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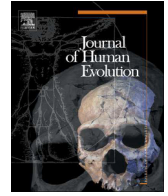
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The lithic assemblage from the 700,000-year-old butchery site of Kalinga (Luzon Island, Philippines): New insights into technological variability in the Early Paleolithic in Island Southeast Asia

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ABSTRACT

Despite a long history of archaeological and paleoanthropological research, our understanding of the Early Paleolithic in Island Southeast Asia remains limited as only a few sites with clear stratigraphic contexts—Mata Menge (Flores Island), Ngebung 2 (Java Island), Calio and Talepu (Sulawesi Island)—have been documented. This scarcity of well-stratified assemblages has led to a poor characterization of technological variability and cultural sequences, which mainly rely on surface collections and early typological classifications/facies (e.g., Pacitanian, Cabengian, Cabalwanian, Liwanian, Arubian, etc.). These classifications, mostly based on a handful of cobble artifacts, have long obscured the technological diversity of early hominin settlements in the region. The Kalinga site (Luzon Island, Philippines), dated to ca. 709 ka, provides a rare opportunity to examine an Early Paleolithic assemblage in a secure stratigraphic context. Previous studies offered only a brief description of the lithic assemblage. In this article, we present the first comprehensive technological and structural analysis of the Kalinga lithic assemblage from two archaeological layers (units F and Y), applying analytical approaches developed for West Eurasian Early Paleolithic contexts. We also reassessed and questioned two previously defined Philippine 'lithic facies'—Cabalwanian and Liwanian—based on surface finds in the Cagayan Valley since the 1930s. By comparing the technological characteristics of Kalinga artifacts with these assemblages, our aim is to clarify their variability, evaluate the validity of typological distinctions, and recontextualize Philippine lithic industries within broader Asian Paleolithic frameworks, with particular focus on small flake technologies. This study contributes new data on early hominin technological behaviors in Southeast Asia and provides a basis for revising cultural classifications built on limited evidence.

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1. Introduction

1.1. A brief history of the Early Paleolithic in Island Southeast Asia and the Philippines

Our knowledge of the Early Paleolithic of Island Southeast Asia is limited to a handful of archaeological sites with clear stratigraphic context (Sémah et al., 2014): the 1 Ma Wolo Sege sites, the 800 ka Mata Menge and Boa Lesa sites in the So'a Basin on Flores Island (Brumm et al., 2006; van den Bergh et al., 2022), the ca. 800 ka Ngebung 2 site on Java Island (Sémah, 2001), the 709 ka site of Kalinga on Luzon Island (Ingicco et al., 2018, 2020), and the Calio and Talepu sites, dating back possibly to 1.48 Ma and 194 ka, respectively, on Sulawesi Island (van den Bergh et al., 2016; Hakim et al., 2025).

This lack of data has resulted in an unknown variability of the lithic productions scheme within each of these islands, for which most of the hypotheses are mainly built on surface collections, leading to several preconceived ideas on limited grounds and to a poor periodization of cultural evolution in this region (Bellwood, 1997, 2017; Moore and Brumm, 2007; Pawlik and Fuentes, 2023; Hakim et al., 2025). Yet, the period and area are crucial as they represent the earliest colonization of islands (either continental or oceanic islands) by hominins worldwide.

Most of the lithic facies terms created by archaeological pioneers in the region to characterize typological changes are still in use today: Pacitanian (Movius, 1944), Cabengian (Van Heekeren, 1949, 1955), or Cabalwanian (Von Koenigswald, 1958). These terms are linked to old discoveries of a few or more stone artifacts found outside any contexts, the significance of which, in terms of traditions, has generally been questioned, if not disregarded (Sémah et al., 2014). Choppers, chopping tools, polyhedrons, spheroids, and bolas (Cabanès et al., 2022), unifacial, and bifacial artifacts made of cobbles and large flakes are the recognizable components of these lithic 'industries.' In contrast, the lithic artifacts recovered from the aforementioned sites also highlight the existence of flake tools of small dimensions in more or less significant proportions, somehow mimicking the small tool assemblages of the European Early Paleolithic, which are currently at the center of attention (Aureli et al., 2016; Rocca et al., 2016; Grimaldi et al., 2020; Capellari et al., 2021; De Caro et al., 2025).

In this context, any description of a Southeast Asian lithic assemblage recovered in a clear stratigraphic context is valuable. The recently discovered lithic assemblage of Kalinga in the northern part of the Philippines has only been the subject of a short description so far (Ingicco et al., 2018, 2020, 2022). In this paper, we provide a comprehensive technological and structural analysis of the stone objects recovered at the Kalinga site from two distinct archaeological layers (units F and Y). Such an analytical approach has never been used for Southeast Asia's Early Paleolithic so far, although it has proven to be particularly pertinent for such archaeological assemblages elsewhere in Europe and in China (Bonilauri, 2010; Rocca, 2013; Zhou, 2021; Capellari, 2023; Guibert, 2024).

In the Philippines, three cultural traditions or 'lithic facies' have been described for the Paleolithic from a small number of stone artifacts. Two of them have been described from surface finds made in the area where the Kalinga site is located and which is broadly known as the Cagayan Valley. The Paleolithic value of this part of the Philippines has been known since 1936 in a report made by two schoolteachers to Lawrence L. Wilson, a mining prospector and anthropologist (Manuel and Manuel, 1995). The report was also sent to the head of the University of the Philippines Department of Anthropology, H. Otley Beyer (Von Koenigswald,

1958; Tobias, 1999). Beyer's collection of faunal remains from Cagayan prompted the renowned paleontologist Ralph von Koenigswald to visit the area in late 1957 (Pawlik and Ronquillo, 2003). He described, in a two-page preliminary report (von Koenigswald, 1958), what he called the Cabalwanian Industry based on 'four to five' unifacial and bifacial cobble tools. These were recovered at the southern tip of the Cabalwan anticline on the cattle ranch property of Pedro Espiñosa, which he surveyed under the guidance of Lawrence Wilson. Von Koenigswald (1958) added that this set of macro-tools significantly differed from artifacts that are commonly associated with the Acheulean that he discovered in Java and which were named Pacitanian by Movius (1944). These surface finds, made in 1953, led the National Museum of the Philippines to establish the Cagayan Valley Archaeology Project with extensive explorations of the area, starting in the early 1970s (Fox, 1978). During these surveys, supervised by Robert B. Fox and Jesus T. Peralta, stone artifacts were collected from the surface of 64 localities (Fox, 1971, 1973; Fox and Peralta, 1974; Wasson and Cochrane, 1979 mention 68 localities). Subsequently this led to the excavation of three of them between 1971 and 1972: Espiñosa locality 1, Espiñosa locality 4, and Madrigal locality 12 (Fox, 1978). At the Espiñosa locality 1 and Madrigal locality 12, the sediments were barren of any fossils or stone artifacts, except for what has been described as a waste flake from the topsoil. At the Espiñosa locality 4 (Fox, 1978; Bondoc, 1980), two stone artifacts described by Fox (1973, 1978) as scrapers were recovered from a silty layer at 3.13 m below the datum point and 10 m above elephant bones recently dated between 834 ± 80 ka and 623 ± 45 ka (Bondoc, 1980; Wasson and Cochrane, 1979; Lambard et al., 2024). The artifactual character of those finds was, however, questioned by Moser (2001: 133) in his review of the Cagayan Valley lithic collections.

Twenty one analyzed localities out of the 64 identified by the National Museum of the Philippines teams resulted in a collection of 971 surface stone artifacts. Among these, Fox (1978) counted 93% were flakes compared to cobble tools, which differed significantly from von Koenigswald's definition of the Cabalwanian Industry from the same area. That prompted Fox to coin the term 'Liwanian Flake Industry' (Fox, 1973, 1978, p. 72) for these flake assemblages, named after the nearby vicinity of Liwan. The Liwanian typology was briefly described by Fox (1978), but almost no technological information was provided for the material, perhaps due to Fox's untimely death in 1985. Liwanian flakes are characterized by numerous retouches used to standardize the final products into a series of identifiable artifacts such as scrapers, end scrapers, as well as denticulates.

