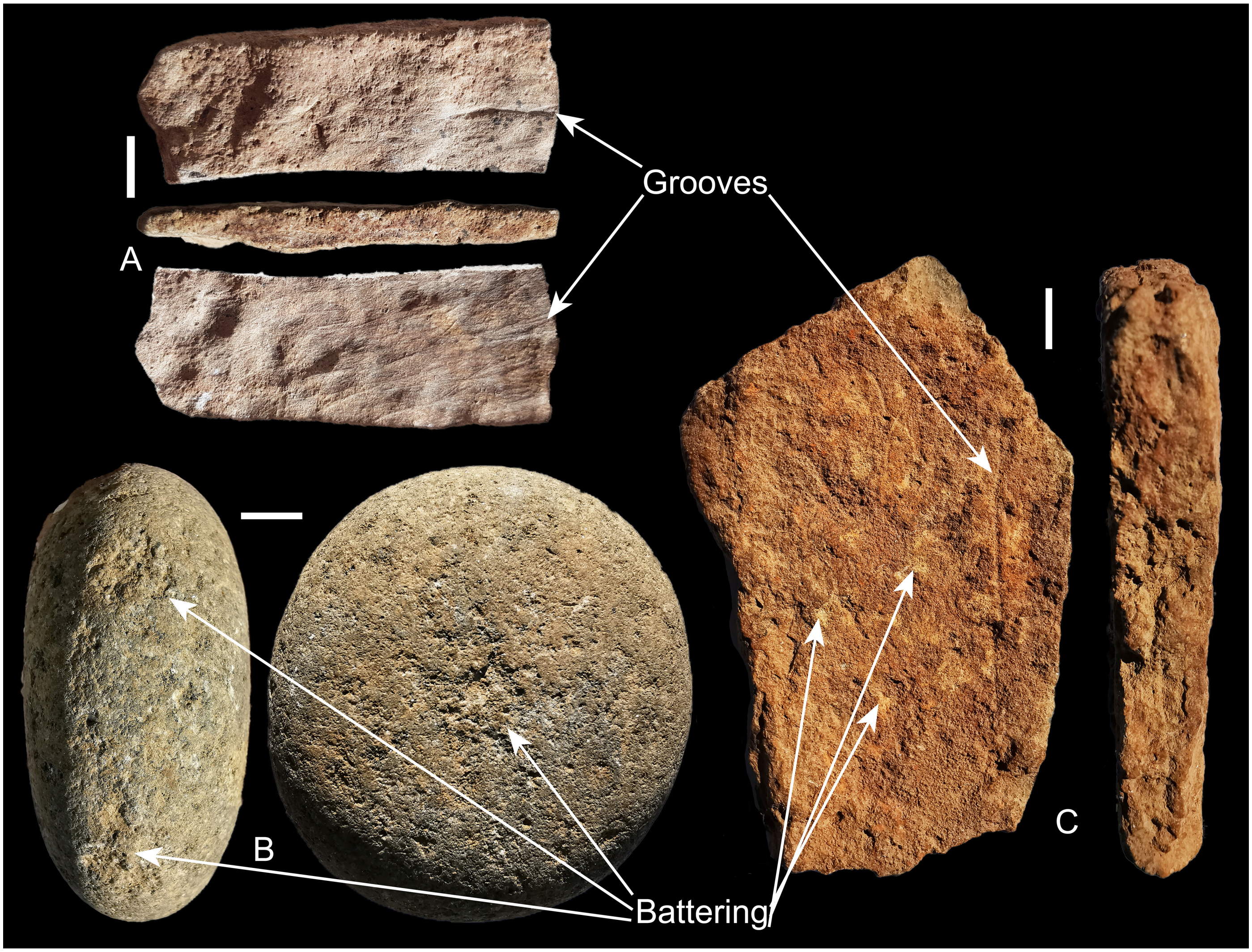

Figure 4. Anvils and grooved stones from Makpan. A is a tabular stone with a series of elongate striations on one surface and a deep groove on the other from Spit 34 (Pleistocene-Holocene transition). B is a hammerstone with two patches of battering on the edge and one in the center from Spit 42 (terminal Pleistocene). C is a tabular piece of basalt with several small battering marks and a long groove from Spit 38 (terminal Pleistocene). Note that not all battering marks are indicated by the arrows on this piece (scale bars are 1cm long).

(Reepmeyer et al. 2019) (see Figure 8). A second as yet unidentified source, known as Group 2, is also thought to occur in the same tuff-glass-andesite deposit as Kulunan (see Figure 8), given their chemical similarity and that they were both exploited extensively and in approximately equal proportions at nearby Tron Bon Lei (Reepmeyer et al. 2016). The changing pattern of materials through the sequence suggests greater use of northern Alor in the terminal Pleistocene, and greater use of south-central Alor in the Pleistocene-Holocene transition.

Similar proportions of cores occur in all three phases, but there are no retouched pieces in the Late Pleistocene (see Table 1). The difference in class proportions between the terminal Pleistocene and Pleistocene-Holocene transition artifacts is not significant (χ^2=2.862, N=1366, p=0.239), nor is the proportion of the perimeter with retouching (Mann-Whitney U=49, N=24, p=0.29) on retouched flakes. Neither the proportion of cortical flakes (χ^2=2.91, N=698, p=0.233), nor the SDI on flakes (ANOVA F=1.549, df=672, p=0.213) showed significant differences between phases. The consistency in class proportions and reduction indices suggests the differences in materials between phases are more to do with different ranging directions rather than overall mobility.

REDUCTION TECHNOLOGY

Five reduction techniques were employed at Makpan, represented by multiple cores of each type—unifacial, multifacial, discoidal (see Figure 6C), and bipolar. Core-on-flake reduction was common with three single-platform, three discoidal, and eight bipolar cores using flakes (see Figure 5B), a total of 34% of the core sample. All four techniques were used in the reduction of chert, but there were no multifacial or bipolar basalt cores, and, conversely, no unifacial

