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Microscopic Use-wear Analysis of Toalian Stone Tools: Reconstruction of Activities at Leang Batti, Bone Regency, Sulawesi Island

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Abstract

South Sulawesi is one area in the Wallacea region that contains many findings of diagnostic stone tools created by ancient hunter-gatherers. Researchers use the term *Toalian techno-complex* as a label for an archaeological culture. Researchers have conducted various studies to understand this culture. However, until now, research has mostly focused on morphological and technological aspects, while studies on the function of stone tools through microscopic use-wear analysis are limited. In this article, we report a description of new data on the function of Toalian stone tools from Leang Batti using microscopic use-wear analysis to provide an understanding of past human activities in South Sulawesi. The results of our research utilized 44 samples of Leang Batti stone tools, consisting of modified stone tools and unmodified stone tools showing evidence of use-wear, such as fractures, striation, gloss, rounding, and residue on the edges of stone tools. Based on the context of use-wear variables found, the Leang Batti stone tools were used for various activities such as cutting, scraping, splitting, and sawing materials, both floral and faunal. These activities are interpreted as a form of adaptation by the Leang Batti people to their natural environment.

Sulawesi bagian Selatan adalah salah satu daerah di kawasan Wallacea yang menyimpan banyak temuan alat batu diagnostik yang merupakan buatan manusia pemburu-pengumpul di masa lalu, para peneliti menggunakan istilah tekno-kompleks Toalian untuk menamakan budaya tersebut. Berbagai penelitian telah dilakukan oleh para ahli untuk memberikan penjelasan mengenai budaya tersebut, namun sejauh ini penelitian masih berfokus pada kajian atau studi morfologi dan teknologi saja, studi fungsional alat dengan menggunakan analisis mikroskopis *use-wear* masih sangat terbatas dilakukan. Di dalam artikel ini, kami melaporkan uraian data terbaru mengenai fungsi dari alat batu Toalian Leang Batti dengan menggunakan analisis mikroskopis *use-wear* sehingga dapat memberikan pemahaman mengenai aktivitas manusia pada masa lalu pada saat mengokupasi suatu daerah. Hasil penelitan kami dengan menggunakan 44 sampel alat batu Leang Batti, terdiri dari alat batu modifikasi dan alat batu nonmodifikasi, menunjukkan adanya bukti jejak pakai seperti fracture, striasi, kilapan, rounding dan residu pada tepi alat batu. Berdasarkan konteks variabel jejak pakai yang ditemukan maka alat batu Leang Batti pernah difungsikan dalam berbagai aktivitas seperti memotong atau mengiris, meraut, membelah dan menggergaji material berupa fauna maupun tumbuhan. Berbagai aktivitas yang seperti ini, kemudian diinterpretasikan sebagai bentuk adaptasi manusia Leang Batti dengan lingkungannya.

Keywords: South Sulawesi, archaeology, prehistory, stone tools, microscope analysis of stone tools | Sulawesi Selatan, arkeologi, prasejarah, alat batu, analisis mikroskop alat batu

Introduction

Sulawesi Island served as one of the maritime migration routes for anatomically modern humans from Sundaland to Australia during the Late Pleistocene period, between 65 and 25 thousand years ago (Kealy et al. 2015; Clarkson et al. 2017; Hawkins et al. 2017). The oldest archaeological evidence on Sulawesi was found at Talepu, dating to 118 thousand years ago (Van Den Bergh et al. 2016), and figurative paintings have been identified in prehistoric caves of Maros-Pangkep, dating between 45.5-18 ka. (Aubert et al. 2014, 2019; Brumm et al. 2017, 2021). Furthermore, evidence of a human fossil in the form of a mandible was found at the Leang Bulu Bettue site, with an estimated age of 25-16 ka. (Brumm et al. 2021). In addition, research at Topogaro Cave in Central Sulawesi provided information on modern human migrations between 42-16 ka, demonstrated by findings in the form of charcoal associated with anoa vertebrae (Fuentes et al. 2021; Ono et al. 2020a, 2020b, 2021, 2023). Modern humans (*Homo sapiens*) in this period were able to make stone tools from stone flakes; however, they were unfamiliar with more complex flake tool modifications (Brumm et al. 2010, 2017b, 2018; Fuentes et al. 2019; Marwick et al. 2016; Moore et al. 2009; Moore and Brumm 2007; Movius 1944; A. F. Pawlik 2010, 2012; Y. L. Perston et al. 2022; Suryatman et al. 2020; Xhauflair et al. 2020; Xhauflair and Pawlik 2010).

In the Holocene, the occupation of caves on Sulawesi Island continued, as evidenced by the finding of flake tools that were more developed when compared with stone tools from previous periods, utilizing more complex modification techniques. The distribution of stone tools discovered in South Sulawesi is known as the *Toalian techno-complex culture* (Bulbeck et al. 2001; Bellwood 2007). The Toalian techno-complex culture is characterized by diagnostic tool types such as Maros points, microliths, blades, and flakes (Chapman 1969; Suryatman et al. 2019; Perston et al. 2021). Further research on the Toalian technological complex is important because its unique industry is recognized in Island Southeast Asian (ISEA) prehistoric chronology (Heekeren 1972; Bellwood 2007, 2013; Forestier 2007).