At c. 300 km distance south of the Kalinga site, a horse-hoof core tool was reported among a set of five cores with various preparation and reduction techniques, including a core on a large flake, found at the open site of Arubo 1 in the province of Nueva Ecija (Pawlik, 2002, 2004, 2021). In this site, only 18 of the 200 lithic finds recovered from the surface during a field school were identifiable artifacts; the rest included shattered and undeterminable chert fragments. Arubo 1 is interesting for its combination of core and flake tools with one 'Acheulean-like' hand axe. This prompted Pawlik (2005), as part of his critique of the practice of creating a new technocomplex or 'lithic culture' for singular sites and finds, to provocatively introduce the term 'Arubian' for this assemblage.

Cabalwanian, Arubian, and Liwanian are three assemblages mostly based on a limited number of surface finds, respectively, described as a chopper- and chopping-tool unifacial industry for the two formers and as a retouched flakes industry for the latter (Fox, 1978). They could be attributed in the evolutionary scheme of Clark (1969), to mode 1, an Acheulean mode 2 industry (Pawlik, 2002), and a core-flake industry, which could be compared

typologically with the European Middle Paleolithic or the African Middle Stone Age (Fox, 1978; Moser, 2001).

While some authors (Pawlik, 2002, p. 9) considered the Cabalwanian (as described by Fox (1978)) as controversial, a brief reconsideration of the 'Cabalwanian' and 'Liwanian' artifacts collected in the 1970s and partly described by Fox (1978) was made by Moser (2001) in his research on the Hoabinhian technocomplex industry. Moser (2001, pp. 133–134) did not question the genuineness of the stone artifacts or their postulated Middle Pleistocene age. He did raise some doubts about the presence of retouches, which were evaluated by Fox and Peralta (1974) as affecting about 30% of the assemblage, and attributed these to edge damage caused by taphonomic processes. Furthermore, the validity of the Liwanian concept as a flake industry in opposition to the Cabalwanian made of cobble tools could be questioned. Fox (1973, 1978) attempted to define the term while lengthily describing the typology of the Cabalwanian (Fox and Peralta, 1974, p. 109), but without providing any descriptions for the flake tools, which certainly explains why this tradition was not considered by any other scholar after him. The typo-technological distinction between the Cabalwanian and Liwanian still remains unclear today.

Therefore, the aim of this paper is twofold. First, we attempt to describe the lithic artifacts recovered during the excavation of the early Middle Pleistocene site of Kalinga, utilizing a combined petrographic, technical, morphometric, and structural analysis as well as an examination of potential use-wear traces. Secondly, in the light of the technological characteristics of the Kalinga assemblage, which is the only one of that time period originating from a secure context in the Philippines so far, we re-evaluate the variability of the surface collections retrieved in the Cagayan Valley since the 1970s, contextualizing them within the Paleolithic of Asia, with a special attention to flake tools. Accordingly, this paper aims to address the following research questions: Which knapping strategies, reduction systems, and percussion techniques were employed by early hominins at Kalinga? What role do small flake technologies play within the Kalinga assemblage, and how significant are they compared to cobble-based and macro-tool components? How does the Kalinga lithic assemblage compare technologically with other Early Paleolithic assemblages from Island Southeast Asia? And what do the technological choices documented at Kalinga reveal about early hominin adaptive strategies in insular environments during the Early-Middle Pleistocene transition?

1.2. Geological and chronological context of the Cagayan Valley

There is a distinction to be made between the Cagayan Valley administrative region and the Cagayan Valley as the main geological catchment basin in Luzon Island and the Philippines as a whole. The area we are focusing on straddles the Cagayan and Kalinga Provinces. Furthermore, the term 'Cagayan Valley' has been used indifferently to refer to the sites within the fluvial sediments of the Cagayan River as well as to the cave sites of the Peña Blanca karst on the east of the river (Mijares, 2005; Mijares et al., 2010). Here we limit the definition of the term 'Cagayan Valley' to the fluvial sediments constituting the western bank of the river where the anticlines have developed and where our findings all come from (Lambard et al., 2024).

The site of Kalinga (17° 33'45.0318" N, 121° 33'35.7372" E) is located at the southern tip of the Cabalwan Anticline in a sub-horizontal layering near the axis of the weakly folded anticline (Ingicco et al., 2018). Stratigraphically, the site's layers pertain to the Awidon Mesa Formation, a Pleistocene sequence of alluvial stream deposits intercalated with dacitic volcanoclastic and

pyroclastic deposits (Ingicco et al., 2020; Lambard et al., 2024). Previous detailed sedimentary facies studies of the basin, including the Cabalwan Anticline (Mathisen, 1981; Mathisen and Vondra, 1983), suggest that the depositional environment of the Awidon Mesa Formation was characterized by braided rivers on an alluvial fan system. This alluvial fan formed in response to uplift in the Cordillera Central to the west. The apex of this fan is thought to have been near the point where the present paleo-Chico River Valley widens into the Cagayan Valley. During periods of volcanic activity in the catchment area of the Chico River, large amounts of pyroclastic flows and lahars were fed onto this alluvial fan system. The ignimbritic layers are characterized by a dacitic composition, and one of the defining characteristics of the Awidon Mesa Formation is the occurrence of reworked pyramidal volcanic quartz crystals in the clastic sediments. Continued east-west compressional deformation led to the uplift of the Pangul Anticline to the South and West of the excavation area, as well as the Cabalwan and other north-south trending anticlines in the Cagayan Valley. This uplift is thought to have redirected the Chico River to the north in its present-day configuration, thus bringing deposition on the westward prograding alluvial fan system as exposed in the Cabalwan Anticline, to a halt (Mathisen, 1981).

Since then, the upper part of the Awidon Mesa Formation has encountered several periods of erosion and aggradation which have shaped the present-day landscape, where the Formation outcrops into rolling knolls. Therefore, the old alluvial deposits of the Awidon Mesa Formation are accessible nowadays through the surface of the slopes of these small hills. These deposits are sometimes pebbly, are sometimes sandy, or even contain finer deposits, within or on the surface of which some prehistoric stone artifacts and fossil bones can be discovered. Several surveys and five excavations have been conducted since the 1970s. The site of Kalinga is the latest of this series and has been excavated yearly between 2014 and 2023, except for 2020 due to the COVID-19 pandemic and consequent lockdown. From a chronological perspective, a new coupled electro-spin resonance (ESR), $^{40}\text{Ar}/^{39}\text{Ar}$, and U/Pb dating cross-study conducted on the Awidon Mesa fluviovolcanic deposits in the central Cagayan Valley suggests that the early human settlement of the region dates back to at least 796 ± 70 ka (Lambard et al., 2024).

1.3. Stratigraphic units of the Kalinga site

The two excavation areas of the Kalinga site are, respectively, situated on the southern and northern slopes of a small southeast-northwest micro-valley with seasonal runoff waters (Ingicco et al., 2018, 2020).

1 The main trench of the excavation accounts for 42 m² down the southern slope of a small hill. From bottom to top, four stratigraphical units, called A, F, G, and H, are delimited along this slope. The lowermost one, unit A, is a coarse- to medium-sandy, indurated fluvial layer, the deposition of which was dated by ESR to 727 ± 30 ka. Unit A contains river-transported plagioclases that formed during a volcanic eruption we dated by the $^{40}\text{Ar}/^{39}\text{Ar}$ method to 1.05 ± 0.28 Ma ago.

Unit A was overlaid by unit F, a massive, very poorly sorted fine-grained mudflow layer. In this unit F, the richest one, fossils of *Varanus salvator*, *Stegodon luzonensis*, and *Rusa cf. marianna* were recovered, along with an almost complete but disarticulated carcass of the Philippine rhino *Nesorhinus philippinensis* (Ingicco et al., 2018; Antoine et al., 2021). The enamel of a rhino premolar from this unit F was dated by combined uranium/thorium and ESR method to 709 ± 68 ka. Unit F delivered some stone artifacts associated with bones on the

same level (Ingicco et al., 2018, 2022). The archaeological material recovered from unit F represents a snapshot of hominins' butchery of a very large game (Ingicco et al., 2020).