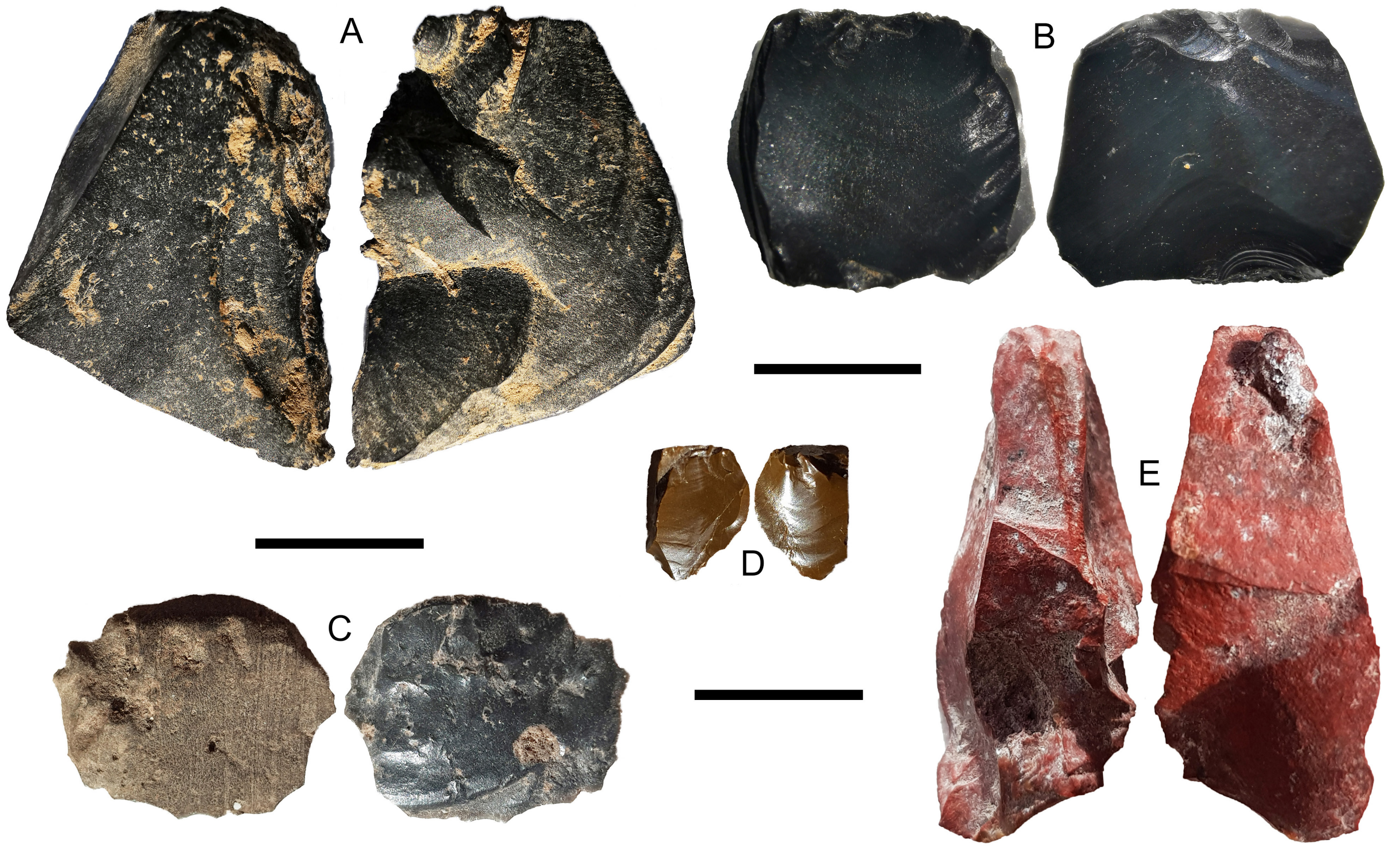

Figure 5. A selection of fine-grained lithics from Makpan Square B (dorsal surfaces on left, ventral on right). A is a fine basalt flake from Spit 48 (terminal Pleistocene); B is an obsidian bipolar core-on-flake from Spit 36 (Pleistocene-Holocene transition); C is a fine basalt flake from Spit 32 (Pleistocene-Holocene transition); D is a glossy brown stone flake from Spit 32 (Pleistocene-Holocene transition; and E is a bipolar chert flake from Spit 34 (Pleistocene-Holocene transition) (scale bars are 1cm long).

or discoidal obsidian cores. The dominant core type was bipolar, representing 26 (63%) of the 41 cores, and reflected in the high proportion of flakes with crushed platforms (Table 2). The battering marks in center of the hammerstone and on the tabular piece of basalt in Figure 4 may have resulted from them being used as hammer and anvil, respectively, in bipolar flaking. The ranges of non-cortical platform types (see Table 2, χ^2=8.125, N=656, p=0.087) and dorsal scar patterns (Table 3, χ^2=10.667, N=643, p=0.099) on flakes do not vary significantly across the sequence, indicating broad continuity in knapping techniques. Overhang removal (N=39), and more rarely facetting (N=5), were used to prepare platforms on 6% of the complete flake assemblage (N=709). Platforms tend to be small (mean thickness 2.52mm), with a high ratio of flake length to platform thickness (mean 9.18).

Redirecting flakes (those preserving old platforms on their dorsal surface) indicating a new phase of core reduction, constitute 3% of the Makpan complete flake assemblage. In some cases, these appear to occur relatively early in a sequence, with the old platform being cortical and the platform for the flake itself being single—examples occur in obsidian in Spit 59 (Late Pleistocene), in chert in Spit 58 (terminal Pleistocene), and in fine basalt in Spit 32 (Pleistocene-Holocene transition). In other cases, these appear to reflect a change in knapping technique at a late stage of reduction—examples include a bifacial old platform on a tertiary fine basalt flake struck from a single platform in Spit 44 (terminal Pleistocene), a hierarchical bifacial old platform on a tertiary obsidian flake struck from a focalized platform in Spit 36 (Pleistocene-Holocene transition), and a single scar old platform on a tertiary chert flake struck from a crushed platform in Spit 33 (Pleistocene-Holocene transition). There were no instances of coarse basalt redirecting flakes indicating there was not a need to extend the uselives of cores in this material.

KNAPPED PRODUCTS

The handful of retouched lithic pieces from the lower levels of Makpan consist mostly of scrapers (steep retouch leaving a straight or convex edge in plan) (N=7), notches (steep retouch leaving a concave edge in plan) (N=6), ventrally retouched pieces (N=4), and denticulates (regular continuous retouch leaving a wavy/serrated edge) (N=2). Several of the notched artifacts have multiple notches with a mean overall notch width of 7.11mm (N=12). Retouched flakes (N=19, median length 18.47mm) are significantly larger than the general flake population (median length 9.59mm) (Mann Whitney U=3884.5, N=737, p<0.001), as well as the small sample of flakes with visible use-wear (median length