A study of Toalian stone artifacts has been underway at the site of Cappalombo, in the karst area of Bontocani, South Sulawesi. The results have revealed that the microlith and Maros point findings are dated to 7000-3500 BP (Fakhri et al. 2018). Stone flakes and pebble plaques made of hematite were also discovered, providing evidence that symbolic behavior continued into the Holocene (Suryatman et al. 2021). Stone artifacts research results in the Leang Jarie karst area of Maros South Sulawesi provide information on the oldest Toalian cultural layer. Maros point findings, with an estimated age of 8000-7000 BP, appear relatively simplistic when compared to the Toalian artifacts. Furthermore, research conducted at Leang Panningnge, Mallawa District, South Sulawesi, showed that the human genome of Toalian techno-complex hunter-gatherers was found in skeletal remains associated with Maros points. The Toalian cultural layer at the site was dated to 7264-7165 cal BP (Hasanuddin 2015; Carlhoff et al. 2021).

Stone artifact research does not only focus on morphological and technological issues. Stone tools can also be assessed based on the intended purpose of each tool. An explanation of the function of stone tools can provide an understanding of human behavior in the past (Fullagar et al. 2006; Price and Burton 2012). One of the best methods of assessing the function of a stone tool is to use microscopic analysis of use-wear (Fuentes et al. 2019, 2020; Fullagar et al. 2006; Kamminga 1982). The study of the function of stone tools on Wallacea Island, specifically at the Leang Sarru site on Talaud Island, suggests that stone tools were generally used for scraping and smoothing plant materials and still retained residues of plant material on their sharpened edges. This study utilized use-wear variables, such as gloss and striation found on the sharp edges of stone tools, to determine their function (Fuentes et al. 2019; Ono et al. 2020a).

Similar research on the function of stone tools has been conducted in central Sulawesi, at the Topogaro Cave site. Stone tools found there were analyzed using the use-wear microscopic method. The purpose was to get an overview of human behavior in the past. Based on the study results, the stone tools were used to process organic materials such as bones and plants (Fuentes et al. 2021; Ono et al. 2020b). Furthermore, research at Tanggera Cave in Southeast Sulawesi in 2011 identified 100 stone flakes with simple manufacturing technology. Based on the results of microscopic analysis of traces of tool uses, 28 stone tools were used for scraping with variable use-wear in the form of concave fractures (conchoid) on the edge, and 72 stone tools were used for sawing or cutting with variable traces of use in the form of fractures and snaps along the edge (Nur 2018). In South Sulawesi, the function of Toalian stone tools from the archaeological sites of Ulu Leang 1, Leang Burung 1, and Leang Burung 2 Maros related to plant processing (Di Lello 2002; Sinha and Glover 1984). However, the description of the data from these sites has unclear details and does not represent the variation of use-wear on stone tools.

So far, research on Toalian stone tools, which are a type of Southeast Asian diagnostic tool, has focused on morphological and technological studies, while functional studies of stone tools utilizing use-wear analysis are limited. Research at Leang Batti in 2018 showed the existence of Toalian stone tools (Fakhri et al. 2018; Suryatman et al. 2020). However, the findings of these tools cannot be classified as stone tools used if only following the general assumption that the form of the stone tool can demonstrate its function. In fact, descriptions of form cannot explain stone tool function, so explaining the function of a stone tool requires research using microscopic analysis. Arguably, the technique of stone tool use-wear can help understand past human behavior (Pawlik 2009, 2010; Xhauflair and Pawlik 2010; Pawlik 2012; Xhauflair et al. 2016, 2017; Bordes et al. 2017). Therefore, in this article we report new data on the function of Toalian stone tools from Leang Batti. This article will attempt to address questions regarding traces of use-wear on Toalian stone tools and what activities occurred in the use of Toalian stone tools at Leang Batti.

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Site Information

Based on administrative boundaries, the Leang Batti site is located in Langi Village, Bontocani Subdistrict, Bone Regency, South Sulawesi, Indonesia, on the border between Langi Village and the area included in the Kahu Subdistrict. Part of Langi Village is a plantation located near limestone mountains, of the Tonasa Formation, and includes the area drained by the ancient Walannae River (Figure 1). The Walannae River has been a human settlement landscape for 180,000 years (Alink et al. 2017; Surytatman et al. 2016; Van Den Bergh et al. 2016b). The locational coordinates of Leang Batti are 4° 59' 7.1" N and 120° 01' 2.8" E with an elevation of 349 meters above mean sea level. The cave is 25-30 m wide at the mouth, with a height of 8-12 m and a length of 34-50 m.