Above this unit was unit G, thick cross-bedded coarse sandy fluvial layers. Unit G had a normal magnetic polarity and was dated by ESR on quartz to 701 ± 70 ka, consistent with units A and F data. The volcanic plagioclases from this fluvial unit were further dated to 1.007 ± 0.29 Ma ago by $^{40}\text{Ar}/^{39}\text{Ar}$ (Ingicco et al., 2018).

On top of unit G was a paleosoil, unit H, which constituted the last sedimentary unit of the Southern hill.

- 2 Excavation squares on the northern slope, representing a total of 50 m^2 , were also opened. The sedimentary units F, G, and H were also identified on that slope, along with an additional sedimentary unit named unit Y, positioned on top of unit H and therefore the youngest one. This unit Y is a cross-bedded medium to coarse very white dacitic sand that was not preserved on the Southern slope. Unit Y was deposited between 365 ± 30 ka and 273 ± 20 ka (Lambard et al., 2024) and delivered some stone artifacts associated with a few unidentifiable fragments of very damaged bones indicating fluvial transport and the acidity of the sand. Considering the sandy sediments which were deposited by a small river and the taphonomic conditions of the fossil bones, one cannot exclude that the few recovered stone artifacts were transported as well and therefore the ESR date for this unit Y should be regarded as a minimal age for the archaeological material.

2. Materials and methods

The aim of this paper is therefore to characterize the Kalinga lithic assemblage in greater detail. It is a small assemblage but, so far, the only dated Middle Pleistocene set of tools in the Philippines and one of the very few in the entire Island Southeast Asia (Ingicco et al., 2022).

For a comprehensive study of the lithic assemblage of the Kalinga site, we describe systematically the raw materials and our survey of potential procurement areas, as well as the technical characteristics and production sequence of the artifacts. We also try to understand the knapping strategies through experiments

and identify the final goal for some artifacts by analyzing their structure, their systemic organization, and searching for the presence of any use-wear.

2.1. Petrography

Studies made during the last 30 years on several Early and early Middle Pleistocene sites in Africa and Eurasia have shown that hominins have mostly collected the siliceous rocks they have knapped and used, either directly on the locality or within local source areas (Féblot-Augustins, 1990, 1994; Byrne, 2004; Braun et al., 2009; Harmand, 2009; Mgeladze et al., 2010; Harmand et al., 2015; Mosquera et al., 2015). We therefore expect that the Kalinga toolmakers would have gathered the siliceous material within the coarse fossil fluvial formation near the site. Consequently, the potential raw material gathering areas were searched for within the local fossil fluvial formations rich in pebbles and cobbles.

A river terrace, hereafter named Cobble Terrace, potentially deposited by the Cagayan River during the Pleistocene as part of the Awidon Mesa Formation was identified in the vicinity of the site (Fig. 1). The sampling was made following the method already used by some of us (Mgeladze et al., 2011; Despriée et al., 2016, 2017). The raw material was sampled within two 1-m^2 areas, R1 and R2, with two different strategies. R1 corresponded to the systematic collection of any pebbles or cobbles (e.g., larger than 40 mm, considering the size of the flakes recovered at Kalinga). R2 consisted of the collection made for the specific use in the knapping experiment, and therefore, the blocks were selected for their aptitude to be knapped. R1 and R2 were both used for petrographic study. This strategy resulted in a sample of 250 cobbles from this alluvial deposit. On the surface of the Cobble Terrace, several knapped stone artifacts were also recovered and collected.

The lithic samples have then been sorted by their granulometric size—pebbles, cobbles, and blocks (after Wentworth, 1922, 1923)—and then by their morphotypes—ovoid, prismatic, or polyhedral volumes. Nodules are defined as sedimentary siliceous elements for which part or all of the cortex is still present.

Every lithic sample was measured for its length, width, and thickness. From these measurements, the elongation index

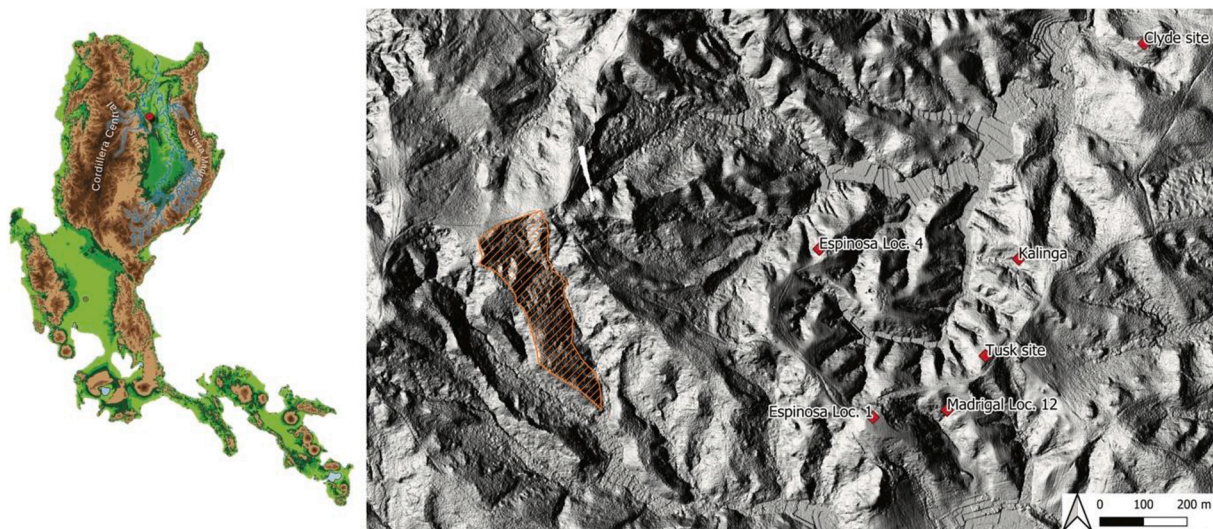


Figure 1. Map of Luzon Island (left), pointing to (red dot) the site of Kalinga of which a zoom-in is presented (right) also showing some of the localities in the Cagayan Valley mentioned in the text and delineation of the 'Cobble Terrace' (orange-striped area). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(length/width), flatness index (width/thickness), and smoothness index (defined as length of the chord of the arc circle in millimeters) were calculated (Cailleux and Tricart, 1959; Despriée and Lorain, 1972).

Physical stigmata and chemical depositions visible on natural surfaces of these 250 samples were studied through naked-eye and magnifying-glass observations. These characteristics are informative regarding modes of transportation as well as the variability of the deposition conditions and, in some cases, the origins of the raw material. Groundmasses (i.e., the mineral matrix of the rocks) were described on fresh breaks: granulometry, vesicles, cracks, recrystallization, and lateritization allowed us to characterize the possible nature of the stones and to confirm their geological background.

To compare the samples to the artifacts gathered on top of the Cobble Terrace and those associated with the rhino skeleton, the natural surfaces of the two prehistoric assemblages were described, and groundmass was determined from the knapped surfaces devoid of any patina or iron deposit. Twenty cobbles and 10 prehistoric artifacts from the Cobble Terrace were selected for petrological comparison with 23 artifacts from the Kalinga site.

Additional macroscopic study was performed after sawing and polishing the surfaces of the cobbles and surface artifacts selected from the Cobble Terrace. These clean surfaces were then observed under a petrographic microscope through analyzed polarized light and nonanalyzed polarized light.

2.2. Technological analysis (productional and structural analysis)

Units F and Y at the Kalinga site yielded two lithic assemblages. The lithic assemblage from unit F is composed of a total of 171 objects collected during excavations carried out between 2014 and 2022. Unit Y yielded 15 lithic objects. In addition to these two assemblages, which probably correspond to two distinct layers of human activities, there are a total of 27 objects collected by sieving or during surface surveys in the immediate vicinity of the site. These were not included in the present study. In order to reveal the objectives and knapping strategies of the hominins of Kalinga, we chose to apply, for the first time in Island Southeast Asia, a combined technological approach, associating a productional analysis (Dauvois, 1976; Tixier et al., 1980; Inizan et al., 1995, 1999; Tixier, 2012) and a structural analysis (Lepot, 1993; Boëda, 2001, 2013; Li et al., 2008; Bonilauri, 2010; Zhou, 2021; Guibert et al., 2022; Rocca et al., 2023; Forestier et al., 2025a, 2025b).