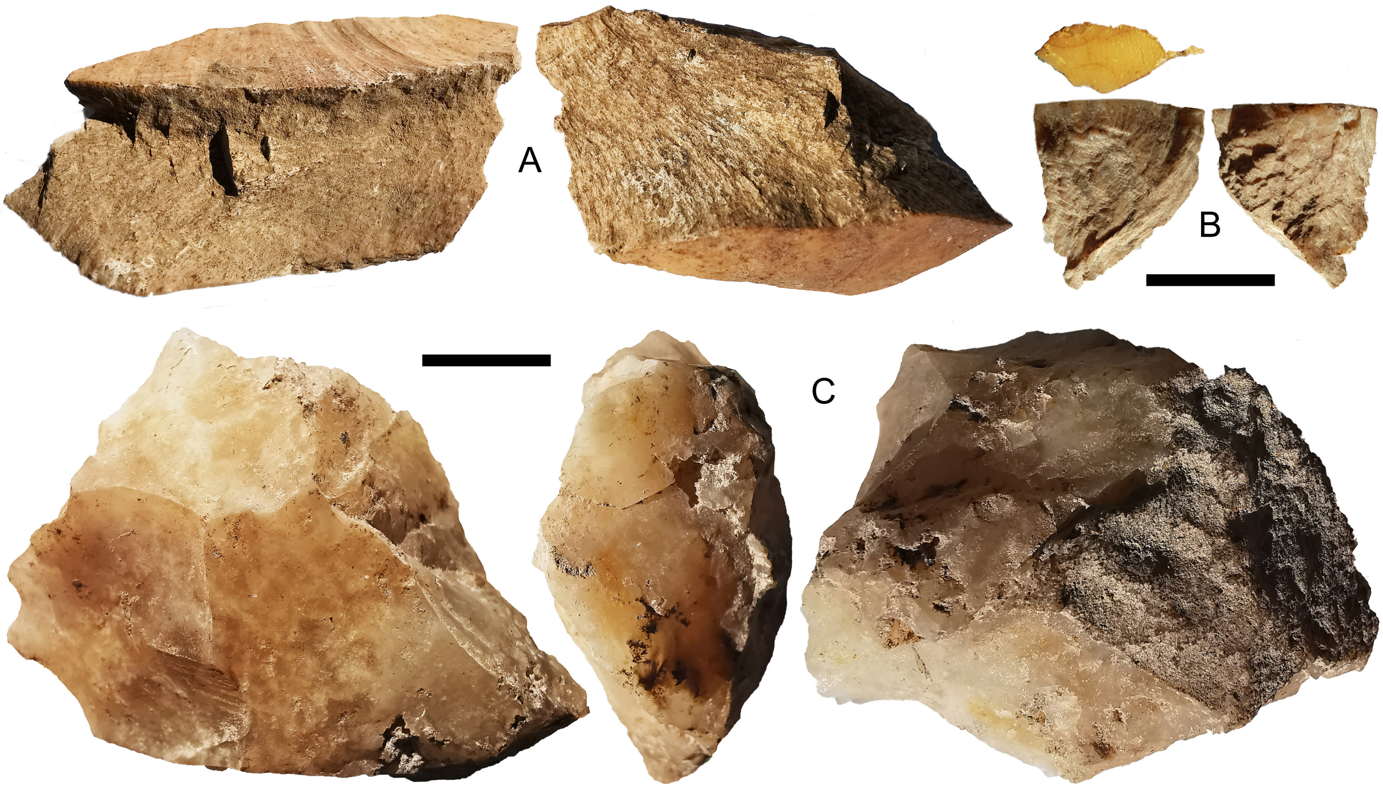

Figure 6. A selection of shell and chalcedony artifacts from Makpan Square B. A is a shell flake, probably struck from an operculum (note the flat platform surface with curved lines and domed distal end), from Spit 39 (terminal Pleistocene). B is a shell flake from Spit 34 (Pleistocene-Holocene transition). C is a chalcedony discoidal core from Spit 33 (Pleistocene-Holocene transition) (scale bars are 1cm long).

TABLE 1. THE BREAKDOWN OF LITHICS BY MATERIAL AND TECHNOLOGICAL CLASS FOR MAKPAN SQUARE B SPITS 32–68.*

	Late Pleistocene	Terminal Pleistocene	Pleistocene-Holocene Transition
Cores	2 (3%)	11 (3%)	29 (3%)
Flakes	74 (97%)	329 (94%)	972 (96%)
Retouched	0	10 (3%)	15 (1%)
Total	**76**	**350**	**1016**
Coarse basalt	19 (25%)	64 (18%)	50 (5%)
Fine basalt	22 (29%)	53 (15%)	172 (17%)
Obsidian	16 (21%)	64 (18%)	429 (42%)
Chert	18 (24%)	159 (46%)	282 (28%)
Glossy brown stone	-	2 (<1%)	12 (1%)
Chalcedony	1 (1%)	6 (2%)	63 (6%)
Shell	-	2 (<1%)	8 (1%)
Cortical flakes	8 (19%)	45 (25%)	143 (30%)
Mean flake SDI	40.83	31.23	37.16
Median perimeter retouch proportion	N/A	0.25	0.35

*Showing also the proportion of cortical flakes and central tendencies of SDI, GIUR, and perimeter retouch proportion. Note that the category "flakes" includes broken flakes, flaked pieces, and pot lids.

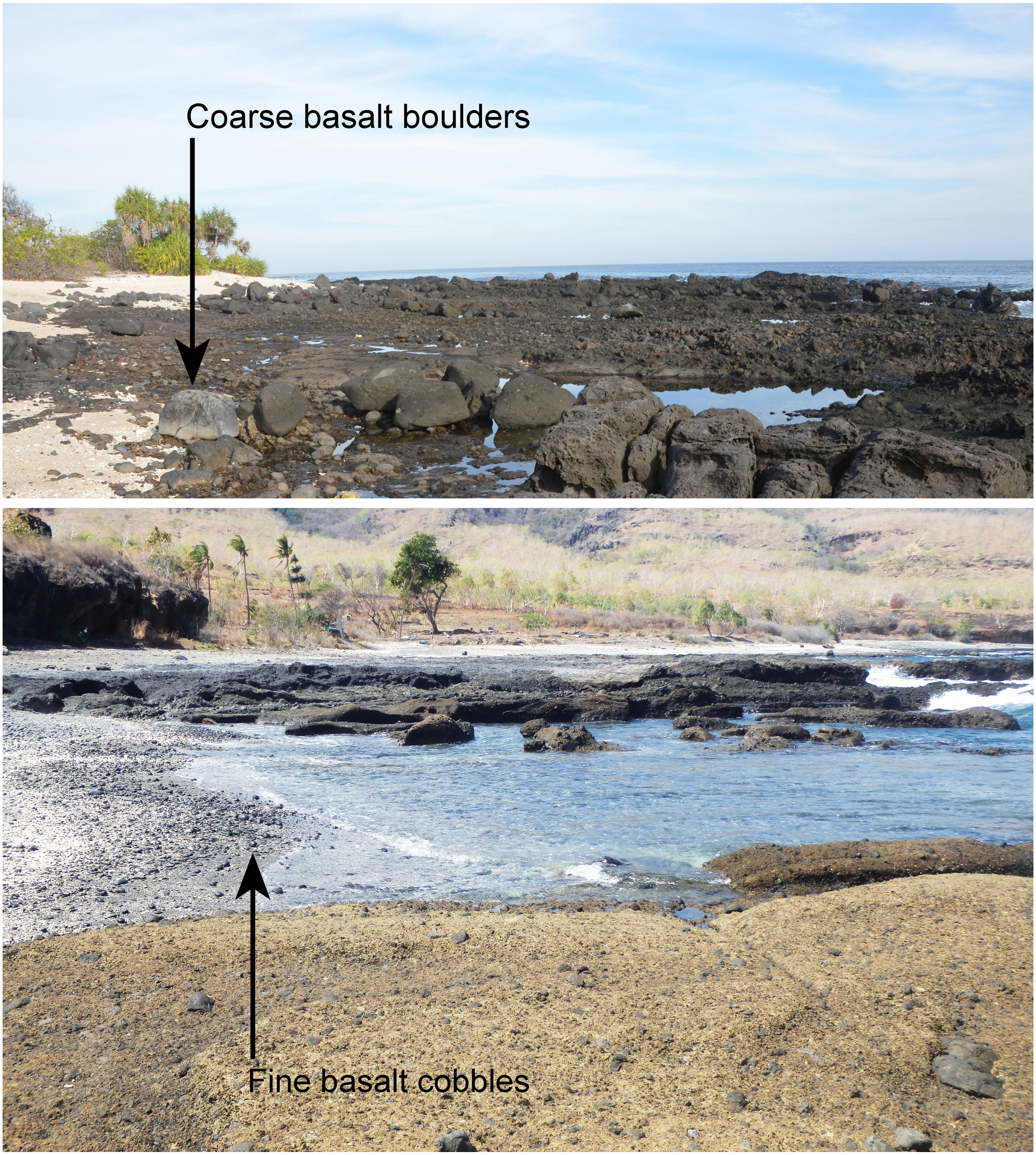

Figure 7. Sources and clast sizes of the coarse and fine basalts. Above) coarse basalt boulders at the beach <0.5km from Makpan; Below) fine basalt cobbles at Airpanas beach 10km east of Makpan. At Airpanas note the dark basalt clasts occurring within their ultra-mafic matrix in the foreground and the eroded and rounded black beach cobbles in the middle distance.