Leang Batti is one among 69 known prehistoric caves that have been discovered since 2009, with periodic excavations between 2010-2013 and in 2018 by the Balai Arkeologi Sulawesi Selatan (Regional Agency for Archaeological Research in South Sulawesi Province) (Hakim 2010; Fakhri et al. 2018). In 2018, excavations opened five squares, labelled U3T2, U1B1, S7B1, S7B2, and S7T1 (Figure 2). The findings were mostly composed of stone artifacts, with some animal bones, including of rats and bats, in small numbers (Fakhri et al. 2018). Additionally, ochre pigments and pigment sprayers from bone were not discovered at Leang Batti. The stratigraphic layering shows three cultural layers. The first layer is 1a, found on each wall of the excavation square, having a fine sandy soil texture with a layer depth of 5-10 cm. Bone fragments and pottery were found in this layer. In addition, soil layer 1b was found in U1B1, having a sandy clay texture. The second layer consists of 2a and 2b. Layer 2a was found in squares U1B1 and U3T2, while layer 2b was found in squares S7T1, S7B1, and S7B2. Both layers 2a and 2b exhibit a very soft sand texture, and stone artifacts began to be discovered within these layers. The third layer includes 4a, located in U1B1, and 4b, found in S7T1, S7B1, and S7B2. Layers 4a and 4b have a clay-sand texture, with a thickness of 30-60 cm; stone artifacts found in these layers are generally larger. Squares S7T1, S7B1, and S7B2 also contain two sterile soil layers: layer 3, which has a fine sandy texture, and layer 5, which has a clay-sand texture (Figure 3). Leang Batti may have experienced erosion, leading to the transformation of its soil layers.

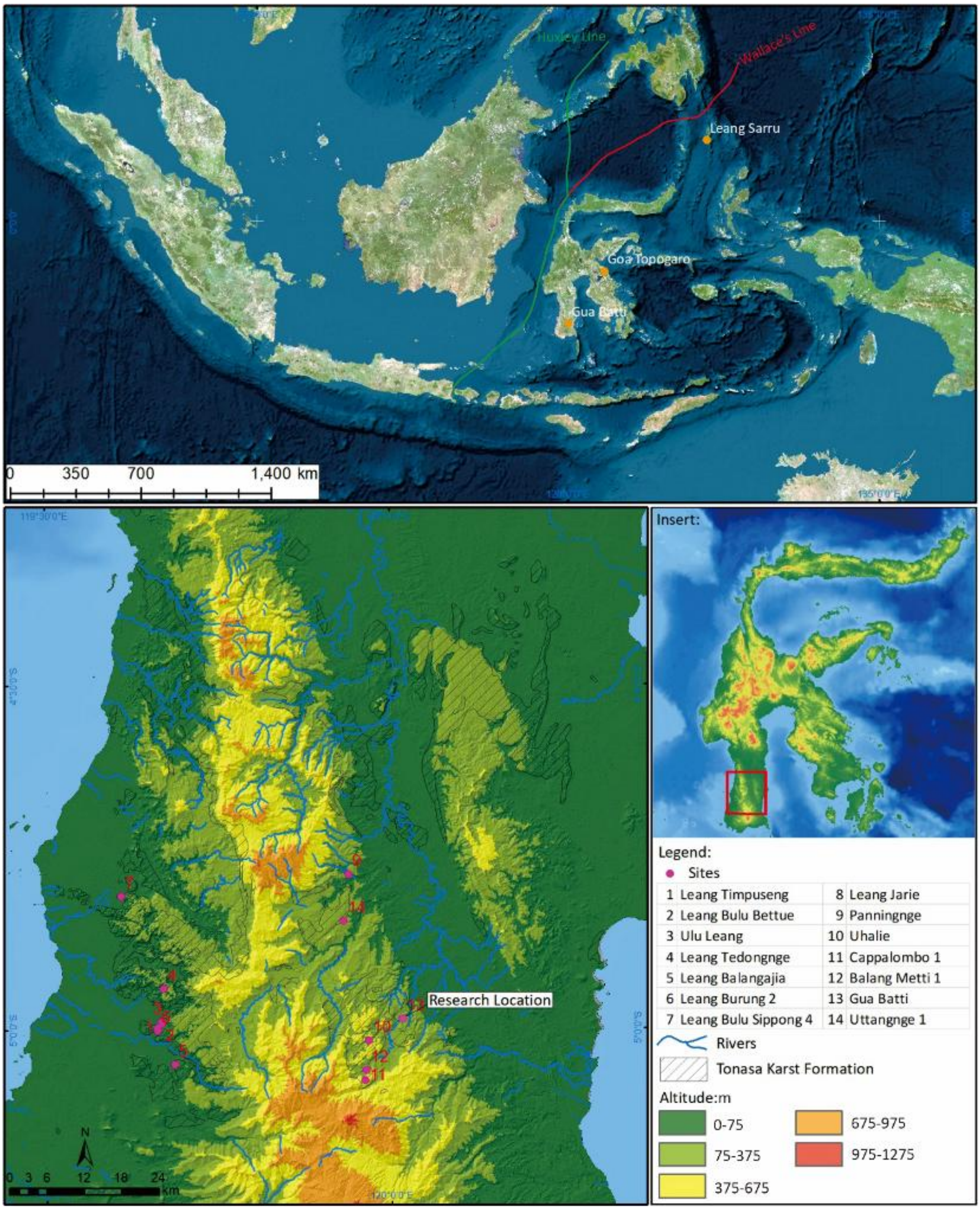

Fig. 1 Map showing the location of the research area, including Leang Sarru, Goa Topogaro and Leang Batti, within Wallacea Region, Sulawesi Island, Indonesia (A). Archaeological sites are distributed through the Tonasa Karst Formation, and Leang Batti is one of the sites in the highlands of South Sulawesi (B). Map data (source): Geologic map of the Pangkajene and western part of Watampone Quadrales and map of the Ujung Pandang, Bantaeng and Sinjau Quadrales, Sulawesi, 1:250.000. Map drawn by Sukamto 1982; Shuttle Radar Topography Mission 2014.