Techno-productional analysis is based on the reconstruction of intentions and technical gestures through a 'conceptual scheme' (Sellet, 1993; Perlès, 2016). Based on the study of all the lithic objects in the assemblage, several production/reduction systems can be identified. Techno-structural analysis, meanwhile, makes it possible to describe the stages of tool construction by highlighting techno-functional units (TFUs) and analyzing their organization and interaction on the tool blank (Lepot, 1993; Boëda, 2001, 2013).

In this framework, the analytical reading relies on a morpho-structural description of the areas assumed to be active (convex, plan, concave), starting from the transformative cutting contact, understood as the primary interface between the tool and the worked material. This approach considers the tool as a structured system composed of inter-related TFUs including a transformative unit (TFUt), a prehensile unit (TFUp), and, where applicable, an energy-transmitting unit. The identification and spatial organization of these units allow the internal dynamics of the artifact to be reconstructed, independently of typological classifications.

For the earliest phases of prehistory, the absence of edge modification through the presence of a modified/retouched back

or a retouching/confection phase to create a specific cutting edge complicates the identification of the tool prehensile and transformative parts.

However, small flakes with an unmodified cutting edge, which account for most of the tools during the Early Paleolithic, can be analyzed using this dynamic and structural approach. In this context, tools with active edges have been distinguished from nontool flakes based on the presence of regularities and morphotechnical recurrences (Soriano, 2000; Bonilauri, 2010).

By focusing on the relationships between TFUs and their integration within the overall volumetric structure, techno-structural analysis provides access to the underlying technical intentions that guided tool production and use. It thus allows a structural interpretation of lithic artifacts that extends beyond conventional typo-technological approaches, highlighting both the flexibility of technical behaviors and the role of affordances in the conception and management of tools.

This combined technological analysis protocol logically ties in with data from petrographic studies, experimentation, and use-wear analysis.

2.3. Knapping experiment protocol

To better understand and describe the final products recovered with the rhino carcass, we attempted to characterize every step of the chaîne opératoire of the stone artifacts from the Kalinga butchery site. An extensive knapping experiment was conducted with the raw material collected from the potential petrological procurement area at the 'Cobble Terrace.' It helped to highlight the constraints and the possibilities faced, owing to the petrography of the raw materials, and the resulting decisions made by the Kalinga toolmakers.

The final goal of this experiment was to replicate the Kalinga stone artifacts by using the same raw material and similar knapping techniques (direct freehand percussion with a hard-hammer and bipolar-on-anvil percussion) as well as, to a lesser degree, the reduction/production strategies and to further compare the stone artifacts from the rhino context with the 1970's Cagayan Valley surface collections of the National Museum of the Philippines (Fox and Peralta, 1974).

The experiment was conducted on an earthen floor to simulate natural conditions, with sackcloth used to retain all resulting products. A single experienced right-handed female knapper (over 10 years of experience) executed the sequences, which were documented throughout by photographic and video recording.

Since Ingicco et al. (2018) reported the use of bipolar-on-anvil percussion in the Kalinga lithic assemblage, some of the largest cobbles of siliceous rock (i.e., metaquartzite) with a naturally flat surface were collected to serve as anvils within this experiment for the production of lithic flakes applying the same technique (Jaubert and Mourre, 1996; Mourre and Jarry, 2009; Soriano et al., 2010; de Lombera-Hermida et al., 2016; Yeşilova et al., 2024).

They were used as passive hammerstones receiving the force transmitted by an active hammerstone that reflects the energy of the strike back into the core from which a flake is meant to be obtained. Two anvils were selected, hereafter named E1, a block with a size of 380 × 180 × 110 mm and a weight of 4.7 kg, and E2, with a size of 240 × 170 × 100 mm and a weight of 3.8 kg.

Bipolar-on-anvil percussion is a flaking technical strategy that has been identified from 3.3 Ma (Harmand et al., 2015) until modern times with no geographical homogeneous distributions (Shott and Tostevin, 2015; Horta et al., 2022). However, there are many variations of the technique. One notable difference is the volume of the raw material exploited. Indeed, the use of bipolar-on-anvil percussion on small pebbles will produce typical

fragments/flakes through fracturing rather than flaking, called 'quartier d'orange' or 'citrus-section' (Cotterell and Kamminga, 1987; Donnart et al., 2009; Byrne et al., 2016; Ma et al., 2020; Yeşilova et al., 2024). In many other examples, such as here in Kalinga, the bipolar technique is employed to split or open a rounded cobble that does not have any natural flat surfaces to be used as a striking surface or to exploit the peripheral convexities of a heavy cobble to produce a diversity of flake morphotypes (Jaubert and Mourre, 1996; Mourre and Jarry, 2009; de Lombera-Hermida et al., 2016; Lourdeau et al., 2023; Guibert, 2024).

With this in mind, four cobbles from petrographic sample R1 and 20 cobbles from sample R2 were used in this knapping experiment ($n = 24$). These cobbles are mainly metamorphic ($n = 23$), and one is an igneous rock. Furthermore, their volume and size were comparable to those of the cores from the lithic assemblage. The surfaces of the selected samples presented ferruginous deposition similar to some of the archaeological cobbles from which the artifacts were knapped.

A total of 16 metaquartzite cobbles with an ovoid shape were selected to be used as active hammerstones. This sample was divided into eight hammerstones used in direct freehand percussion and eight hammerstones used for bipolar-on-anvil percussion. Every single hammerstone was alternatively used during the conduct of the experiment in order to observe the variability of the impact stigmata left by these two percussion techniques.

2.4. Use-wear analysis

Traceology or microscopic use-wear analysis is an efficient method for the reconstruction of prehistoric technologies and activities carried out with prehistoric stone artifacts interpreted as tools (Semenov, 1964). It applies optical and digital low- and high-power microscopy with stereomicroscopes and reflected-light microscopes, as well as laser-scanning microscopes and scanning electron microscopes coupled with micro-analyzers, to detect and identify the different kinds of wear traces that can appear on the functional parts of prehistoric tools (Keeley and Newcomer, 1977; Hayden, 1979; Keeley, 1980; Odell and Odell-Vereecken, 1980; Plisson, 1985; Vaughan, 1985; Anderson, 1990; Evans and Donahue, 2008; Stemp et al., 2015).

Subject to use-wear analysis are the various patterns of edge damage, especially the diagnostic proximal and distal cross sections of scars (Hayden, 1979; Vaughan, 1985), and structural alterations of the tools' surfaces, the so-called micropolishes, as well as striations indicating the motion of a tool vs. the worked material. In addition, residues on the surfaces of stone tools can give clues about their former use. Postdepositional alterations of surfaces and edges, caused by taphonomic factors such as transport or trampling, can hamper traceological analysis, especially for open-air sites of that age (Eren et al., 2011; Guibert-Cardin et al., 2021, 2022).

Yet, Ingicco et al. (2020) considered the Kalinga assemblage to be autochthonous to the place where it was recovered by us during the excavation, and no significant postdepositional alteration was observed during analysis. In this study, a sample of 21 lithic artifacts directly associated with the rhinoceros skeleton within Kalinga's unit F were subjected to traceological analysis applying the low-power method (Odell and Odell-Vereecken, 1980), using a zoom-stereomicroscope Olympus SZX-9 with a magnification of $6\times$ – $57\times$, and the high-power method (Keeley, 1980), using a reflected-light microscope Olympus BXFM-LWD with differential-interference-contrast attachment and $100\times$ – $500\times$ magnification, and a portable Olympus BHMJ-LWD with differential-interference-contrast attachment and $110\times$ – $440\times$ magnification. The microphotographs were taken with Nikon D-5000 and Canon

G9 digital cameras and a Promicon microscope adapter system. Digital postprocessing of the microphotos was conducted with Helicon Focus and Adobe Photoshop. Low-power images are labeled with letters (a, b, c, etc.), whereas high-power images are numbered (1, 2, 3, etc.). Prior to microscopic analysis, the artifacts were carefully cleaned in an ultrasonic tank using a solution of dishwashing soap and distilled water and subsequently rinsed with a 70% alcohol solution and air-dried.