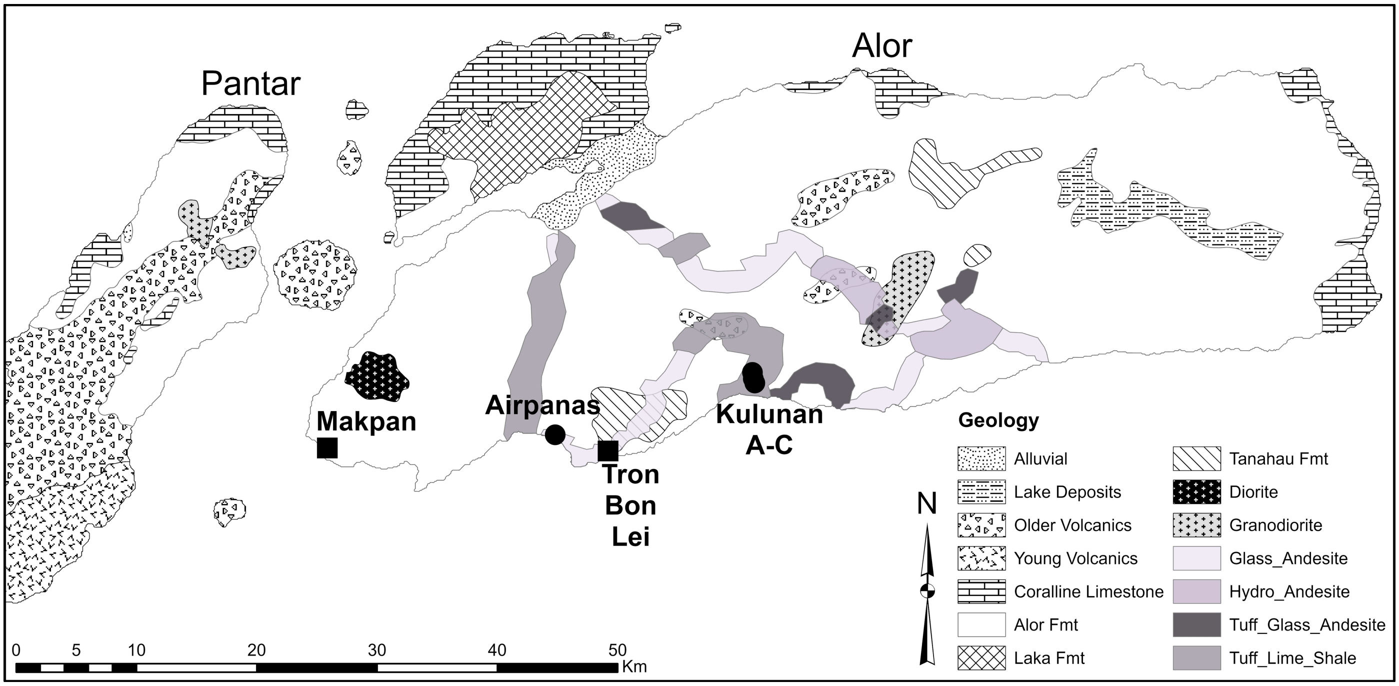

Figure 8. Surface geology map of Alor showing location of archaeological sites (black squares) and lithic source localities (black circles) (geological data compiled from Heering [1941], Koesoemadinata and Noya [1989], and Noya et al. [1997]).

TABLE 2. COMPLETE FLAKE PLATFORM TYPES FROM MAKPAN SQUARE B SPITS 32–68.*

	Late Pleistocene	Terminal Pleistocene	Pleistocene-Holocene Transition	Total
Cortical	3 (7%)	14 (8%)	34 (7%)	51 (7%)
Single	24 (54%)	90 (52%)	244 (50%)	358 (51%)
Dihedral	4 (9%)	12 (7%)	27 (5%)	43 (6%)
Multiple	3 (7%)	13 (7%)	18 (4%)	34 (5%)
Crushed	7 (16%)	28 (16%)	94 (19%)	129 (18%)
Focalized	3 (7%)	17 (10%)	71 (15%)	91 (13%)
Total	**44**	**174**	**488**	**706**

*For the χ^2 test, dihedral and multiple were combined, as were crushed and focalized platforms.

TABLE 3. COMPLETE FLAKE DORSAL SCAR PATTERNS FROM MAKPAN SQUARE B SPITS 32–68.*

	Late Pleistocene	Terminal Pleistocene	Pleistocene-Holocene Transition	Total
Cortical	1 (3%)	-	7 (2%)	8 (1%)
Proximal	15 (38%)	74 (45%)	258 (55%)	347 (52%)
Bidirectional	7 (18%)	30 (18%)	65 (14%)	102 (15%)
Orthogonal	10 (25%)	42 (26%)	99 (21%)	151 (23%)
Radial	5 (13%)	12 (7%)	25 (5%)	42 (6%)
Redirecting	1 (3%)	6 (4%)	14 (3%)	21 (3%)
Total	**39**	**164**	**468**	**671**

*Note that the category bidirectional includes distal and the category orthogonal includes left and right scar directions. The χ^2 test did not include cortical and redirecting flakes.

TABLE 4. THE BREAKDOWN BY ROCK TYPE OF PERCENTAGE CORES AND RETOUCHED PIECES, COMPLETE FLAKE MEAN LENGTH, NUMBER OF COMPLETE FLAKES (N), SDI, AND PERCENTAGE CORTICAL FLAKES FOR MAKPAN SQUARE B SPITS 32–68.

	% Cores	% Retouched	Mean Flake Length (SD)	N	SDI	% Cortical
Coarse basalt	3.9	4.5	26.72 (19.81) mm	65	8.82	37
Fine basalt	0.8	2.4	10.96 (7.02) mm	121	32.58	25
Obsidian	5.1	0.2	8.99 (4.74) mm	239	51.69	24
Chert	1.7	1.7	11.49 (8.11) mm	229	32.41	27
Glossy brown stone	-	-	5.81 (1.56) mm	9	53.7	13
Chalcedony	1.4	5.7	15.29 (9.58) mm	43	17.25	40
Shell	-	-	9.56 (6.15) mm	8	27.7	100

12.01) (Mann-Whitney U=94, N=38, p=0.035). This indicates that retouched flakes were not merely rejuvenated forms of the generally used flake population but were initially selected for heavy duty work for which typical smaller flakes were less suited. Although sample size is small, chalcedony flakes do not follow this trend, with retouched pieces (N=4) shorter than other flakes (N=43) (mean length 13.13mm vs. 15.29mm), perhaps reflecting resharpening of an exotic material. The general selection of retouched artifacts for heavy duty work is also reflected in the greater proportion of retouched artifacts among coarse basalt than any of the finer-grained materials except chalcedony (Table 4).

Shell flakes appear in the Makpan sequence in the terminal Pleistocene alongside fishhooks, suggesting wider engagement with this material. One of the shell flakes from Makpan appears to have been struck from the base of a large operculum (see Figure 6A) and may have been from the manufacture of operculum scrapers, a technology documented in the Pleistocene occupation at Golo Cave in north-eastern Wallacea (Szabó et al. 2007).

Flake elongation is consistent across the three phases (ANOVA F=0.734, df=691, p=0.481), with a total mean value of 1.3. However, there is a reduction in median flake length across the three phases from 11.6mm in the Late Pleistocene to 8.92mm in the Pleistocene-Holocene transition (Kruskall-Wallis H=1.522, N=712, p=0.001). This reflects the increasing use of obsidian, which has the smallest mean flake size of the main materials (see Table 4).

An asymptotic relationship exists between core SDI and the length of the largest complete scar (Figure 9), such that, for a wide range of higher values of SDI, cores were discarded when the final flake removed was in the range of 3mm–11mm long. Even adjusting for the logarithmic relationship between SDI and mass lost to the core in long reduction sequences (Clarkson 2013) and the higher SDI of flake blanks (Shipton and Clarkson 2015), this asymptotic relationship still exists; with final flake scar length remaining constant in the 3mm–11mm range for very high values of SDI on fine-grained materials (see Figure 9). Coarse basalt cores were consistently abandoned in the early stages of reduction when the maximum flake size produced exceeded 20mm. This pattern corresponds to the mean flake size of less than 20mm for all five classes of finer-grained material, but not the coarser-grained basalt (see Table 4).