Fig. 2 Conditions of rock art in panel 1,7 and excavation box (S3T2, U1B1, S7B1, S7B2, S7T1) Source: Fakhri et al. 2018.

Radiocarbon dating of charcoal samples from layer 4a in box U1B1 indicates that Leang Batti has been occupied since the Early Holocene (9000-7000 cal BP). Occupation continued into the Middle Holocene, estimated to last from 7000 to 3500 cal BP (Figure 4). The dating is supported by the findings of stone tools in layers 2a and 2b, which tend to be smaller and more complex compared to the stone tools found in layers 4a and 4b (Fakhri et al. 2018; Suryatman et al. 2020).

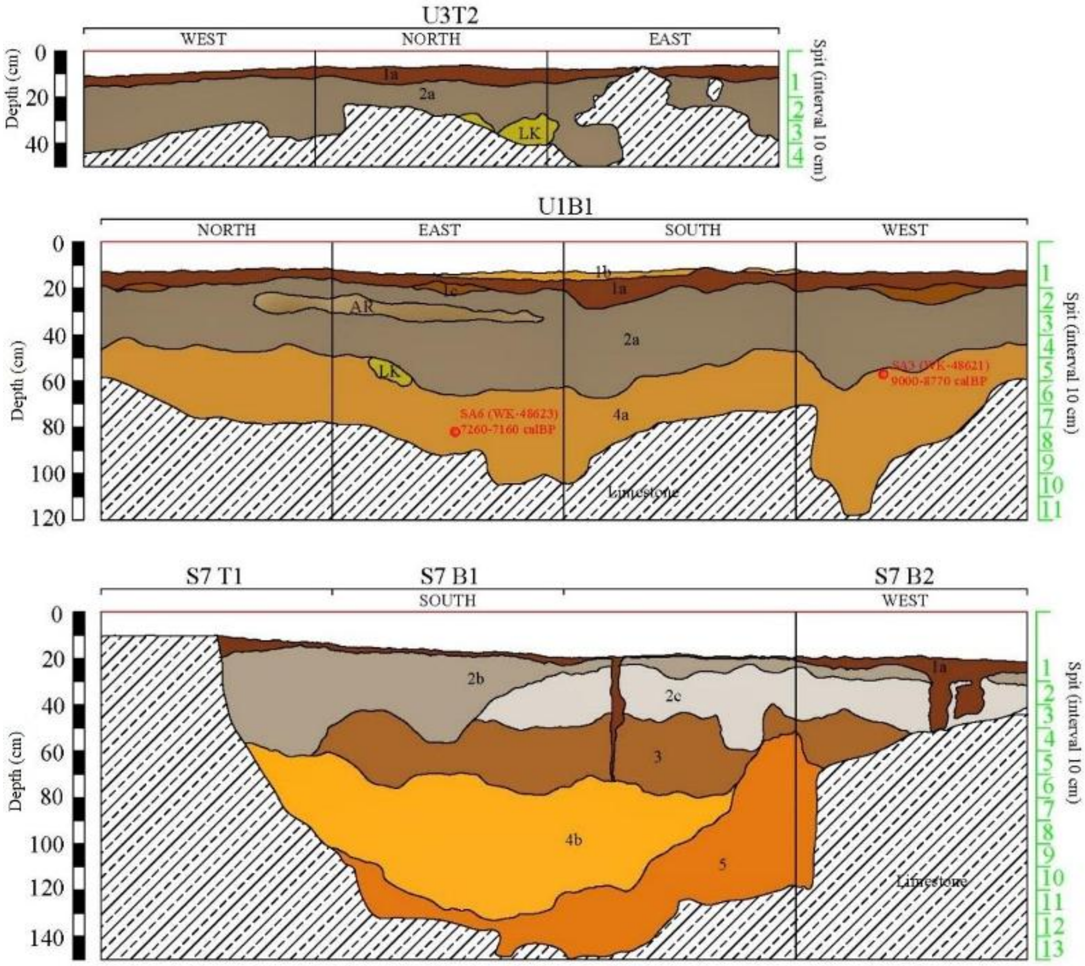

Fig. 3 Excavation box stratigraphy and sample positions for dating. Dating sample SA6 (WK-48623) obtained from box U1B1 layer 4a, and sample SA3 (WK-48621) obtained from box U1B1 layer 4a.
Source: Fakhri et al. 2018.