2.5. Re-investigation of the 1970s surface collections

The Kalinga lithic assemblage was compared with the ancient Cagayan Valley surface collections. These collections were made by the National Museum of the Philippines in the 1970s and are actually either surface or topsoil finds from three excavated localities (Fig. 1) named Espiñosa 1, Espiñosa 4, and Madrigal 12. None of them were properly found in situ, except for two artifacts from Espiñosa 4 that were recovered within clear stratigraphic context (Fox and Peralta, 1974). In addition to these three excavated sites, we re-examined the stone artifacts collected in the 1970s on the surface of 11 other localities of the Cagayan Valley. These sites are the sites of Espiñosa, Espiñosa North of Pirit, Espiñosa N.R. House, Espiñosa localities 3, 5, 6, 9, 11, 22, and 28, and Madrigal locality 12 South. In this comparison, we have also included the few lithic artifacts ($n = 6$) from the excavation of the Clyde site, dated between 516 ± 45 and 399 ± 40 ka (Jago-on, 2009; Lambard et al., 2024). In total, these lithic assemblages of the Cagayan Valley amount to 2969 objects.

3. Results

3.1. Raw material (stone morphology, quality, raw material potential sources, and distances)

Granulometry and morphology of the raw material The geological sample acquired from the surface of the Cobble Terrace is composed of pebbles (56.3%) and cobbles (43.7%). Blocks (width >250 mm) are absent (Wentworth, 1922, 1923). Most pebbles and cobbles have an ovoid volume (63.9%) with one or two continuous rounded surfaces. The low elongation index of 1.4 and flatness index of 1.7 classify the stones as subspherical (Fig. 2), resulting from high fluvial energy transportation. Used cobbles are lithic elements resulting from the repeated breakage of rocky banks after dismantling. Their volumes are prismatic or polyhedral with multiple planar, convex, concave, or concave-convex surfaces. The smoothness index of the edges of these stones is relatively high, up to 50 mm. This smoothness is also indicative of a fluvial origin of the deposit.

Nodules are almost absent, which suggests either a complete disappearance of the cortex during the acquisition of their present natural morphologies or the absence of any sedimentary rocks at the origin.

The vast majority of rounded or worn pebbles and cobbles (97.5%) have their surface covered with a crust of iron and manganese oxides. These oxides are common in the region—as shown by the commonality of iron pisolites on the surface of the Kalinga area—and result from long-term lateritization phenomena in this region. This iron-manganese crust covers several impact marks, shattering, and natural removals on the rocks that are related to their fluvial transport. Ingicco et al. (2020) described the presence of a ferromanganese crust that developed on some of the bones of the rhino within unit F of Kalinga, evidencing the advanced diagenetic evolution of these minerals in the region.

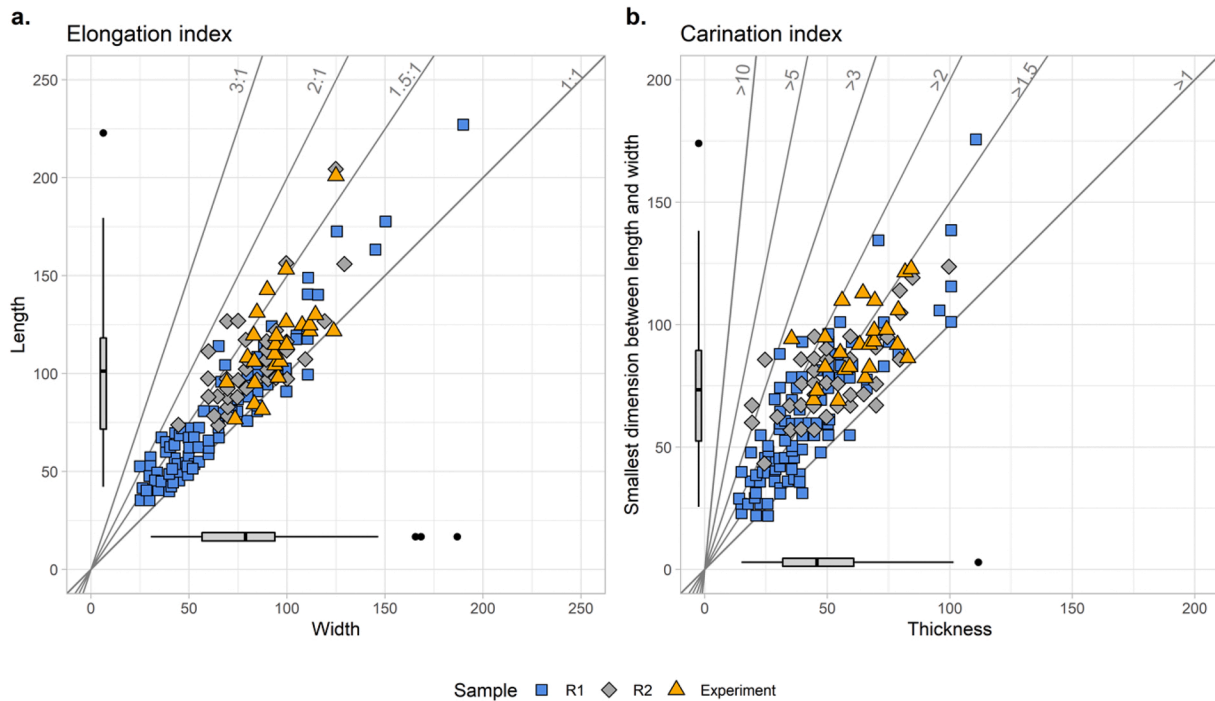


Figure 2. Elongation (a) and carination (b) indices of materials collected in areas R1 and R2, as well as those selected for experimentation. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

Petrography

Rocks from the Cobble Terrace – The composition of the groundmasses was observed on the fresh fracture planes. Breaking the rocks proved quite difficult and required up to six impacts with a 1.5-kg steel hammer.

After breakage, different types of groundmasses were visible: a very homogeneous fine-grained groundmass (35% of the sample), within which crystals were not visible; a groundmass with different granulometric mineralized areas ranging from fine-grained or medium-grained to coarse-grained groundmass (25% of the sample); a fine-grained groundmass (21% of the sample) with breccia areas; and quartzites with coarse-grained groundmass (15% of the sample). Only one specimen contained crystals of pyroxene.

Faces or edges of coarse crystals of quartz are visible in 30% of the medium- or coarse-grained groundmasses. Aggregates of very small and small crystals are present in 25% of the samples.

On slides observed in analyzed polarized light and nonanalyzed polarized light, the dimensions of the crystalline faces of the quartzitic elements are very fine ($\leq 10 \mu\text{m}$), fine ($5\text{--}20 \mu\text{m}$), medium ($10\text{--}50 \mu\text{m}$), or coarse ($10\text{--}100 \mu\text{m}$). Quartz microcrystals measure between 100 and 200 μm to 1 mm and are sometimes isolated and sometimes accumulated into small areas.

We observed elongated fibrous crystals of chalcedony, feldspathic crystals, and sometimes fibrous sulfur elements. The boxwork is filled with fine grains.

Massive rocks composed of knitted quartz crystals, sampled on the Cobble Terrace, are all quartzites or microquartzites (35%). These quartzites could be original sedimentary rocks recrystallized by silica carried by gravitational waterflow (orthoquartzite) or metamorphized sandstones (metaquartzite). These types of rocks have previously been reported in these local formations (Mathisen, 1981).

Half of the geological samples from the Cobble Terrace show lateritization of varying intensity. Iron oxides are spread in $10\text{--}50 \mu\text{m}$ or

100 μm areas within the siliceous groundmass. They are generally present in the partial filling of the numerous vesicles associated with secondary chalcedony. Despite textural and granulometric variability, the Cobble Terrace assemblage is lithologically homogeneous and dominated by quartz-rich rocks, primarily orthoquartzites and metaquartzite. Other mineral phases are rare and accessory.