Differences in initial clast size may drive the differences in flake size between the (large package) coarse basalt (see Figure 7) and the finer grained materials (see Table 4), with the latter occurring in smaller packages than boulders—certainly in the case of fine basalt (see Figure 7), and presumably in the case of the others. Due to surface area increasing more slowly than volume as package size increases, we would expect to see higher proportions of cortex on flakes from small package materials for a given level of re-

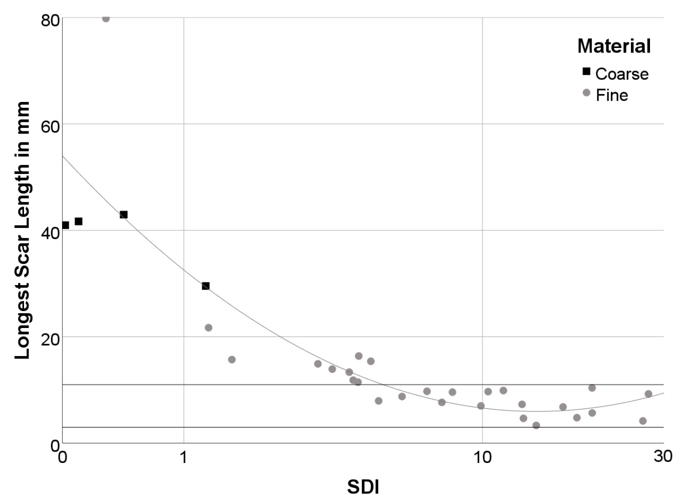

Figure 9. The relationship between SDI and the length of the largest complete scar on cores from Makpan Square B Spits 32–68. The reference lines are at 11mm and 3mm and the quadratic regression line has an r^2 value of 0.78. Note that coarse basalt cores were abandoned at low levels of reduction intensity when resultant flakes were still large, whereas cores of fine materials continued to be worked into very high SDI values for the production of flakes between 3mm and 11mm. Even when the three coarse basalt cores and the fine-grained piece at the top of the distribution are excluded there is still a quadratic relationship with an r^2 value of 0.743. Likewise, when the higher SDI of flake blanks (Shipton and Clarkson 2015) is corrected for by subtracting 1 from the SDI of core-on-flakes, there is still a quadratic relationship with an r^2 value of 0.712.

duction intensity. In fact, the opposite is true; other than chalcedony, all finer grained materials have lower levels of cortex than the boulder package coarse basalt (see Table 4, χ^2=4.357, N=707, p=0.037). It appears that rather than differences in clast size *per se* driving differences in flake size, higher reduction intensity of the smaller clast results in smaller flakes.

High levels of reduction intensity may be a result of long-distance transport of some materials, with much of the flaking sequence taking place elsewhere. To examine this issue, we looked at the proportion of cores by material in the assemblage (see Table 4). Obsidian has the highest proportion of cores suggesting that a significant proportion of the knapping of this material (which probably came from ~35km away) took place off site, with cores (including core-on-flakes) preferentially transported to Makpan for the final stages of reduction. On the other hand, both obsidian and local basalt have higher proportions of cores than either chert or fine basalt (see Table 4), suggesting much reduction of the chert and fine basalt took place on-site, depositing many flakes for each core. Indeed, imported fine-grained flakes in general outnumber those of local basalt by approximately 10:1 in the Pleistocene levels of Makpan, confirming that much of the reduction of fine-grained materials took place at the site. Makpan knappers therefore generally had a strong preference for very small flakes of fine-grained materials over larger flakes of coarser local basalt.

The flake data confirms that finer grained materials underwent greater reduction intensity at Makpan, with higher values of SDI than coarse basalt (see Table 4). This may in part be because the finer materials were curated from further afield than coarse basalt, but it mostly results from the on-site reduction of these materials and indicates the continued utility of the resultant small-sized flakes. The total mean length of fine-grained flakes is 10.63mm (SD=7.08), similar to both the upper limit of the largest flake size on cores in the asymptotic part of Figure 9 and the median length of flakes with macroscopic use-wear. We suggest that this approximates the optimal size of unretouched fine-grained flakes that the Pleistocene knappers at Makpan were aiming to produce, with flakes only losing their utilitarian value below ~3mm.

DISCARD AND RECYCLING

Lithic density is low in the Late Pleistocene, increases in the terminal Pleistocene, and is much higher in the Pleistocene-Holocene transition, in line with other evidence for human occupation intensity (Kealy et al. 2020). Hearths were a common feature of the Makpan stratigraphy from the Pleistocene-Holocene transition upwards, but were not preserved as distinctive features below this (see Figure 2) (Kealy et al. 2020). The igneous lithics which constitute the bulk of the assemblage are not prone to heat damage as the stones are formed at high temperature. However, six of the chert artifacts did display pot lidding or were pot lids themselves, four of which were in the terminal Pleistocene (2.5% of chert artifacts), attesting to their deposition in hearths in this phase.

An interesting feature of the Makpan assemblage is the presence of five basalt artifacts with a double patina—two levels of patination on knapped surfaces indicating recycling of old artifacts (see Figures 3A and 9). Using a colorimeter, basalt patination colors on large artifacts were measured and contrasted (Figures 10 and 11). Mann-Whitney U tests showed significant differences in general between the fresh blueish scars versus reddish patinated cortex and older flake scars (a, U=6, N=43, p<0.001; b, U=16, N=43, p<0.001). Wilcoxon Signed Ranks tests indicated significant differences between paired readings for artifacts with both cortex and flake scars (a, Z=-3.408, N=15, p=0.001; b. Z=-3.408, N=15, p=0.001). On the double patina artifacts, the reddish scar patina is significantly different from the blueish truncating scars on these artifacts (Wilcoxon Singed Ranks: a, Z=-2.023, N=5, p=0.043; b, Z=-2.023, N=5, p=0.043), while not significantly different from the cortex on other artifacts (Mann-Whitney U: a, U=29, N=17, p=0.959; b, U=19, N=17, p=0.279).

The five artifacts with reddish patina scars occurred in all three phases—one in the Pleistocene-Holocene transition, two in the terminal Pleistocene, and two in the Late Pleistocene. This suggests that they are not merely a reworking of one of the sporadic early Late Pleistocene occupations of the cave, but instead were introduced from an older open-air locality where the patina developed to the color level of the cortex before they were recycled during the accumulation of the Makpan Square B sequence. Despite there being only five of these pieces, they are technologically noteworthy. In addition to the large elongate flake shown in Figure 9D, there is also a large flake that meets the criteria for Levallois—being elongate (longer than it is wide), decorticated, flat, with a facetted platform, and apparent preparation of distal and lateral convexities (Figure 12).

REGIONAL COMPARISON

The Makpan lithics are distinctive from most other MIS 3-2 Wallacean assemblages in the dominance of igneous stone over chert and other sedimentary rocks. Despite this material difference, there are some shared similarities among these assemblages. The dominance of finer-grained stone when other knapping materials were more immediately available is a notable feature. At Liang Bua this has been highlighted as a key distinguishing feature of the post ~50 ka assemblages associated with *H. sapiens* from the earlier *H. floresiensis* associated assemblages.

On Timor, the dominance of introduced chert over local limestone is a consistent feature of the Asitau Kuru lithics throughout the occupation of the site over the last 44 ka (Shipton et al. 2019). Chert is also the dominant material at the nearby site of Lena Hara, which has an occupation sequence of similar antiquity (O'Connor et al. 2010; O'Connor et al. 2002). The caves of Leang Sakapao and Leang Burung on Sulawesi, as well as Leang Sarru in the Talauds were all occupied from ~35 ka, with chert the dominant material used for flaking in each (Brumm et al. 2018; Bulbeck et al.