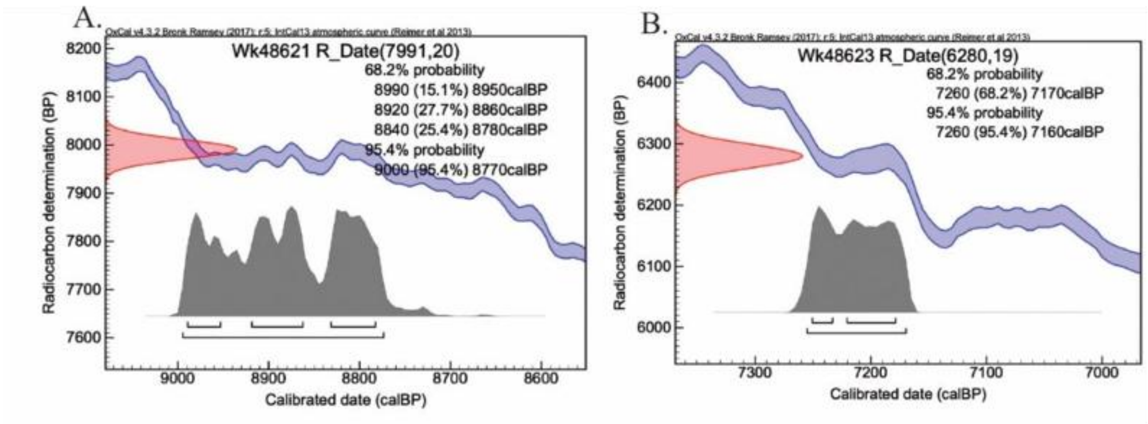

Fig. 4 Graph of radiocarbon dating and calibration results of charcoal samples SA3 (A) and SA6 (B) (WK-48621) (A) with measurements OxCal v4.3.2 Bronk Ramsey (2017) and Intcal atmospheric curve (Remier et al. 2013).
Source: (Fakhri et al. 2018)

Material and Methods

The stone artifacts analyzed in this study were obtained from excavations conducted at Leang Batti by the South Sulawesi Archaeology Center in 2018. The stone artifacts recovered total 1369 pieces, classified into two categories: flake stone artifacts and non-flake stone artifacts. Flaked artifacts include core 1.2% (n=17), debitage from unidentifiable flakes 61.6% (n=843), damaged flakes 31.6% (n=433), complete flakes 1.6% (n=22) and modified flakes 1.6% (n=22). Non-flaked artifacts consist of hammerstone 0.4% (n=5), manuports 1.8 (n=24), and manuport fragments 0.2% (n=3). (Table 1). In this project, the stone artifact collections sampled consisted of complete flakes (unmodified) (n=22) and modified flakes (n=22), due to the consideration of having sharp edges and potential areas of contact with worked materials (Kamminga 1982). Whole flakes were formed directly from the flaking of core stones, while modified stone tools were made with retouching techniques such as direct reduction or freehand, pressure, bipolar artifact, and backed bipolar. Striking the sharp edge of a flake artifact held by hand without using specific tools is referred to as the freehand technique. The pressure technique is carried out by pressing the sharp edge of the flake to be modified using specific tools. The bipolar technique involves striking the flake artifact against an anvil. These techniques are intended to shape the sharp edges of stone artifacts. (Maloney et al. 2014; Pargeter and Eren 2017; Y. Perston et al. 2021; Suryatman et al. 2017) This project resulted in the classification of modified stone tools (MST) and unmodified stone tools (UST) (Figure 5).

After passing the identification stage, stone tools were analyzed macroscopically and microscopically. Observations of physical characteristics include dimensions, material, edge profiles, and the location of sharpening (Andrefsky 2005). Material analysis is intended to provide information on the variety of materials used in the production of stone tools, such as chert, limestone, and volcanic materials. The edge profile aims to provide an overview of the sharp shape of stone tools such as being straight or flat, concave, and convex (Tringham et al. 1974). Then, the location of the stone tool sharpness was divided into left edge, right edge, proximal, and distal variables (Andrefsky 2005). The purpose of this analysis was to determine the location of the tool sharpness that was in contact with the material being worked. In microscopic analysis, three things were considered: microscope magnification, quantification, and photography (Olausson 1980).

Table 1 Count and percentages result classified stone artifacts

Category	Collection	Count (n)	Percentages (%) n/1369
Flaked Artifacts	Core	17	1.2%
	Debitage	843	61.6%
	Damaged Flakes	433	31.6%
	Complete Flakes	22	1.6%
	Modified Flakes	22	1.6%
Non-flaked Artifacts	Hammerstone	5	0.4%
	Manuport	24	1.8%
	Manuport fragments	3	0.2%
Total		1369	100

