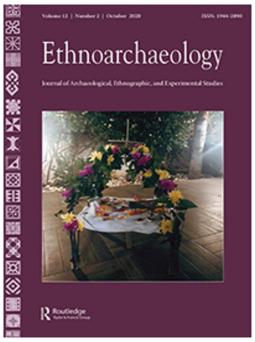

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ABSTRACT
The distinctive "saddle-shape" stone knives known as Tembeling knives of West Malaysia (Peninsular Malaysia) have long been used to characterize the early agricultural activities of Neolithic populations in the region. While these tools are morphologically suggestive of a reaping function, their association with early plant use has never been established. The present study explores for the first time the function of Tembeling knives through a preliminary experimental study focusing on technological attributes and usewear profiles. The results indicate continuity in lithic technological processes between Neolithic populations and their foraging predecessors. The experimental work suggests an efficient reaping function for the tool. Additionally, usewear patterns on archaeological examples correspond most closely to the profiles found for siliceous plant-working tools replicated in the experiment.

KEYWORDS
Neolithic; agriculture; stone reaping knife; West Malaysia; Tembeling knives; usewear; slate tool usewear; reduction technology

Introduction

Stone reaping knives are widely considered to have been a "harvesting tool" introduced through the crop-reaping technological innovations of the Neolithic period. They have traditionally been used by archaeologists as a marker of early agricultural plant use across many parts of Asia (Bellwood 1992; Choe 1982; Evans 1931; Solheim 1983; Taha 1989; Tweedie 1953). This typically flat or halved-stone knife, usually characterized by a distinctive semilunar, rectangular, or saddle shape, has been reported from many archaeological sites in East Asia and Southeast Asia (Bellwood 1992; Chang 1956; Hung and Carson 2014). While their morphological characteristics have generally

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been assumed to reflect their primary function as a reaping tool for stalked plants, usewear and residue analyses have also been deployed in other regions to investigate technological and economic aspects of the use of these tools (see Anderson 1999; Fullagar et al. 2012; Liu, Wang, and Levin 2017; Marreiros et al. 2015). Usewear analysis has the potential to identify the use of stone knives particularly through the observation of "sickle-gloss" which might indicate their use for cereal harvesting (Anderson 1999; Carvalho, Gibaja, and Cardoso 2013; Fullagar et al. 2012; Ibáñez et al. 2016; Unger-Hamilton 1985). On the other hand, analysis of residues, particularly starch and phytolith residues, is useful for the detection of early plant use among prehistoric communities (Fullagar et al. 2012; Liu, Chen, and Ji 2016; Liu, Wang, and Levin 2017; Yang et al. 2014). The combination of these two approaches offers a powerful method for reconstructing both the technological and economic activities of past societies.

In West Malaysia, stone knives have long been assumed to represent the Neolithic mode of technology as they are usually found in association with the earthenware pottery and ground stone implements within archaeological contexts (Evans 1931; Ramli and Arbi 2014; Taha 1989). Two types of Neolithic stone knives have been reported from West Malaysia with the majority of them distributed across the inland plains of Central West Malaysia, particularly along the Tembeling River region in the state of Pahang (Figure 1). The first type of stone knife is the "semilunar-shape" stone knife with two perforations. This type of stone knife is well-distributed in many parts of East Asia (see Chang 1970; Choe 1982) but has rarely been reported in Malaysia. To date, only one such implement has been documented from the Tembeling River (Tweedie 1953). The other, more common type is the "saddle-shape" stone knife made on slate which has been widely described as the "Tembeling knife" (TK), after the region where it was first discovered, and described as a tool most likely functioning as an axe, adze, or reaping knife (Bellwood 2007; Evans 1931; Taha 1989). The distribution of the TK in Mainland Southeast Asia is restricted to West Malaysia, but a morphologically similar stone knife has been reported from Taiwan in a cursory account by Chang (1956).

Figure 1. (A) The location of Tembeling region in Southeast Asia; (B) The distribution of Tembeling Knives in West Malaysia. Redbox indicates the Tembeling region.

Malaysian archaeologists have long considered the TK to be artifactual evidence signaling the presence of early horticultural or agricultural practices accompanying the Malaysian Neolithic (Leong 1991; Taha 1989;). This hypothesis is founded in two lines of reasoning: (i) the morphological characteristics of the TK fit with a stalk "reaping" function (Tweedie 1953), and (ii) they have most often been found in association with other Neolithic polished stone implements which were identified as early farming tools (see Bellwood 2007). While the physical characteristics of the TK do indeed seem to correspond with the features of a harvesting tool, all previous studies of them have simply assumed it was used in a reaping function without elucidating their technological attributes and function through a more systematic approach (see Duff 1970; Evans 1931; Ramli and Arbi 2014; Taha 1989). A recent experimental study conducted by Hashim et al. (2014) has suggested that macroscopic usewear traces on a sample of the TK do not exhibit evidence of plant use. However, the reliability of these findings is open to question given that only one TK was examined in their study.

In light of the ongoing uncertainty surrounding the economic use of this important Neolithic marker in West Malaysia, our study aims to identify the role of TK through a preliminary experimental study focusing on technological attributes and usewear. We first investigate the technological attributes of the TK and assess the association between morphology and function. We then use experimental usewear to document functional traces on experimental slate tools worked on rice paddy plants and animal hide, later using them as a reference to assess the function of the TK.

Archaeological background

The Tembeling River is a tributary of the Pahang River, flowing in a south-westerly direction through the inland alluvial plains of the state of Pahang (Figure 1). The river is 153 km in length, originating at the Besar Mountain Range of the Pahang-Terengganu state border, and serves as the major waterway connecting the interior area of the Pahang National Park to the east coast of West Malaysia. Small clusters of *Orang Asli*[1] communities are located along the Tembeling River with the majority of them practicing small-scale wet paddy-farming in the swampy areas on the streams and other small tributaries of Tembeling River (Takaya, Fukui, and Yamada 1978).