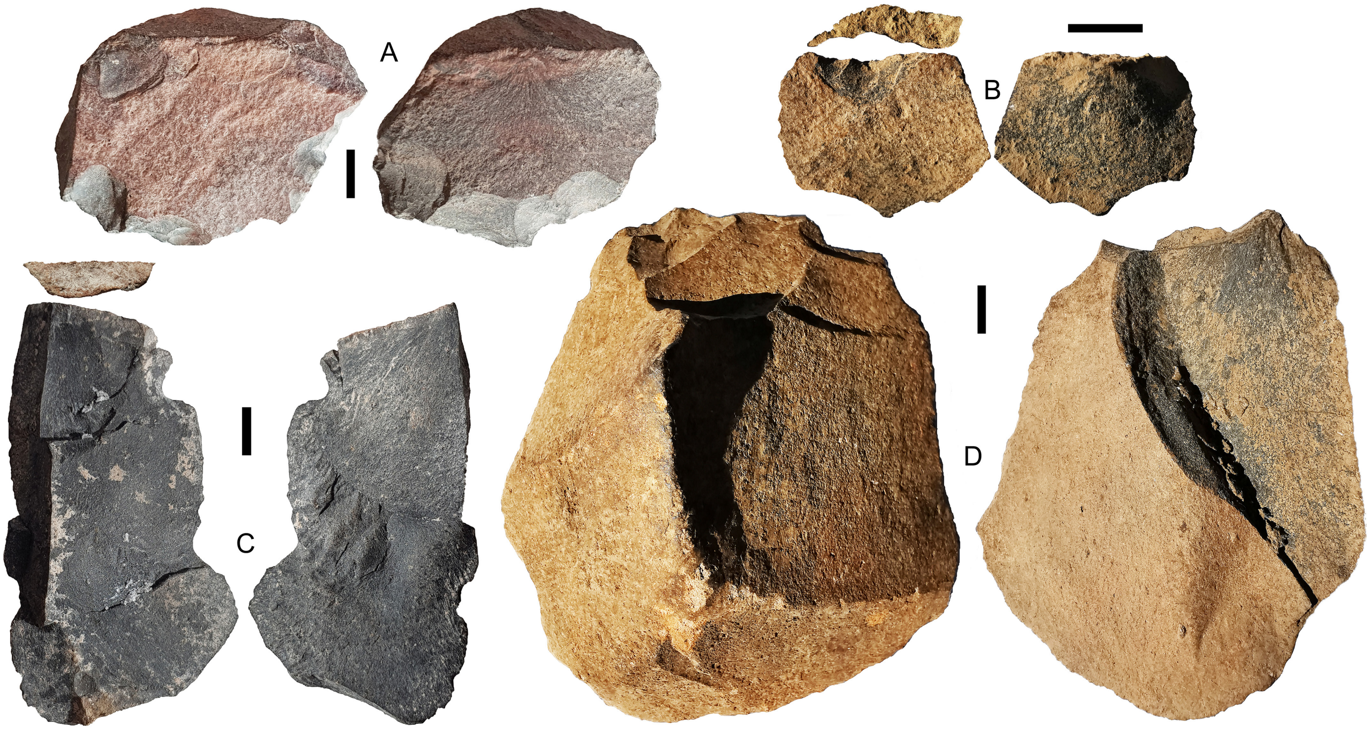

Figure 10. Basalt flakes from Makpan Square B. A is from spit 34 (Pleistocene-Holocene transition) with bifacial retouch on its distal end, with the retouch a distinctly blueish color, while the ventral surface and largely cortical dorsal and platform have a reddish patina. B is from Spit 64 (Late Pleistocene) and struck from a previously knapped surface, with the ventral surface and the overhang removal a blueish color, while the distal flake scar covering the remainder of the dorsal and the cortical platform both have a reddish patina. Note that this relatively small flake is shown at a different scale to the other artifacts. C is a siret break from Spit 32 (Pleistocene-Holocene transition), with the freshly flaked dorsal and ventral surfaces a blueish color while the cortical platform is reddish. D is a large elongate flake from Spit 56 (terminal Pleistocene), which has a reddish patina except for a more recent blueish scar on the ventral that has removed the original platform.

2004; Tanudirjo 2001). This preference for cryptocrystalline chert and obsidian in MIS 3-2 may be contrasted with the Lower Paleolithic Wallacean sites. At Wolo Sege on Flores "local volcanic/metavolcanic cobbles of varying quality comprise the dominant materials (95.8%) of flaked material although high-quality chert (2.1%) and chalcedony (2.1%) are also present" (Brumm et al. 2010a: 750). At Mata Menge on Flores, "coarse-grained stones of poor quality amount to 64.7% of volcanic/metavolcanic artefacts …while higher quality medium- to fine-grain materials comprise 35.2% … [in addition to] small amounts of chert, chalcedony and other fine-grained siliceous stones" (Brumm et al. 2010b: 460). At Talepu on Sulawesi "the main source of raw material is coarse- to medium-grained silicified limestone cobbles" (Van den Bergh et al. 2016: 208). Notably, at Leang Burung 2 on Sulawesi an industry of large limestone artifacts dated to ~80 ka, underlies a "markedly different" industry of "high-quality chert" artifacts dated to <35 ka (Brumm et al. 2018: 21/9). These younger Leang Burung 2 artifacts feature signs of burning and are also associated with ochre crayons.

The focus on finer grained materials in MIS 3-2 Wallacea occurs in conjunction with the small size of the lithic products. This miniaturization may in part be explained by the smaller clast sizes of fine-grained materials, in particular, with the transport of these usually non-local materials to occupation sites. However, the Makpan data show that much of the reduction of these materials took place on site and even cores that were only producing small flakes (<11mm) continued to be worked to very high levels of reduction intensity, presumably because such small flakes were still considered useful. Continued reduction of cores producing small flakes and their small products are also a feature of the Asitau Kuru assemblage, where the median length of Pleistocene flakes is 12.23mm for Square C.

Similarly to Asitau Kuru, there are high proportions of redirecting flakes in the Makpan complete flake assemblage (3.6% and 3% respectively), suggesting the deliberate prolonging of core reduction through the rejuvenation of exhausted platforms. In comparison, post-Toba eruption assemblages from Jwalapuram in southern India that are dominated by multifacial cores have less than 2% redirecting flakes (Clarkson et al. 2012); while the MIS 3-1 site of Fa Hien Lena on Sri Lanka which is dominated by bipolar reduction has just 0.1% (Wedage et al. 2019). Both *H. floresiensis* and *H. sapiens* levels at Liang Bua have very high proportions of redirecting flakes (>5%), but this is thought to result from a burination mode of reduction that is par-

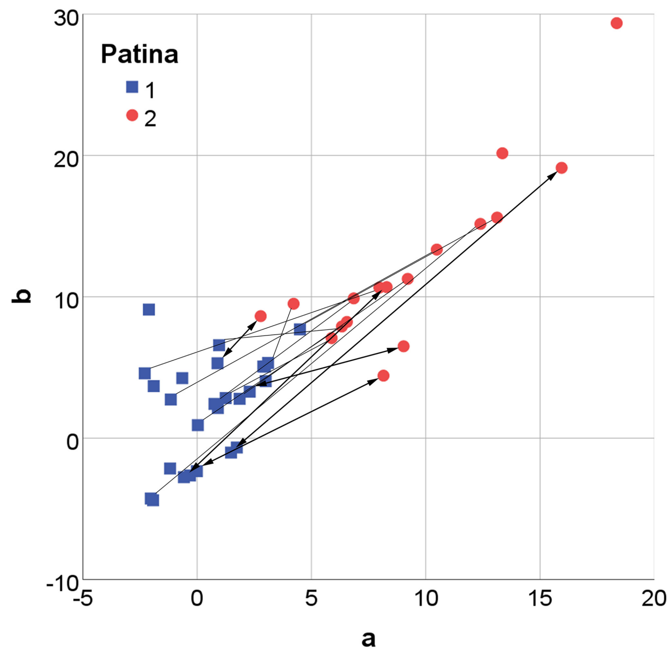

Figure 11. Scatter plot of colorimeter values for reddish patinated (2) and fresher blueish (1) basalt flake scars. The a values on the x axis are the red-green range with red being positive and green being negative. The b values on the y axis are the yellow-blue range with yellow being positive and blue being negative. Cords denote differential patina on the same artifacts, with the bold lines with arrowheads indicating recycled artifacts with differential patina on flake scars. The artifact on the top right of the distribution is the anvil in Figure 4C, which was never flaked.

ticular to the site (Moore et al. 2009).