Artefacts from the Cobble Terrace – The prehistoric lithic artifacts from the Cobble Terrace were knapped from very-fine- to fine-grained quartzites. In two samples, we observed some rose-like organizations of the matrix, which are an indication of the presence of metamorphous minerals such as sillimanite. The quartzite elements are $5\text{--}100 \mu\text{m}$ large.

Quartz crystals are present in half of each sample. One to three faces of their pseudo-hexagonal crystal perimeter are visible. In most of the samples, numerous areas with different granulometries of quartzite grains can result from primordial formation (e.g., breccias) but are more likely from secondary lateritization phenomena.

The largest quartz grains could be of primordial formation, although their frequent clustering may also be due to lateritization phenomena with imbricated pseudo-hexagonal shapes associated with larger areas of iron oxides. All samples contain areas of iron oxides between quartz grains and within the incomplete filling of the numerous vesicles and cracks.

Artifacts from the Kalinga Site – The artifacts recovered at the Kalinga site in association with the rhino skeleton also have similar characteristics to the geological and artifact samples collected from the Cobble Terrace. Only three artifacts from the sample are highly lateritized with a characteristic ruby-red coloration. In these samples, quartz crystals of millimetric size and hexagonal circumference are the result of recrystallization phenomena.

In Kalinga unit F, coarse- and fine-grained quartzites were equally selected for knapping.

Cobbles and prehistoric stone artifacts sampled on the Cobble Terrace were all quartzites. These latter can be subdivided into metamorphized (metaquartzites) and resiliified sedimentary

rocks (orthoquartzites). These siliceous rocks are characterized by very high indices of hardness (7–9), impact resistance (toughness, $R1 < 200$), and crushing resistance (Mohs, 1812; Atkinson and Potts, 1977). These petrographical indices, together with the degree of lateritization, have been meaningful data for conducting the knapping experiments.

3.2. The Kalinga lithic assemblages from units F and Y

We describe here the 186 lithic objects from units F and Y by a combined technological approach.

An initial techno-typological seriation of the objects by unit and raw material reveals a balanced representation between metaquartzite and orthoquartzite (Table 1). These two dominant raw materials, collected mainly in the form of cobbles, are associated in unit F with several elements of volcanic porphyritic rocks such as andesite or dacite, as well as lava and basalt that have been heavily lateritized. An artifact made of silicified wood is also present in the assemblage of unit F.

From a typological and technological point of view, the assemblage of unit F at Kalinga mainly consists of flakes and flake fragments, as well as debris/chunks and fragments resulting from production activities. Twelve flakes have been identified as tools, i.e., they have one or more active cutting edges. Several cobbles have been identified as hammerstones because they show multiple traces of percussion on their distal and/or proximal areas, while nine cobbles correspond to geofacts, i.e., they show no traces of anthropogenic action. The lithic assemblage also includes several cobble fragments resulting from knapping activities, fractured cobbles corresponding to larger pieces than the fragments, as well as a tested cobble showing isolated, nonadjacent removals.

In addition, the cores are represented by a total of six objects, mainly made of metaquartzite. Also, two cobble tools were identified, adding to the diversity of the Kalinga humans' toolkit.

The lithic assemblage of unit Y is limited to 15 debris/chunks derived from production operations on metaquartzite and orthoquartzite cobbles/pebbles (Table 1). In this context, we describe in detail, for this study, the technological results for the assemblage of the unit F.

Techno-productional analysis of the unit F The lithic assemblage from unit F documents a flexible technological system adapted to the constraints of the locally available quartzite cobbles. Four main flaking strategies were identified (Fig. 3) through techno-productional analysis, based on the reconstruction of knapping intentions, volumetric management, and percussion techniques (Dauvois, 1976; Pelegrin et al., 1988; Pesesse, 2019).

The first reduction strategy consists of recurrent parallel unipolar removals initiated from natural flat cortical surfaces adjacent to peripheral convexities (Fig. 4). This reduction system mainly exploits the affordances of ovoid cobbles and produces small- to medium-sized flakes with parallel or slightly divergent edges. The diagnostic stigmata indicate the frequent use of bipolar-on-anvil percussion for this reduction strategy.

The second strategy corresponds to alternating orthogonal removals, in which striking and flaking surfaces were successively reorganized during short reduction sequences (Fig. 5). This strategy generates a high variability in core morphologies and edge flake shapes and is consistently associated with direct freehand percussion using a hard hammer.

A third strategy is represented by a centripetal reduction system applied to hemi-cobbles produced by splitting (Fig. 6). Removals converge toward a central or ventral convexity from peripheral striking platforms, resulting in oval to convergent flakes. This strategy combines an initial bipolar splitting phase followed by direct freehand percussion.

Finally, a combined reduction strategy integrates successive bipolar and freehand percussion phases within a single reduction sequence (Fig. 7). Bipolar percussion is mobilized to initiate and structure the core volume, while subsequent freehand removals exploited newly created convexities. This flexible strategy maximizes flake production from resistant quartzite matrices.

Overall, these four production/reduction strategies highlight a technological system characterized by a specific volumetric exploitation, minimal striking-platform preparation, and frequent alternation between complementary percussion techniques. This technological flexibility reflects both the mechanical constraints of the raw materials and the functional requirements of on-site activities associated with unit F (see [Supplementary Online Material \[SOM\] SI-1.1](#) for detailed descriptions of individual cores, metrical data and reduction sequences).

Morphological and technical characteristics of the blanks from the reduction strategies – The lithic assemblage from unit F is dominated by flakes and flake fragments, which account for the main products of the identified reduction sequences. In order to ensure data consistency, the following description focuses on complete flakes only, either tools or nontool blanks.

Complete flakes display limited dimensional variability, with mainly small- to medium-sized products (Fig. 8). Their global morphology is characterized by oval, parallel, or slightly divergent edges, reflecting the diversity of reduction strategies and the limited volumetric preparation of the cores (Figs. 9–11). Flake dimensions and morphologies are consistent with short

Table 1
Typological and technological classification by raw material of the Kalinga assemblages from the units F and Y.

Technical category	Metaquartzite	Orthoquartzite	Volcanic rocks	Silicified wood	Total
Unit F					
Flakes and fragment of flakes	42	44	7	1	94
Flake tools	2	8	2	–	12
Debris	13	7	–	–	20
Cobble fragments	7	3	4	–	14
Tested cobbles	–	1	–	–	1
Fractured cobbles	2	–	–	–	2
Cores and fragments of cores	4	1	1	–	6
Geofacts	7	1	1	–	9
Cobble tools	1	–	1	–	2
Hammerstones	4	–	7	–	11
TOTAL	82	65	23	1	171
Unit Y					
Debris	12	3	–	–	15
TOTAL	12	3	0	0	15