Archaeologically, the Tembeling River region has been known to contain important prehistoric localities since work by Linehan during the early twentieth century (1928, 1930). He reported the discovery of some polished stones and iron implements attributed to late prehistoric period at four different localities in this area (Linehan 1928, 1930). Soon after, Evans (1931) investigated Nyong, an archaeological locality around 45 km from the mouth of Tembeling River, unearthing a large number of ground and polished stones implements, stone knives, earthenware pottery, and metal implements including a fragment of a Dong Son drum. The majority of the polished stones and stone knives were found associated with cord-marked and plain pottery sherds. Both Evans (1931) and Tweedie (1953) later assigned the ground stone assemblage from Nyong to the Neolithic period. A long hiatus in research ensued until archaeological investigation occurred again between 1976 and 1980 at three different localities along the Tembeling River: Ulu Tembeling, Jeram Koi, and Kampung Bantal. A six-square-meter trench was opened on the riverbank of the Jeram Koi locality, and excavations unearthed a high volume of plain pottery sherds, an iron spearhead, and an iron knife. Excavations at Kampung Bantal and Ulu Tembeling, on the other hand, recovered only a few stone adzes, a bark-cloth beater, and a stone bracelet (Taha 1989). Generally, the polished stone implements from the Tembeling River are presented in a wide variety of forms including quadrangular adzes, beak-shaped adzes, shouldered adzes, stone chisels, and stone spearheads (Figure 2). Often these polished tools were also found in association with earthenware pottery and bark-cloth beaters, perforated quoits-discs, and stone bracelets.

Evans (1931) first recovered six TKs from a secure stratified context from Nyong—an open site located on the bank of the middle reach of the Tembeling River. Typologically, these TKs were classified into the polished/ground stone family based on their morphology which features a polished edge (see Duff 1970). This type of stone knife is usually made from locally available slate cobbles and has a distinctive notch within the cutting edge. Upon its discovery during the 1930s, this saddle-shape stone knife was believed to have been unique to the Tembeling Region. However, similar stone knives were reported later from open air Neolithic sites at Pasir Mas, Baling, and Jenderam Hilir (Ramli and Arbi 2014) (Figure 1). Up until now, the age of localities along the Tembeling River has been the subject of debate as none of the artifacts from the area have been chronometrically dated. On the basis of artifact types and their cultural context, archaeologists have widely accepted that ground-stone assemblages from the Tembeling River are attributed to a mid-late Neolithic culture, ca. 3,000 cal. BP (Taha 1989).

Materials and methods

Reduction technology

In this study, a total of four stone knives (TK1 -TK4) made on slate were analyzed (Figure 3). All of these stone knives were retrieved from an archaeological collection at the Pahang Museum but the archaeological contexts of these tools are uncertain. Lithic analysis focused on the reconstruction of the technological attributes of the tools including reduction technology, number of removals/blows, edge modification, and raw materials (e.g. Andrefsky 1998; Duff 1970; Duke and Pargeter 2016) (Table 1). The study of the reduction technology also helped to examine the technological development of stone tool during the transition to Neolithic in West Malaysia. The data generated from this analysis were integrated into the replication of experimental slate stone knives for this study.

Experimental tool use

We replicated two stone knives on slate cobbles sourced from the Tembeling River region (Figure 3). The experimental tools were replicated based on the reduction technology of the TKs established through this study to obtain the target morphology and attributes. The cutting edges of the replica knives were later unifacially or bifacially ground on the slate slabs to obtain the optimum sharpness (Figure 4). Given that the main objective of this study is to determine the usewear patterns of the TKs worked on different materials, (i) one replica tool was later used to cut and skin hide (*Bos taurus*), and (ii) the other was used to reap rice paddy plants (*Oryza sativa*) sourced locally. Each

Figure 2. The ground-stone assemblage recovered from the Tembeling River. (A) Polished axe; (B) Perforated quoits-disc; (C) Bark-cloth beater; (D, F & I) Quadrangular adze; (E) Stone spear; (H) Chisel; (G & J) Beak Adze.