Bipolar and discoidal reduction dominate the Pleistocene sequence at Makpan, with a prominent role for core-on-flakes in both methods. This combination of reduction strategies also characterizes nearby Tron Bon Lei where obsidian was exclusively reduced using bipolar knapping; as well as Asitau Kuru, where 33% of cores were made on flakes (Shipton et al. 2019), and the Holocene of Liang Bua, where 49% of cores were on flakes (Moore et al. 2009). The widespread use of bipolar and core-on-flake knapping likely reflects their utility in working smaller clasts (Pargeter and de la Peña 2017). Core-on-flakes and discoidal knapping were used at the Middle Pleistocene site of Talepu on Sulawesi. However, here the mean length of flakes produced was 40.35±14.55mm (N=55), significantly longer than those from the Pleistocene occupation phases at both Makpan (14.15±12.25mm, N=222, t=13.66, p<0.0001) and Asitau Kuru (14.55±8.2mm, N=330, t=18.926, p<0.0001). Bipolar and discoidal flaking as well as core-on-flakes were also prominent techniques employed by *H. floresiensis* at Liang Bua (Moore and Brumm 2009; Moore et al. 2009). Again, however, the flake products produced by *H. floresiensis* using these techniques were significantly larger (mean length = 28±11.4mm, N=846 (Moore et al. 2009)) than those produced in the Pleistocene occupation phases at either Makpan (t=15.4, p<0.0001) or Asitau Kuru (t=19.548, p<0.0001). Therefore, despite the similarities in knapping techniques between MIS 3-2 and earlier hominins in Wallacea, both the materials chosen and the size of the flake products show marked differences.

Another feature common to both Makpan and Asitau Kuru is the small size of the platforms relative to the flakes, with mean flake length to platform thickness (depth) ratios of 9.18 and 11.7 respectively (the latter on a sample of flakes longer than 20mm). We may contrast this with a large *H. floresiensis* assemblage at Liang Bua, where the flake length to platform thickness ratio is 5 (Moore et al. 2009). This may in part be related to high levels of overhang removal which is a prominent mode of platform preparation at Asitau Kuru and to a lesser extent Makpan, occurring on 11% and 6% of complete flakes, respectively.

Retouch rates are low (<5%) at Makpan, similar to

Figure 12. Broken, decorticated, elongate, and flat flake with a facetted chapeau-de-gendarme platform from Spit 62 (Late Pleistocene). Note that while the break is ancient it has a blueish color unlike the reddish patina on the ventral and fully flaked dorsal surfaces.

Asitau Kuru, with narrow (<15mm) notches among the most common retouched artifacts at both sites (Marwick et al. 2016; Shipton et al. 2019). Notches are the most common retouched artifact type at Leang Sarru, as well as from an occupation beginning in early MIS 2 on Sulawesi at Topogaro cave (Ono et al. 2020). Experimentation and microscopy indicates notches were used in plant processing at Leang Sarru (Fuentes et al. 2020), while at Topogaro they may have been used in the creation of an associated bone point industry.

The deposition of lithics in and around hearths and the associated heat damage is a notable feature of many MIS 3-2 Wallacean sites. Heat damage is common on lithics from Asitau Kuru, while at Leang Sakapao it occurs on 25% of all excavated stone clasts (Bulbeck et al. 2004). At Liang Bua heat damage is very common in the Holocene (Moore et al. 2009), with the introduction of hearths to the sequence coincident with the shift to *H. sapiens* occupation ~50 ka (Morley et al. 2017), and a "negligible" proportion (<1%) of heat damage in the *H. floresiensis* units (Moore et al. 2009: 516). In the Makpan Pleistocene assemblage heat damage is rare because of the igneous nature of most of the stone, but it is present on >1% of chert pieces. Charcoal occurs throughout the Makpan Square B Pleistocene sequence, but hearth features were only preserved by the rapid sedimentation from the Pleistocene-Holocene transition (Kealy et al. 2020).

The MIS 3-2 assemblages from Liang Bua, Makpan, Asitau Kuru, and Leang Burung 2, all share a preference for cryptocrystalline materials, in particular chert and obsidian. This is in contrast to earlier occupations at Liang Bua and Leang Burung 2 which are characterized by the use of relatively coarser grained silicified tuff and limestone, respectively. At Leang Burung 2 the upper artifacts are described as distinctively smaller than the lower ones, while at Makpan and Asitau Kuru artifacts are also particularly small. No size data are yet available for the Liang Bua upper artifacts, but the Makpan and Asitau Kuru Pleistocene flakes are around half the size on average of the Liang Bua artifacts associated with *H. floresiensis*. This size difference is all the more noteworthy given the diminutive stature of *H. floresiensis* and, conversely, the association of the Asitau Kuru lithics with *H. sapiens* (Roberts et al. 2020).

The systematic manufacture of small flakes, including from core-on-flakes and bipolar cores, is known elsewhere from the Lower Paleolithic onwards. The Levantine sites of Revadim and Bizat Ruhama are two such examples of core-on-flake production (Agam and Barkai 2018; Zaidner 2013), while L1 at Thomas Quarry 1 in the Maghreb is an example of bipolar production (Gallotti et al. 2020), but even in these cases mean flake length exceeds 20mm. Likewise, the Asinipodian Mousterian of Pech de l'Azé in Middle Paleolithic France, shows systematic core-on-flake production of small flakes, but here again mean flake lengths are in excess of 30mm (Dibble and McPherron 2006). In the Middle Paleolithic of the Levant, core-on-flakes were used for the systematic production of small flakes (Goren-Inbar 1988), and are at least in part related to provisioning situations where there are relatively few cores in relation to the number of flakes (Hovers 2007), similar to the finer-grained material at Makpan. However, in Levels B1 and B2 of Amud Cave where core-on-flakes reach particularly high proportions (>40% of all cores), mean flake length is still in excess of 40mm (Hovers 2007). In none of these Lower and Middle Paleolithic examples of miniaturization do we see the levels of mean flake size in the <20mm range that occur in MIS 3-2 southern Wallacea.

Knappers favored isotropic materials from the early Oldowan, but a focus on relatively finer-grained materials is harder to demonstrate. Certainly, there are Acheulean sites in the Levant and north-western Europe where chert and flint are the dominant materials, but they are often also the most widely available knapping materials in these regions. Melka Kunture in Ethiopia is unusual in documenting obsidian use from as early as 1.7 Ma, in a setting where it was easily available while preferred over coarser-grained igneous rocks from the same proximal fluvial source (Gallotti and Mussi 2015). The Lower Paleolithic site of Longgudong in southern China has a chert dominated assemblage including bipolar flaking, but here mean flake length is 24.11±11.1mm (N=20), significantly greater than Makpan ($t=3.504$, $p=0.0005$) and Asitau Kuru ($t=4.946$, $p<0.0001$). *Homo erectus* fossils dating from the early part of the Late Pleistocene at Sembungan on Java are associated with a small assemblage of chalcedony and chert flakes, as well as a single obsidian artifact, but size data are not yet published and the illustrated artifacts are well in excess of the mean sizes of the Makpan lithics (Rizal et al. 2020). We suggest that miniaturization (of the order of less than 20mm mean flake size), the focus on (typically imported) fine-grained cyptocrystalline materials like chert and obsidian, and the deliberate manufacture of very small flakes of those materials is a distinctive feature of MIS 3-2 across southern Wallacea.

In addition to miniaturization, Makpan, Asitau Kuru, and the upper levels of Leang Burung 2 also share the use of red ochre, while the upper levels of Liang Bua and Leang Burung 2, as well as Asitau Kuru, all share abundant signs of burning on the lithics (something that is in part less common at Makpan because of the igneous stone formed at high temperatures). These four sites are on four different islands that were never connected to each other, so without precociously early inter-island connectivity, diffusion cannot explain the co-occurrence of these traits. We must therefore consider population dispersal and/or adaptive convergence among a highly behaviorally plastic species such as *H. sapiens* (Barsbai et al. 2021; Roberts and Amano 2019) as the mechanism for their concurrent appearance.