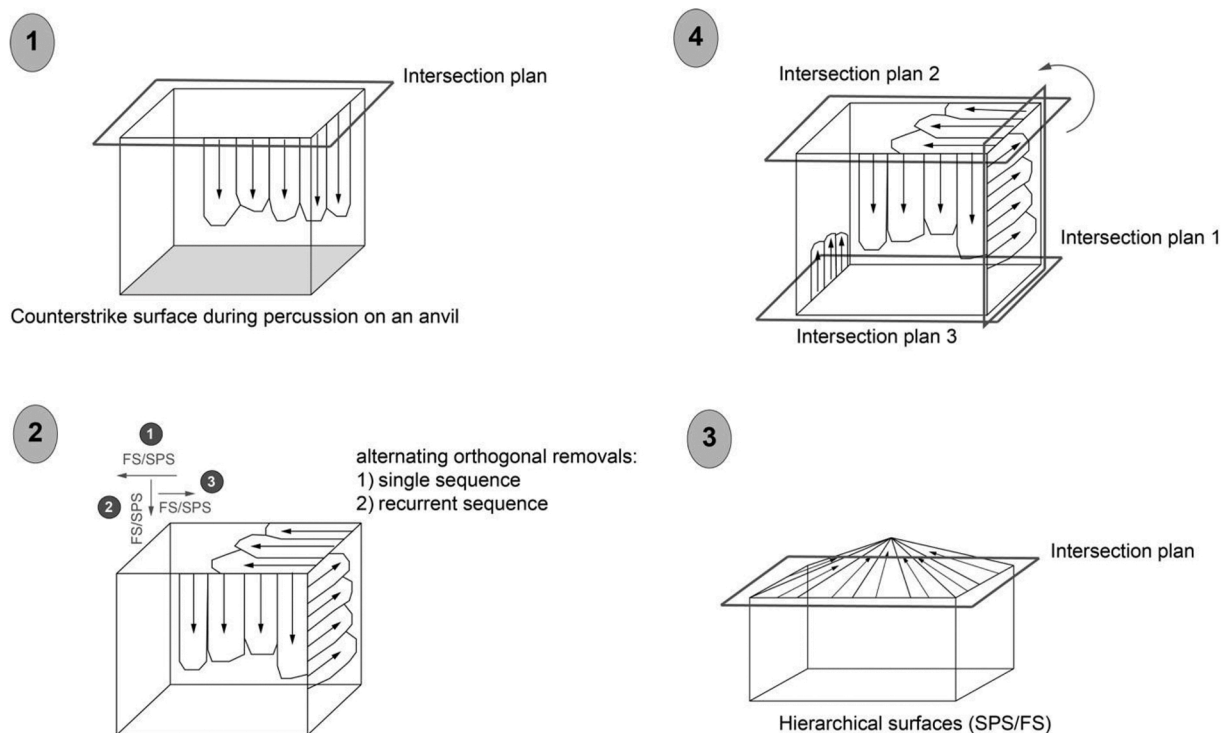


Figure 3. Diagram of the four flaking reduction strategies of the Kalinga site (unit F). SPS, striking platform surface; FS, flaking surface.

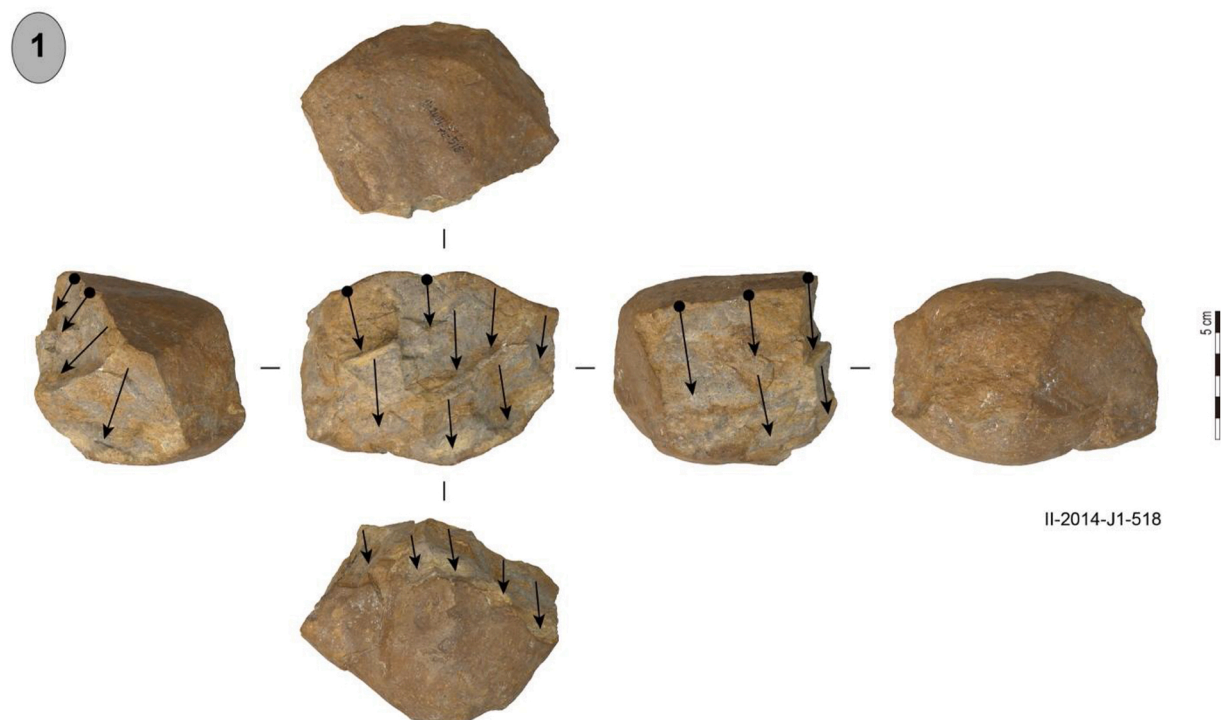


Figure 4. Core with recurrent parallel unipolar removals. Black dots indicate impact points, and arrows indicate the direction of the removals. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

reduction sequences aimed at the rapid production of useable cutting edges.

From a technological perspective, most flakes exhibit cortical or plain butts, indicating minimal preparation of striking surfaces.

Flaking angles range from open to near-orthogonal values, reflecting the combined use of direct freehand percussion with a hard-hammer and bipolar-on-anvil percussion (Fig. 11). Diagnostic features such as silet-type fractures, hinged terminations, and

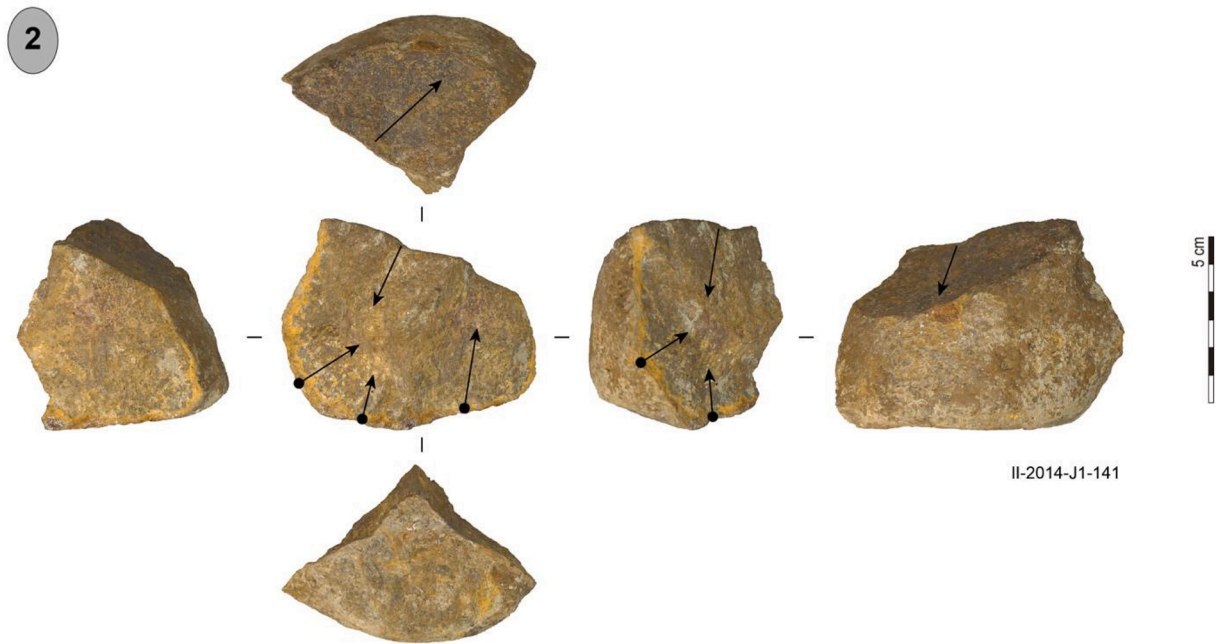


Figure 5. Core with alternating orthogonal removals. Legend is the same as Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