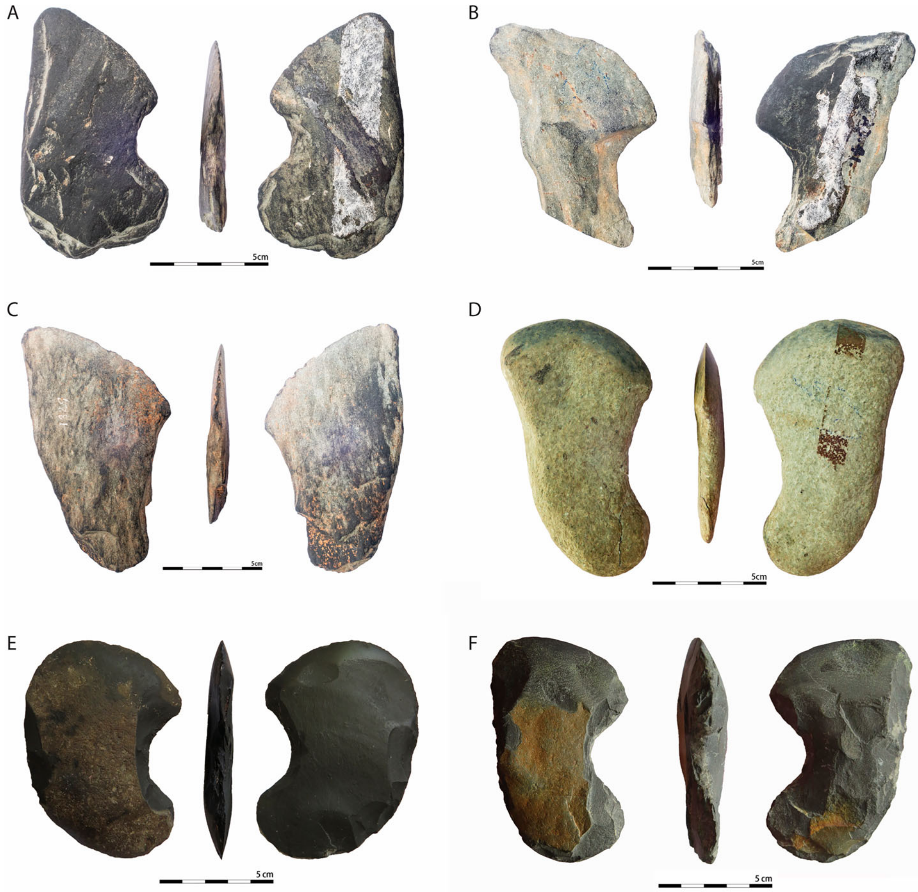

Figure 3. The Tembeling Knives and experimental tools described in this study. Specimens A-D were sampled for usewear analysis and Specimens E and F are the experimental tools produced for this study. (A) TK1, (B) TK2, (C) TK3, (D) TK4, (E) RK1, (F) RK2.

replica tool was used in a slicing motion over two 30-minute sessions (60 min in total) (Figure 5). The usewear patterns of each replica tool were observed and documented using a Three-Dimensional Digital Microscope (3D DM) and Scanning Electron Microscope (SEM) after every 30 min in contact with materials. Both tools were microscopically examined and documented prior to the commencement of the experiment in order to establish a control for the raw material.

Usewear analysis

The usewear analysis method adopted in our study aimed to determine tool function and evaluate whether the slate stone knives recovered from the Tembeling River possess the diagnostic microwear traces to characterize the use and function of the tool. Previous studies have demonstrated utilized stone tools often possess diagnosable usewear patterns or microscopic traces which result from their direct contact with different materials (Knutsson et al. 2015). In our study, a total of four prehistoric TKs and two experimental

Table 1. Results of metric analysis of the Tembeling Knives sampled in this study.

					No. of blow (*n*)					
		Dimensions (cm)			(proximal & medial shaping)		(edge shaping & retouch)			
Knife ID	Localities	Max Length	Max Width	Max Thickness	dorsal	ventral	dorsal	ventral	Edge angle (°)	Ground surface
TK 1	Jerantut	10.2	5.8	1.4	13	9	0	5	47	Not ground
TK 2	Tembeling River	10.4	7.4	1.8	6	11	5	8	64	Ventral
TK3	Jerantut	12.4	8.05	1.4	4	7	0	6	41	Ventral
TK 4	Kuala Lipis	10.9	6.3	1.6	1	2	0	0	53	Bifacially ground
RK1 (Hide)	Experimental sample	10.6	6.5	2.1	16	17	5	3	53	Bifacially ground
RK2 (Paddy rice)	Experimental sample	9.2	7.2	1.4	8	12	0	5	53	Bifacially ground

Figure 4. Stone tool replication experiment.

slate stone knives were sampled for usewear analysis. Four major variables were identified in our study, namely polish, striae, scarring, and edge rounding. Extended usewear features such as polish brightness, polish coverage, and the degree of polish development (see Hayes, Pardoe, and Fullagar 2018) were also documented, given that these micropolish characteristics can be diagnostic of worked material (see Fullagar 1991; Knutsson et al. 2015; Yamada 1992). In general, previous studies indicated that when the stone tool was in contact with plant materials, it will usually produce traces such as polish (gloss), slight edge rounding and striations on the surface of stone tools (Anderson 1999). In comparison, processing hard materials, such as bone, will produce wide and long striations (Liu, Wang, and Levin 2017) with less developed or weak polish (Vaughan 1985, 204; Yamada 1992). Although the number of specimens sampled for this usewear study seems to be small ($n = 6$) by conventional experimental

Figure 5. Cutting meat and siliceous paddy stalks using experimental tools.

standards, given the main purpose of the study is to establish a preliminary functional connection between tool morphology, the performance of tools on different materials, and consumption activities, we argue that the combined dataset generated from both the technological and usewear studies is sufficient to allow us to propose the primary function of the Tembeling knives.

All specimens were examined using a Keyence 7000 3D DM and a Quanta SEM FEC650 at high magnifications (100–400x). All usewear traces were sequentially recorded (before the experiment, at 30 min of utilization, and at 60 min of utilization), evaluated, and cross-referenced with usewear profiles developed from our experimental study as well as previously published experimental findings (see Anderson 1999; Borel et al. 2014; Fullagar 1991; Fullagar et al. 2012; Ibáñez et al. 2016; Liu, Wang, and Levin 2017; Vaughan 1985; Yamada 1992).

In this project, we opted for SEM and 3D DM techniques to identify the polish, striae, scarring, and edge rounding associated with the tools sampled for the study. While conventional usewear studies, especially for the examination of micropolishes, tend to utilize optical light microscopy (OLM) in a larger scale, the lesser depth of field of the OLM often limits the acquisition of well-focused photographs due to the uneven topography of the stone stool's surface. SEM and 3D DM are arguably useful in this context, as both of these instruments are equipped with a greater depth of field that facilitates the acquisition of well-focused micrographs without having to process the micrographs using the focus stacking software (see Borel et al. 2014). While it is widely established that OLM, SEM, and 3D DM are complementary in usewear analysis, previous studies have proven that SEM and 3D DM approaches are sufficient in facilitating the understanding and interpretation of usewear on stone tools in the absence of OLM (see Borel et al. 2014; Martín-Viveros and Ollé 2020; Ollé and Vergès 2014).