CONCLUSION

Thus far only 1m^2 of the Pleistocene levels at Makpan have been excavated, so the patterns identified here must be regarded as provisional, particularly for the late Pleistocene phase. It is difficult to say much about the double patina artifacts as their sample size is so small, but they do appear to be distinct from the other lithics. The similarities of the rest of the assemblage (N=1437) to those from elsewhere in Wallacea suggests their characterization is robust. Bipolar and discoidal knapping techniques, with frequent use of flakes as cores, and moderately elongate flake products are consistent throughout the Makpan Pleistocene sequence, indicating long-term continuity, as has been documented in other records spanning MIS 3-1 in Wallacea (Marwick et al. 2016; Shipton et al. 2019). Higher up the sequence such technology is also found in association with an *H. sapiens* burial dated to 7 ka (Samper Carro et al. 2021).

A peak in chert usage in the terminal Pleistocene suggests more use of northern and eastern Alor and perhaps also Pantar which was connected at this time. Use of intervening interior areas is consistent with the partly terrestrial isotopic diet signature of the human tooth from this phase (Roberts et al. 2020). In the Pleistocene-Holocene transition, the focus on obsidian suggests ranging eastwards along the southern coast, according with the midden formation during this phase. Flaking of shell alongside shell fishhook technology occurs in the terminal Pleistocene and the Pleistocene-Holocene transition, with the grooved artifacts shown in Figure 4 potentially for grinding fishhooks. More engagement with the sea perhaps explains the increase in chalcedony in the terminal Pleistocene and again into the Pleistocene-Holocene transition, as we think this material is an exotic import.

The Makpan Pleistocene lithic sequence provides an assemblage that articulates with the MIS 3-1 industries known from Liang Bua on Flores to the west, Leang Burung 2 on Sulawesi to the north, and Asitau Kuru on Timor to the east. Despite Makpan being distinguished from the others by the dominance of igneous materials, the four assemblages share a preference for imported fine-grained stone over local knappable stone. Bipolar and discoidal knapping is common to all four assemblages while core-on-flakes are known from Liang Bua, Makpan, and Asitau Kuru. Comparison of the Liang Bua lithic assemblage associated with *H. floresiensis* with those from Makpan and Asitau Kuru, show that flakes from the latter two are markedly smaller as well as having relatively narrower platforms, despite all three assemblages being produced through bipolar, discoidal, and core-on-flake techniques. One potential explanation for these differences is that the miniaturized assemblages reflect the later reduction stages of the same broad sequence as the larger artifacts (Moore and Brumm 2007). We think this hypothesis is confounded by the differences in materials between miniaturized and older assemblages, including at Leang Burung 2 where they occur in the same sequence (Brumm et al. 2018), as reduction intensity cannot change material type. It may be that lower levels of reduction intensity and the use of more local materials reflects lower mobility among Lower Paleolithic hominins. However, this is not the whole explanation as we would then expect local materials to dominate MIS 3-2 assemblages when knapping is carried out on-site, whereas instead what we see is on-site reduction of imported fine-grained material. The very high reduction levels of fine-grained material at Makpan shows the continued utility of very small, but sharp flakes, with imported fine-grained material worked far longer than coarser local material.

Hominins were judiciously selecting appropriate isotropic materials for knapping since the early Oldowan (Goldman-Neuman and Hovers 2012; Harmand 2009; Stout et al. 2005). We suggest the need for consideration of the functional differences between coarser and finer lithic materials, as experimentation has revealed their different affordances: finer-grained chert produces sharper edges, but relatively coarser-grained basalt produces more durable edges (Key et al. 2020). The selection of coarser material in longer use tasks accords with the evidence from Makpan of a higher proportion of coarser basalt being retouched than the finer materials. Oldowan hominins at Kanjera in East Africa who were using stone tools to butcher bovids among other things (Lemorini et al. 2019; Lemorini et al. 2014), are shown to have prioritized stone tool durability over fracture predictability (Braun et al. 2009). Lower Paleolithic assemblages in Wallacea, including the *H. floresiensis* levels from Liang Bua, are associated with megaherbivore prey (Shipton et al. 2021b) that would have required lengthy stone tool assisted butchery, perhaps placing a premium on relatively coarse materials with more durable edges. By contrast, MIS 3-2 assemblages are associated with marine invertebrates, fish, and small mammals that may not have needed stone cutting tools at all to process (O'Connor et al. 2017). Exactly what miniaturized stone tools were used for in Wallacea is an elusive question requiring further investigation, but there are indications that some were hafted (Fuentes et al. 2019), some were used in plant processing (Fuentes et al. 2020) and some in bone carving (O'Connor et al. 2014; Ono et al. 2020).

A basalt muller from near the base of the Makpan sequence attests to the early use of grinding technology, with other grinding stones also occurring in subsequent phases. Grinding stones for plant processing were an important technology for early *H. sapiens* populations in Australia (Clarkson et al. 2017). The red ochre covered grinding stone and hammerstone are part of a general engagement with this material across Wallacea in MIS 3–2, taking in the red ochre crayons from Asitau Kuru (Langley and O'Connor 2019; Shipton et al. 2019), the MIS 2 site of Leang Bulu Butte on Sulawesi (Brumm et al. 2017), and the MIS 3 dated red painted Pleistocene rock art from Sulawesi (Aubert et al. 2014; Aubert et al. 2019). Red ochre use was generally widespread among Pleistocene *H. sapiens* but rare in other species, and likely reflects distinctive cognitive and social capacities (e.g., Bar-Yosef Mayer et al. 2009; Watts 2009).

The co-occurrence of both grinding technology and pigment with miniaturized lithics at Makpan is noteworthy. In southern Africa it has been suggested that miniaturization was an adaptive response of technological efficiency to environmental change, with miniaturization maximizing flake yields from cores and reducing the costs of lithic transport (Pargeter and Faith 2020). At Boomplaas Cave, MIS 2 miniaturization goes hand-in-hand with new subsistence strategies to include smaller-bodied prey such as tortoises and hares (Chase et al. 2018). The diet of the

Makpan occupants, with animal protein from diverse marine invertebrates and fish, with occasional turtles and rat (Kealy et al. 2020), as well as possibly ground vegetable resources, may be a parallel phenomenon of subsistence breadth in association with miniaturized lithics. Likewise, an increase in personal ornamentation at Boomplaas Cave is interpreted as reflecting social network expansion to mitigate a less predictable environmental situation. Ochre processing from the earliest phase of occupation at Makpan may similarly reflect expanded social networks in the colonization of new island environments.

Miniaturized assemblages in MIS 3-2 Wallacea provide a distinctive lithic technology signature from earlier Lower Paleolithic occupation in the region. On neighboring Java at the eastern edge of the Sunda shelf, Simanjuntak et al. (2015: 162–163) identify small flakes on imported siliceous stones as a key distinguishing feature of *H. sapiens* behavior in the second half of the Late Pleistocene, in comparison to the lithics of *H. erectus* earlier in the Pleistocene. The occurrence of miniaturized lithics at Makpan now places this technology on four different Wallacean islands beginning in MIS 3 and in association with red ochre use on three of those. There is a further correlation at Makpan and elsewhere in the region between miniaturized lithics and marine invertebrates, fish, and small mammal prey. We suggest that the appearance of these traits reflects high social connectivity and adaptation to novel depauperate island environments during a dispersal of behaviorally plastic *H. sapiens* across Wallacea in MIS 3. The crypto-industry of technologically distinct, large, double patina artifacts from Makpan hints there might be an earlier dispersal in eastern Wallacea that remains to be elucidated.

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