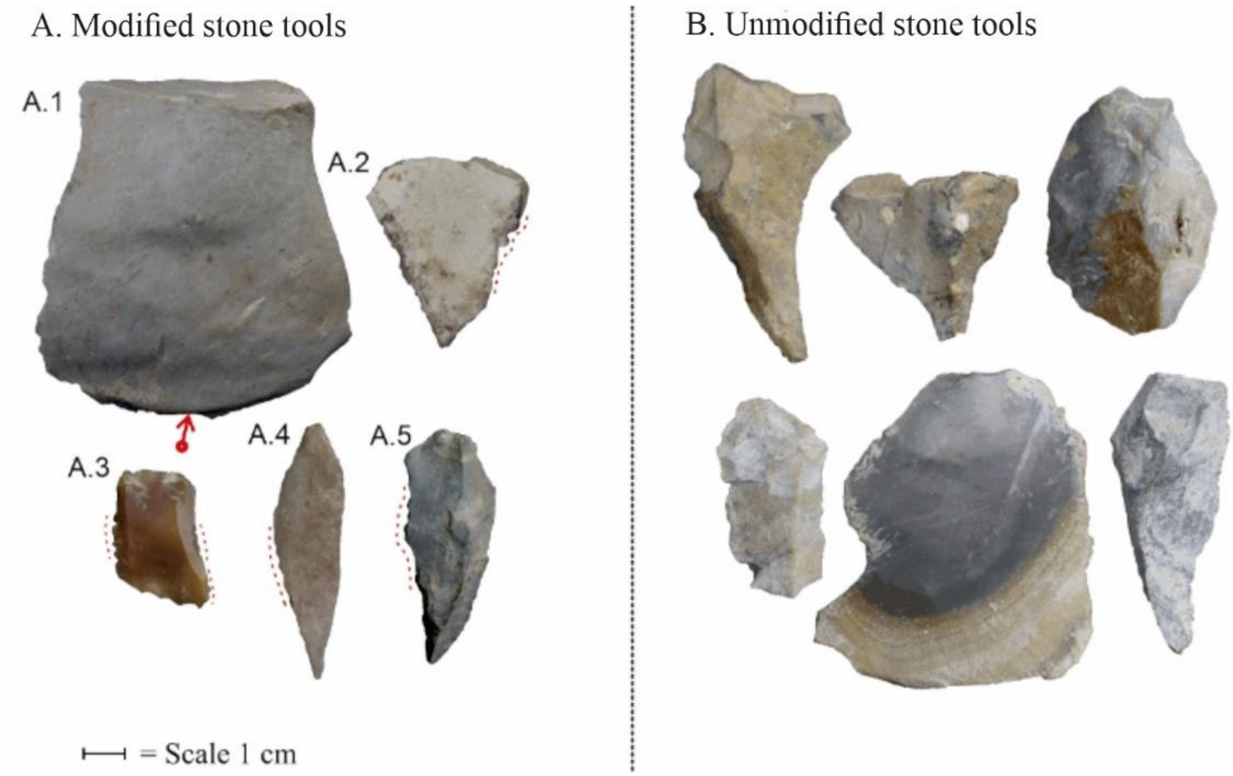

Fig. 5 Samples of modified stone tools (A), bipolar modification (A.1), pressure modification (A.2, A.3, A.4), backed bipolar modification, and unmodified stone tools (B)

Microscope magnification is divided into two, being low and high magnification (Odell and Odell-Vereecken 1980; Kamminga 1982). Microscope magnification is categorized into high and low. The choice of technique is adjusted according to research objectives. This study utilized a Dino-Lite Pro 2.0 microscope with low magnification to examine variables such as micro flakes, micro fractures, striations, gloss, and rounding (Kamminga 1989; Hardy and Garufi 1998; Fullagar et al. 2006; Marreiros et al. 2015), which are observable under such magnification (Odell and Odell-Vereecken 1980). Quantification or observing and recording micro fractures on the sharp side of a stone tool includes the length and depth of the fracture. To differentiate between fractures created due to usage compared to fractures resulting from the modification process (retouching), stone tools are observed considering the size and orientation of the fractures. If the fractures have almost the same size, orientation, and the distance between fractures, this can help indicate that the fracture is probably caused by the modification process rather than by wear caused by usage (Kamminga 1982). In the final stage, stone tools will be illustrated in the form of photomicrographs to show the use-wear of stone tools in detail.

Results and Discussion

In this article, the processing of stone artifact data focuses on the classification results of modified (MST) (n=22) and unmodified (UST) stone tools (n=22). Based on measurement results, generally unmodified stone tools (UST) are larger than modified stone tools (MST). The average size of unmodified stone tools is 40.7 mm length, 32.5 mm width, 11.3 mm thickness, and 13 g weight, while the size of modified stone tools is 33.9 mm length, 25.5 mm width, 8.7 mm thickness, and 11.9 g weight (Table 2). Based on size, the unmodified stone tools seem to have been prepared for material processing.

Table 2 Measurements of samples with metrical variables as length, width, thickness and weight

Metrical Variables	MST (mm)		UST (mm)	
	Mean	Median	Mean	Median
Length (mm)	33.9	32.1	40.7	41.5
Width (mm)	25.5	22.9	32.5	33.0
Thickness (mm)	8.7	7.1	11.3	10.4
Weight (g)	11.9	6.3	13.0	12.7

Information on the edge profile of stone tools is also important because it is always indicated as a place where the material being worked on intersects. Based on the analysis, the edge profile of stone tools is dominated by a combined concave and convex shape of 27.27% (n=12). Objects shaped concave, straight, and straight-concave combined to a total of 18.18% each (n=8), while convex shapes form 13.64% (n=6) and the combined straight-convex shapes form 4.55% (n=2) (Table 3). In addition, information on the location of sharpness on both edges showed a dominance with a percentage of 36.6% (n=16). The location of sharpness on all edges is 20.45% (n=9), left-right and distal edge 15.91% (n=7), left edge and right edge with each percentage 9.09% (n=4), right-distal 4.55% (n=2), and the distal edge and left-distal edge, comprising 2.27% each (n=1) (Table 3). The dominance of stone tools with combined edge profiles and sharpness on both lateral sides suggests that stone tools from Leang Batti were likely multifunctional.