Results

Technological attributes: morphology and reduction sequence

The four stone knives from Tembeling River vary in size and have cutting edges often ground to produce a sharp polished surface. They range in size from 10–12.5 cm in length, 5–8 cm in width, and 1.4–1.8 cm in thickness. Our analysis suggests that the reduction sequence of the TK usually involved a range of about 10–20 removals along the proximal and medial edges, with occasional retouch flaking on the distal edge to reach the target shape. Our observations show that 25% ($n = 1$) of the implements show no signature of retouch with the remaining 75% being retouched unifacially (50%, $n = 2$) or bifacially (25%, $n = 1$). The cutting edge of the stone knives was sharpened through extensive polishing and grinding to obtain an acute angle (approximately 40–64°). Of four specimens, three (75%) were sharpened on the ventral edges and one specimen (25%) was bifacially ground along the cutting edge (Table 1).

In terms of the reduction technology, our analysis indicates that all four stone knives sampled in this study were made on medium-sized slate cobbles (approximately 10–15 cm in maximum length) with an estimated maximum thickness of 5 cm. Slate cobbles were subsequently halved using the axial bipolar technique to produce the "A/

A1" techno-type cobble blank (see Duke and Pargeter 2016; Forestier et al. 2013). This technique involves the placement of a core on an anvil and hammering downwards from above. This reduction method will usually produce A/A1 cobble blanks with a sheared ventral surface and rebound force scar on the distal end. The proximal and medial edges of the halved A/A1 blank were later reduced, either unifacially or bifacially, and an "active part" was prepared at the distal end. The distal end is ideal for use as an active part because the process of splitting the cobble will produce a half-cobble blank with a thinner distal end which is easy to manipulate into sharp cutting edges through grinding. This reduction technique is remarkably similar to the technology used in the production of Hoabinhian pebble tools as reported in several archaeological sites in West Malaysia (see Taha 1985), and this observation flags possible continuity of lithic technology through time between them (Figures 6 and 7).

The performance and usewear patterns of the experimental tools

Two replica stone knives (RK1 and RK2) were each used, one to process the animal by cutting through the hide then skinning the animal (RK1) and the other to cut rice paddy stalks (RK2) for one hour. Both experimental tools were examined microscopically before and after these experiments (Figure 8ad). Under the SEM, the edge of RK1 demonstrates some scarring and the surface near the edge appears to be uneven and pitted before use. No visible striations or polish were presented (Figure 8a). The cutting edges of RK1 exhibited significant rounding after 30 min of use, and the edges became extensively abraded after 60 min (Figure 8b and c). Weak polish, represented by slightly darker areas on 3D DM micrograph, was developed on the dorsal surface of RK1, and a few short striations were observed on areas near the cutting edge of the ventral surface (Figure 9a).

The edge of RK2 was sharpened through freehand flaking and was bifacially ground to obtain a smooth and sharp edge before it was used to harvest the rice. The surface area near the dorsal edge of RK2 was smooth and scars were evident along the edge. Some very short and shallow striations were observed on the edge before use; these attributes were recorded as the striations created by the grinding and discriminated from the usewear interpretations. The cutting edges of RK2 demonstrated a slight rounding after cutting rice paddy stalks for 30 min (Figure 8e). The edges appeared to be rounder after one hour and the scars and fractures from grinding and sharpening the edge disappeared (Figure 8f). Unlike the shallow striations created by the edge grinding, long and fine striations began to develop in parallel to both dorsal and ventral cutting edges after 30 min with several other short diagonal striations observed on the dorsal surface. A few long and deep striations were also observed on areas adjacent to the dorsal cutting edge (Figure 8e–f). Intermediate polish began to develop on the edges after 30 min of use and the areas near the ventral edge began to exhibit a brighter polish after 60 min, and these characteristics are demonstrated by the very dark and smooth areas on DM micrograph (Figure 9b). The experiment suggests that RK2 is very effective in harvesting grassy plants; 3.2 kg of rice paddy stalks was harvested over a course of 30 min in our experimental work. In comparison, RK1 is not very efficient in butchering and skinning the animal; 30 min were required to cut through the hide to produce an 18-cm opening.

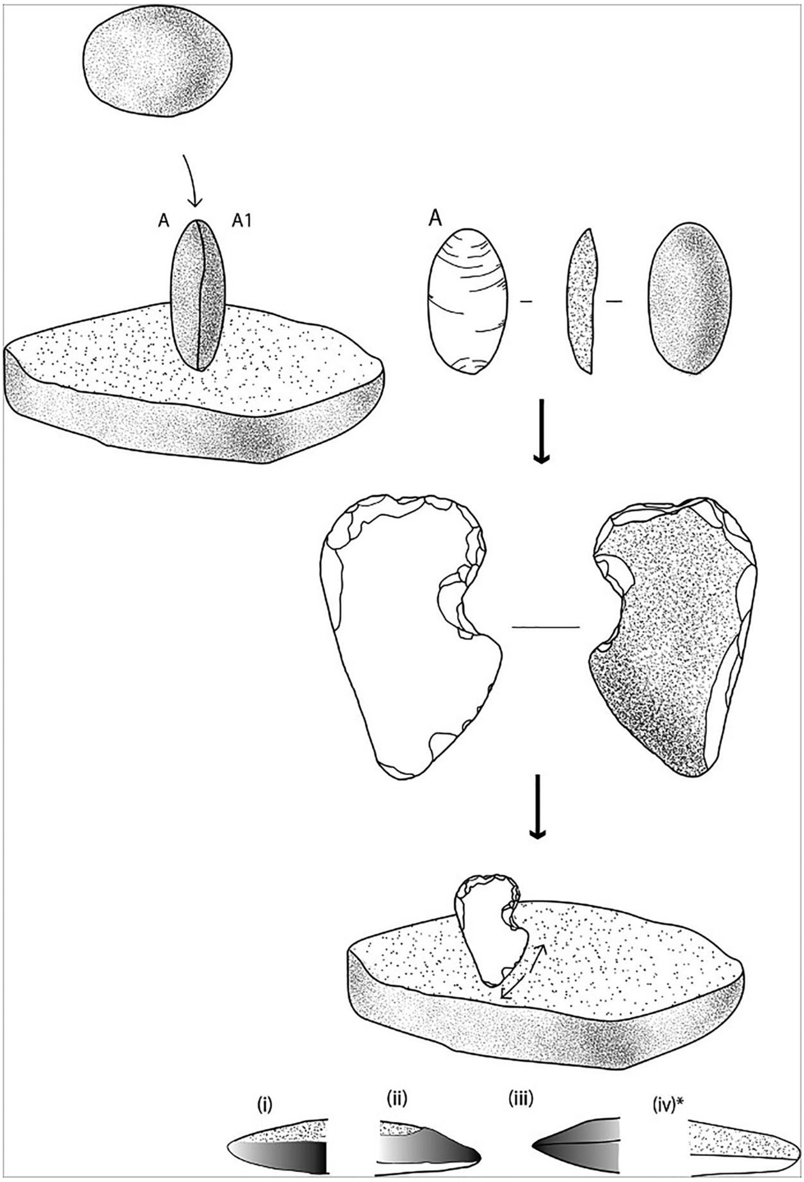

Figure 6. Schematic drawing of the reduction sequence of the Tembeling Knives. A slate cobble is halved through bipolar flaking to produce A/A1 split cobble blanks. The cobble blank is then bifacially or unifacially flaked to obtain the desired shape. The active part (distal edge) would then be (i & ii) unifacially ground or (iii) bifacially ground to produce an optimal cutting edge; and (iv) unground Tembeling Knife with an acute angle (<70º) also present within the assemblage.

Usewear patterns on the tembeling knives

Four archaeological TKs (labeled TK1-4) were examined for usewear analysis. Macroscopically, scarring is visible along the cutting edge of all of them. The edges of TK1, TK2, and TK4 exhibit slight scarring (<2 mm), whereas scarring along the edges of

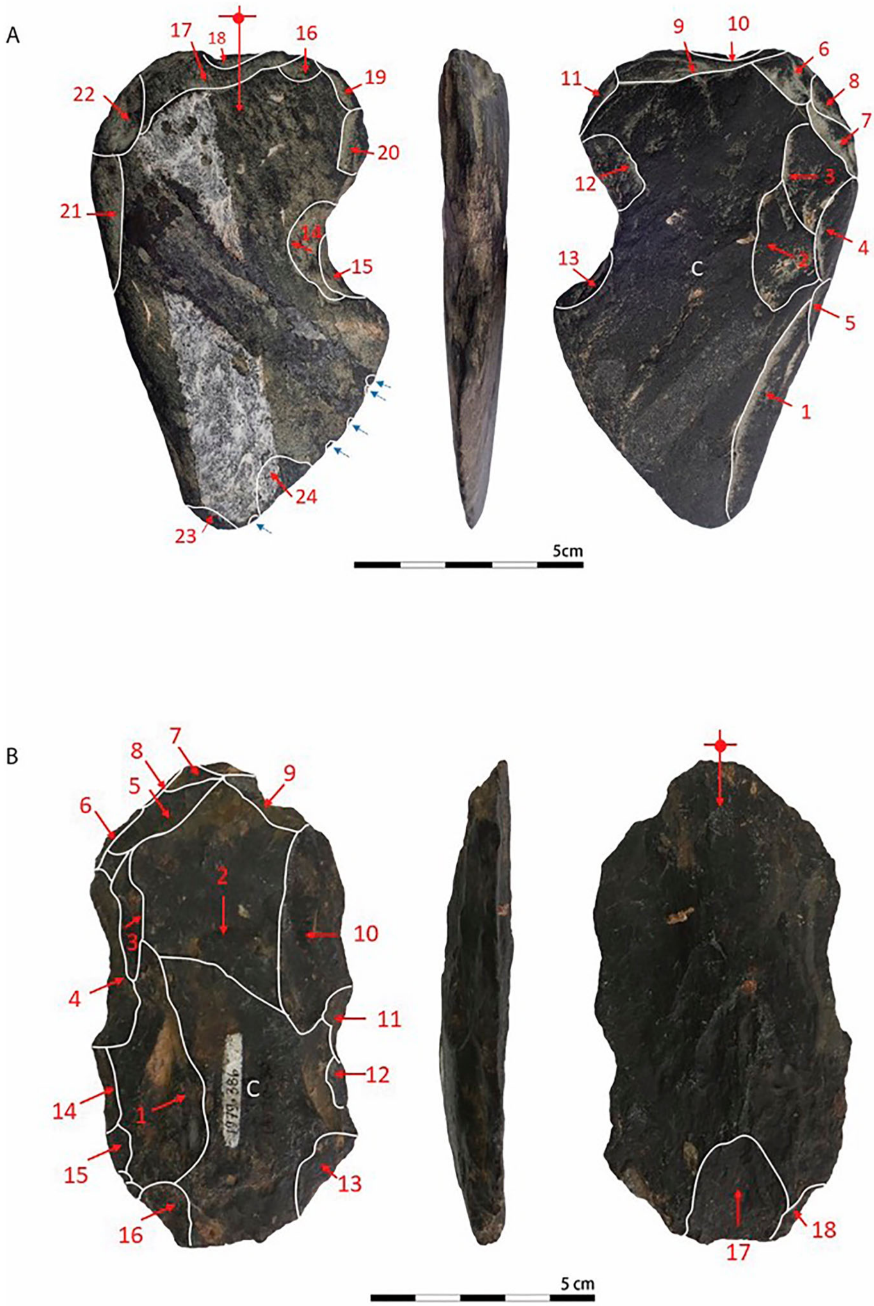

Figure 7. (A) Tembeling Knife & (B) Hoabinhian Bifacial Pebble Tool from Gua Cha. The reduction analysis indicated that both specimens were produced on medium-sized cobbles (~10–15 cm) and were bifacially flaked or retouched to obtain the target size and shape.