Table 3 Percentage of edge profiles and sharpening locations of stone tools n/44

Variable		Count (n)	Percentages (%)
Edge Profile	Concave	8	18.8%
	Convex	6	13.64%
	Straight	8	18.8%
	Concave and Convex	12	27.27%
	Straight and Concave	8	18.8%
	Straight and Convex	2	4.55%
Total		44	100%
Sharpening Location	All edges	9	20.45%
	Left and right edge	16	36.6%
	Left edge	4	9.09%
	Left edge and distal	1	4%
	Distal	1	2.27%
	Left -right edge and distal	7	15.91%
	Right edge	4	9.09%
	Right edge and distal	2	8%
Total		44	100%

The results of our analysis also show that the raw materials of the 44 stone tools were generally made from chert, with a total of 79.55% (n=35), other materials consist of limestone 13.64% (n=6), volcanic rock 4.54% (n=2) and jasper 2.27% (n=1) (Figure 6). The dominance of chert in stone tools as indicated by the data reflects the ability of early humans to select high-quality materials. Chert contains high levels of silica (SiO_2), which allows for the production of sharp and durable edges during the modification process. The chert tools found at the Leang Jarie site are suspected to have been sourced from a seasonal river located 3.5 km from the site, near the Maros-Bone axis road

(Suryatman 2021; Suryatman et al. 2022). Chert tools have also been discovered at several other sites in South Sulawesi, such as Leang Burung 2 (Brumm et al. 2018; Glover 1981) and Leang Jarie (Suryatman et al. 2019).

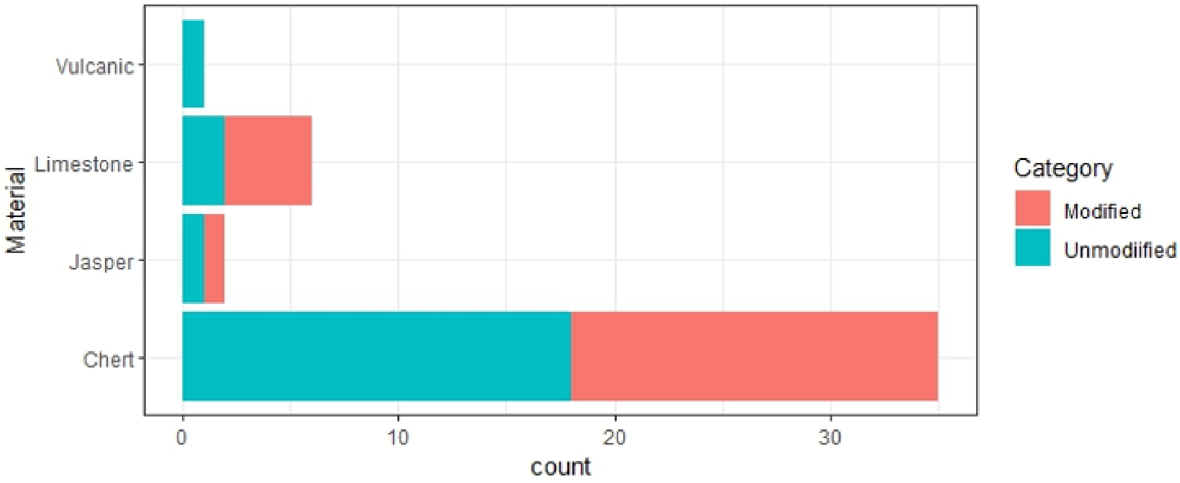

Fig. 6 Comparison of material quantity of stone tools

In the microscopic use-wear analysis, the types of variables analyzed included fractures, striations, gloss, rounding, and residue (Fullagar et al. 2006; Kononenko 2011; Marreiros et al. 2015). The results show that the types of wear of Leang Batti stone tools are dominated by gloss variables 89% (n=39), steep fracture 59% (n=23), and shallow fracture 36% (n=16). Furthermore, use-wear in the form of striations was also observed on the sharp edges of Leang Batti stone tools. Transverse striations 73% (n=32) were more dominant than longitudinal striations 29% (n=13), due to the different intensities of activity. The minimal use-wear in the shape of rounding was observed to comprise 18.2% (n=9) of the samples, suggesting that stone tools at Leang Batti were not used intensively for scraping, cutting, splitting, or sawing.

The analysis of 44 stone tool samples from Leang Batti revealed their association with various activities, including cutting or scraping, splitting, and sawing. Scraping was the dominant activity, accounting for 64% (n=28) of tools, characterized by transverse striations, fractures, gloss, and residue. Use of stone tools for splitting comprised 11% (n=5) of the samples, being characterized by steep fractures, gloss, and material accumulation on the tool edges. Sawing was the least common activity, representing only 2% (n=1), with use-wear attributes such as longitudinal striations, serrated fractures on the edges, gloss, and rounding. Variations in striation orientation are influenced by differences in tool use or activity type (Kononenko 2011; Semenov 1964). For 23% (n=10) of samples, it was not possible to determine their primary usage.