TK3 was more invasive (>5 mm). Our analysis indicates these scars probably resulted from retouch flaking when the tools were knapped or as part of subsequent tool-sharpening. The microwear analysis demonstrated that all TKs sampled in our study exhibited

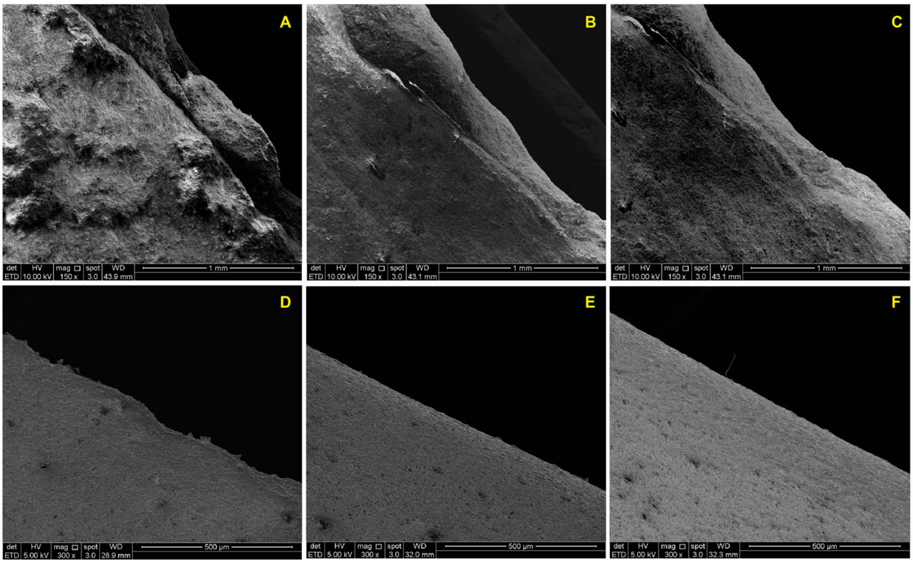

Figure 8. SEM images of the dorsal cutting edge of the experimental tools (Magnification: 150X). (A) RK1 before the slicing of meat and hide; (B) Edge of RK1 was rounded slightly after slicing flesh and hide for 30 minutes; (C) Edge of RK1 became abraded after 60 minutes; (D) RK2 before cutting paddy stalks; (E) Edge of RK2 exhibiting slight edge-rounding and long, fine, striations parallel to the edge after cutting paddy stalks for 30 minutes; (F) Edge of RK2 showing more rounding and striations after cutting paddy stalks for 60 minutes.

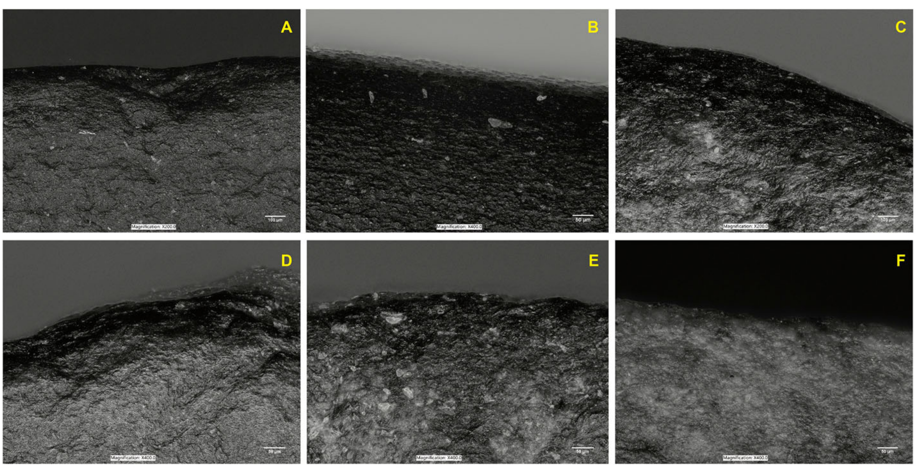

Figure 9. Micrograph of polish patterns seen on experimental tools (A–B) and Tembeling Knives (C–F) sampled in this study under Keyence VHX-7000 Digital Microscope (Magnification: 200-400X). A) Micrograph showing the polish traces of the dorsal cutting edge of RK1 after working of hide and flesh for 60 minutes (200x); (B) Well-developed bright polish (darker area) developed on the cutting edge of RK2 after cutting paddy stalks for 60 minutes (400x); C) Bright-glossy polish on the edge of TK1 (200x); (D) Well-developed polish, with fine striations, on the edge of TK2 (400x); (E) Moderate (dull-bright) polish associated with deep striations on the edge TK3 (400x); (F) Patches of localized glossy polish observed along the edge of TK4 (400x).

diagnosable usewear. Striations, polish, and edge-rounding of different degrees were identified on all studied tools, as characterized below (Table 2):

(a) The cutting edge of TK1 exhibited slight edge-rounding with long fine striations parallel to the edge (Figure 10a and b). Bright polish (shown as dark and smooth spots on 3D DM micrography) were found to be distributed across the surface of the edge (Figure 9c).

(b) The edge of TK2 appeared slightly rounded and micro-scars were observed along the edge (Figure 10c and d). A mixture of long and short striations formed parallel to the edge. High numbers of fine striations also were observed on other areas adjacent to the edges. Well-developed polish accompanied by fine striations also was present on the edge of TK2 (Figure 9(d).

(c) A mixture of deep, shallow, and long striations was present essentially parallel to the dorsal edge of TK3 (Figure 10e and f). Dull-to-bright polish accompanied by striations was recorded on the edge (Figure 9e). Interestingly, the edge of TK3 exhibited an invasive scar pattern; our analysis shows that these traces resulted from a series of retouch-flaking activities after tool use rather than during tool use. This interpretation was supported by the pattern of flake scars across use-wear striations on the dorsal edge of TK 3 documented through the SEM at a magnification of 150x (Figure 10f).

(d) TK4 showed slight edge-rounding with only minor scarring (<0.5 mm). Long, fine striations were visible parallel to the cutting edge (Figure 10g) A large number of short and fine striations, mostly diagonal to the edge, were also present (Figure 10h). Patches of bright polish were observed on the edges of TK4 (Figure 9f).

Table 2. The usewear characteristics identified on the stone knives sampled for this study.

	Usewear features/Characteristics				
	Polish				
Sample	Polish Brightness	Polish Coverage	Polish Development	Striae	Edge Rounding & Scars
RK1	Moderate/ Dull-bright	Localized on few spots on the edge	weak	Short, multi-directional	Edge extremely abraded
RK2	Bright	Extensive along the edge	Well-developed	Long, fine striations Parallel with the edge	Slight edge-rounding
TK1	Bright	Extensive along the edge	Well-developed	Long, fine striations Parallel with the edge	Slight edge-rounding
TK2	Bright	Extensive along the edge	Well-developed	Long and fine striations parallel with the edge. Few short and deep striations diagonally	Minor scarring presented
TK3	Moderate	Localized on few spots on the edge	Moderately-developed	Long and a mixture of deep and shallow striations Parallel with the edge	Scars from retouch
TK4	Moderate	Localized on few spots on the edge	Well-developed	Long, fine striations. Parallel with the edge	Minor scarring presented

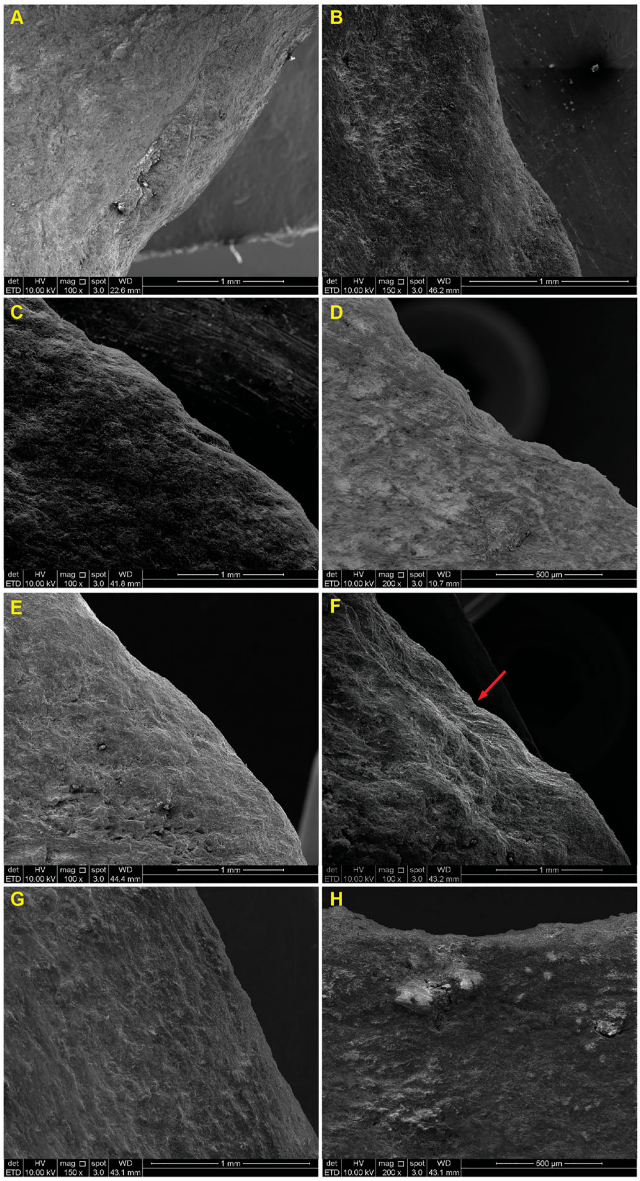

Figure 10. Usewear traces on TK1 (A and B), TK2 (C and D), TK3 (E and F), and TK4 (G and H) under SEM (Magnification: 100X, 150X & 200X). (A, B) Edge of TK1 exhibiting slight edge-rounding with fine striations; (C, D) Edge of TK2 showing traces of edge-rounding with a number of deep, long, striations, with micro-scars also present along the edge; (E and F) Edge of TK3 exhibiting a scarring pattern resulting from recent retouch flaking, and a SEM image recording a broken striation on the dorsal edge of TK 3; (G) Edge of TK4 presenting slight rounding and minor scarring with striations along the edge; (H) Fine, short striations diagonally distributed on the edge of TK4.

Discussion

In this study, the functionality of the TK was preliminarily assessed for the first time through a research strategy combining an analysis of tool morphology with usewear patterns. This was complemented with analysis of experimental tools which were replicated in order to: (i) re-evaluate the lithic technology of the TK to better understand the relationship between tool morphology and function; and (ii) identify usewear patterns on slate knives worked on hide and siliceous plants to establish a library for comparison with TKs recovered from other archaeological localities of Malaysia.