Stone tool use activities such as cutting, scraping, sawing, and splitting materials are integrated practices that lasted from the late Pleistocene to the mid-Holocene (Kononenko 2011; Sillitoe and Hardy 2003). Stone tools from Tabon Cave in the Philippines have been identified as being used for scraping and splitting plants, likely for the production of plant-based tools such as baskets and ropes (Xhauflair et al. 2023). Similarly, stone tools found at Leang Sarru on Talaud Island are interpreted to have been used predominantly for scraping activities (Fuentes et al. 2019), reflecting a pattern of stone tool use that is comparable to that observed at Leang Batti.

Fig. 7 Stone tools from Leang Batti UST (A, D, G, J) and MST (M) use-wear in the form of fractures on the tool edge (B, E, H, K) gloss on the tool edge due to intense use (C, L, N), transverse striations (F, H, O), longitudinal striations (L) (Fuentes et al. 2021), rounding (H), and suspected residual material still bound to the tool edges (B, C, E, F, H, I).

The use of microscopic use-wear analysis has proven to be effective in solving problems regarding stone tool function in Southeast Asia (Fuentes et al. 2019, 2020; Fullagar et al. 2006). Our research has confirmed that not only modified stone tools (MST) (e.g. retouch) were used, but unmodified stone tools (UST) were also used to support past human survival at Leang Batti. The stone tools found there were used to process soft to hard materials, including plants and animals. UST seems to have been prepared for this activity. The stratigraphic data of Leang Batti support this assertion with the discovery of associations between stone tools and fragments of vertebrate fauna such as anoa (Bubalus sp) and pigs (Sus) (Hakim 2010; Saiful and Hakim 2016; Fakhri et al. 2018). It is clear that at the time humans occupied Leang Batti, stone tools were used in faunal processing. Several Toalian sites in South Sulawesi that have been studied also show a close relationship between the association of stone tools and faunal bone fragments (Fakhri et al. 2021; Hasanuddin 2017). Human interactions with animals such as pigs and anoas were not new in the Holocene period, because in the Pleistocene the presence of fauna was illustrated in rock-art on prehistoric cave walls in South Sulawesi (Aubert et al. 2014, 2019; Brumm et al. 2021).

In addition, the presence of use-wear in the form of a gloss on the edge of stone tools is a strong attribute to the interpretation of plant processing. In the context of Southeast Asia, several functions of stone tools identified, and the reconstructed activities, involved the processing of plants (Borel et al. 2013; Fuentes et al. 2019, 2020; Kononenko 2011; Mijares 2008; Pawlik 2010; Xhauflair et al. 2020, 2023; Xhauflair and Pawlik 2010). The gloss on the edge of stone tools at Leang Batti has similarities with the gloss of stone tools from the Aisitau Kuru (Jerimalai Cave) site of Timor Leste (Marwick et al. 2016), from Leang Burung 2 Maros South Sulawesi (Brumm et al. 2018), from Topogaro Cave Central Sulawesi (Fuentes et al. 2021), and from Liang Bua East Nusa Tenggara (Hayes et al. 2021). Previous experimental studies indicate that stone tools were used for cutting, rasping, and splitting siliceous plant species (e.g. bamboo and rattan) (Fuentes et al. 2021; Kononenko 2011; Xhauflair et al. 2020). Plant processing activities in this case are not always related to subsistence or food procurement. However, it can also be related to the procurement of tools, such as stone tools used to make knives and spears from bamboo (e.g. Kononenko 2011; Kononenko and Kajiwara 2003). Therefore, on the basis of the results of the microscopic use-wear analysis (Fig.7), we suggest that the stone tools discovered at Leang Batti have relevance to plant and fauna processing activities. Stone tools are strongly suspected to have been used by hunter-gatherers at Leang Batti (Toalian) to support their activities for basic survival.

Conclusion

Forty-four stone tool samples from Leang Batti, consisting of 22 MST and 22 UST, showed evidence of use activities such as fractures, striations, glossing, rounding, and residue. Leang Batti stone tools were used in various activities such as cutting, scraping, splitting, and sawing materials, ranging from soft to hard and including both flora and fauna. Based on microscopic analysis, these stone tools are also closely related to the integrated activity of plant processing. It seems that the unmodified stone tools (UST) of Leang Batti were also made and prepared as part of this process. Plant processing using stone tools in Leang Batti is not always related to subsistence, but can also be associated with the activity of procuring tools from plant materials; all of this as a form of human adaptation to their environment.

The results of this study also add to the limited understanding of the function of stone tools in Southeast Asia, especially in the Wallacea Island region. It is important to recognize that use-wear information on stone tools can be used to address problems regarding human activities in the past, be it how tools were used, what materials were used, what activities occurred, and even the social structure of the community. Our research has not yet provided use-wear data, such as the types of residues or materials that came into contact with Toalian stone tools. Future studies should build on this to enhance our understanding of how Toalian stone tools were used.

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