It is worth reiterating that the TK has long been identified as a harvesting tool based solely on its morphology which was used to infer a "reaping" function (Evans 1931; Taha 1989). However, a range of studies over several decades have shown that tool morphology may not necessarily reflect attributed function (Andrefsky 1997; Odell 1981). This is because the development of tool morphology is a dynamic process whereby the availability of raw material, economic patterns, production, tool use processes, and idiosyncratic preferences are among the variables acting across different individuals and populations through time (Andrefsky 1997; Rondeau 1996). From a technological perspective, our analysis of the reduction technology of the TK indicates that this distinctive tool type was a Neolithic innovation that likely developed from a pre-Neolithic pebble-tool tradition widely known as the Hoabihnian, given their close similarities in reduction technology and morphology (see also Forestier et al. 2013; Taha 1985). An important difference, however, is that TKs demonstrate a new technological innovation in which improved edge morphology was obtained through extensive grinding to produce a sharp cutting edge (approximately 41–64°). Previous studies have considered the Hoabihnian pebble-tool as a bone or wood working tool (see Bannanurag 1988; Taha 1985). However, the results of experimental research in our study indicate that the TK was likely a tool to process soft material. The ground edge of TKs prepared with an acute angle (<65°) greatly increased their cutting efficiency, and the distinctive "saddle" shape provides a hand-grip platform. All of these features indicate that the TK was likely developed for plant harvesting activities.

The results of our usewear analysis, on the other hand, demonstrate that usewear patterns on our experimental tools used to work animal hide produced larger amounts of edge rounding compared to rice harvesting. Striations were present on both experimental tools but rice-cutting activities produced a larger number of long, shallow, and fine striations parallel to the cutting edge. Similarly, polish was found along the edges of both tools used, but the experimental tool used for harvesting exhibited marked polish in a denser distribution. All these characteristics are relatively consistent with the usewear traces described in two previous experimental studies on the harvesting various siliceous plants using slate knives (see Fullagar et al. 2012; Liu, Wang, and Levin 2017): (i) striations are long, fine, and shallow from cutting grasses, but cutting cattails produces deeper striations, usually parallel to the cutting edge; (ii) medium to well-developed polish is usually formed, and the degree of polish is subject to different dryness of the plants; and (iii) slight to medium edge rounding is present when tools were used to cut grass, cattails, or acorns.

When examining archaeological TKs, the usewear characteristics of three of them (TK1, TK2, and TK4) were relatively homogenous and resembled the profile obtained from tools used to work siliceous plants. The cutting edge of the fourth tool (TK4) further documented a large number of long, fine striations with polish. This most likely resulted from its use to process drier siliceous plants (see Liu, Wang, and Levin 2017) compared with the other TKs. While invasive scarring along the cutting edge of

TK3 might be taken as evidence undermining an interpretation of its use for plant harvesting, our analyses also showed that such scars were most likely the result of a sequence of retouch-flaking after the striations and polish were formed (see Figure 9(f)). Furthermore, compared to the usewear traces of our experimental tools, the usewear traces on TK3 taken together resemble a plant-cutting tool. This observation adds weight to our suggestion that TK3 was probably used as a harvesting tool before it was retouched to produce a sharper working edge (see Kuhn 1990), perhaps in deployment for other functions or preparation for more plant-cutting activities.

Conclusion

Our technological and functional study of the TKs from West Malaysia have provided new insights into questions relating to the technological innovations and economic activities of the Neolithic in West Malaysia. Across Southeast Asia, ground stone tools have always been associated with Neolithic technological innovations and considered to have emerged alongside domesticated plants (Bellwood 2007). Our research suggests that the TK technology may have been adapted from the earlier pebble-tool tradition in West Malaysia (see Taha 1985) attributed to the Hoabihnian culture. This would imply continuity in lithic technological processes between the Neolithic populations and their foraging predecessors in West Malaysia. The reduction technology of TKs strongly resembles those of *Hoabihnian* pebble-tools found at Gua Cha in Northern West Malaysia and dated to ca. 7,000–8,000 cal. BP (Taha 1985). Such homogeneity may signal a cultural exchange during the transition to the Neolithic between the new immigrating farmers and their foraging predecessors. This assumption seems to agree with the ancient DNA evidence for the demographic expansion in Mainland South East Asia which demonstrated a localized admixture between the Neolithic migrating farming society (ca. 4,000 years ago) and their hunter-gatherer predecessors (McColl et al. 2018). In terms of functional connections between tool form and workable materials, our experiments suggest that TK appeared to be a more proficient reaping tool than a butchering or wood working tool, as its distinctive saddle or notch shape and sharp edges are morphologically ideal for harvesting activities.

Overall, usewear patterns observed on the TKs would appear to support the hypothesis of early agriculture among the Neolithic communities of Central West Malaysia (see Taha 1989). All of the usewear characteristics we have identified on them correspond to the profile for siliceous plant-working, further strengthening the assumption that TKs were highly likely used as a crop reaping implement. We agree that the usewear profile alone is insufficient to determine the taxonomic details of the types of utilized plants (see Fullagar et al. 2012), but our finding still adds considerable weight to current debates on the origins of agriculture during the West Malaysian Neolithic (see Chia 2006; Goh et al. 2019; Leong 1991). To date, archaeological investigations at more than 20 Neolithic sites across West Malaysia have been unable to recover direct paleobotanical evidence of human plant use extending earlier than 1,500 cal. BP (Shuhaimi and Rahman 1991; Taha 1985). Proposed trajectories for the expansion of Neolithic rice farming across East/Southeast Asia have suggested that rice cultivation arrived in the Malay Peninsular ca. 3,500–4,000 BP (Bellwood et al. 1992; Cobo, Fort, and Isern 2019; Silva et al. 2015). If the suggested aged of ca. 3,000 cal. BP for the TK is close to accurate, the development of early agricultural activities in West Malaysia would hypothetically be traceable back to at least ca. 3,000 cal. BP. This would be in accord with the archaeological record further north where the southern expansion of rice farming from China arrived in Thailand ca. 3,500–4,000 cal. BP (Higham and Lu 1998). In the absence of direct paleobotanical evidence and a secure chronological context, however, more evidence would be required to validate this hypothesis. Apart from residue analysis and chronometric dating schemes, additional experimental studies involving a larger sample size and a multi-scalar microscopy approach would be crucial in the future to resolve questions relating to the connection between the TK and the origins of agriculture in West Malaysia.

Note

1. *Orang Asli* is a local term that refers to the Indigenous people of West Malaysia.

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