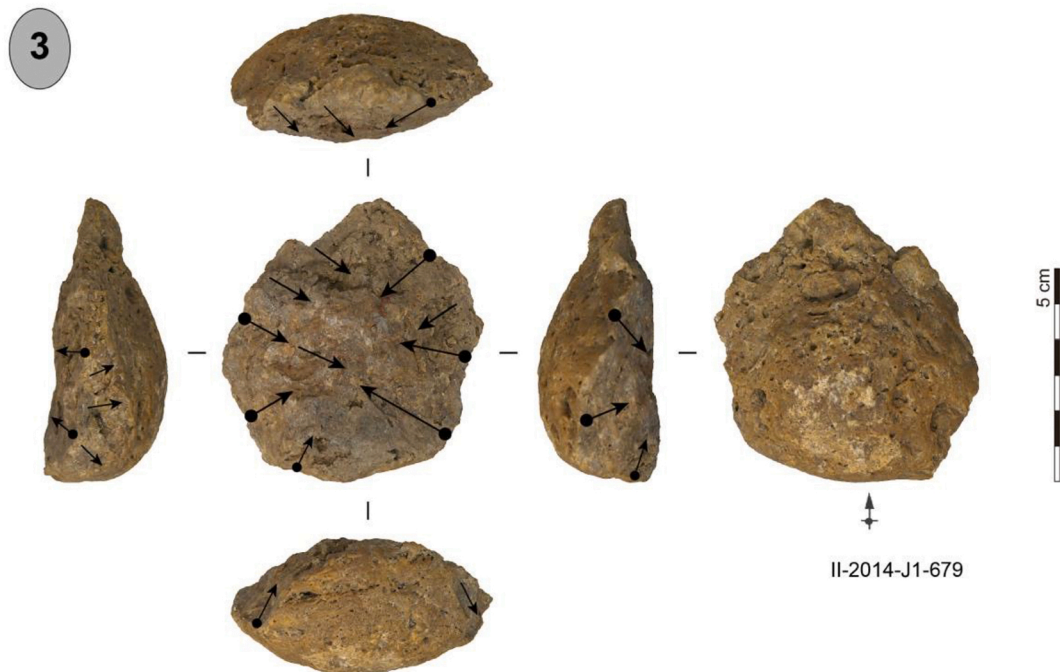


Figure 6. Core with recurrent centripetal removals and hierarchical surfaces. Legend is the same as Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

thick or angular butts further support the frequent alternation between these two percussion techniques.

Several technical categories of flakes are represented including first flakes, semicortical, and noncortical flakes, as well as a limited number of débordant (overshot) flakes (Table 2). This distribution indicates that reduction sequences were generally short, without a strong emphasis on core maintenance or extensive volumetric anticipation. The presence of backed flakes, whether cortical or

noncortical, further illustrates the recurrent exploitation of peripheral convexities during knapping sequence.

Overall, the morphological and technical characteristics of the blanks produced at Kalinga reflect a flexible flake-oriented technological system. Blank variability appears to result primarily from raw material constraints and the alternation of percussion techniques, rather than from the pursuit of standardized product morphologies (see SOM SI-1.1 for detailed description of flakes).



Figure 7. Core with recurrent parallel bipolar removals followed by alternating orthogonal removals. Legend is the same as Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

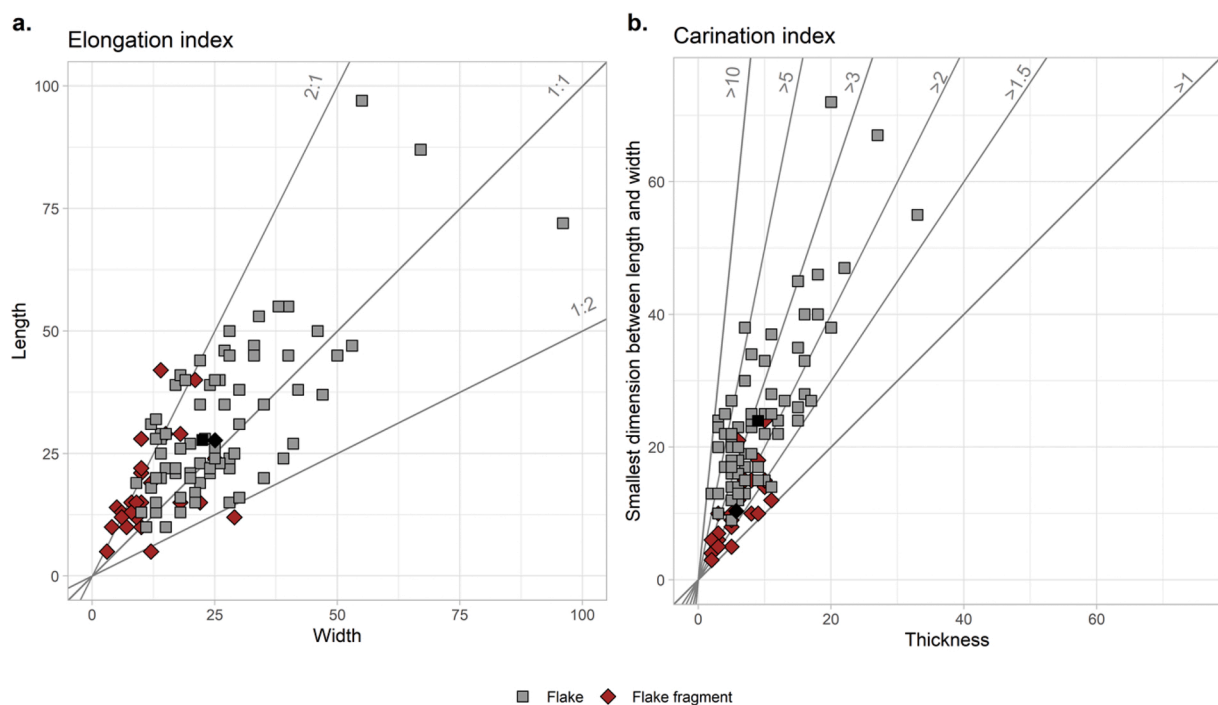


Figure 8. Visualization of elongation and carination indices for flakes and flake fragments from the Kalinga unit F assemblage. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

Finally, among these blanks, 12 flakes were identified as tools by techno-structural analysis.

Techno-structural analysis of unit F The techno-structural analysis was conducted to characterize the organization of active and prehensile units on the blanks produced in unit F including flakes

without any formal retouch. Fourteen artifacts were identified as tools based on recurrent morpho-technical configurations and the systematic presence of potentially functional cutting edges.

Most of the tools are small flake tools, less than 5 cm (Burdukiewicz and Ronen, 2003), produced on noncortical or



Figure 9. Examples of the different flake categories from the Kalinga assemblage. Déjeté flake (n°519); convergent flake (n°391); parallel flakes (n° 1122 and 1092); oval flake (n° 1116); divergent flake (n°1113). Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

semicortical blanks, although a limited number of macro-tools made on flake or cobbles are also present. The majority of the tools exhibit a simple structural organization, in which a single active transformative unit (TFUt) is opposed to or associated with a prehensile unit (TFUp) formed by a thick butt, a cortical surface, or a méplat (i.e., a flat surface).

Three main technotypes of small flake tools were identified (Table 3). The first consists of tools with rectilinear mesio-distal cutting edges, generally unmodified, and produced on quadrangular flakes (Fig. 12). The second technotype comprises tools with denticulated lateral cutting edges created by abrupt retouch (Fig. 13), while the third technotype includes convergent tools produced either by retouch or by the selection of naturally convergent edges (Figs. 14 and 15). These technotypes reflect different ways of organizing and structuring cutting edges on small blanks rather than distinct tool classes in a typological sense.

In addition to these three technotypes, a single composite small tool was identified (Fig. 16). This artifact combines two distinct active transformative units on the same flake blank, each corresponding to a different cutting-edge morphology. These active units are spatially organized in relation to a shared prehensile unit materialized by a flat surface and a thick proximal area. Although unique within the assemblage, this composite configuration highlights the flexible use of small blanks and illustrates the capacity to integrate multiple functional edges on a single tool without extensive retouching.

In addition to these small tools, three macro-tools are part of the assemblage. Two correspond to cobble tools shaped by limited removals to create convex (Fig. 19) or convergent (Fig. 18) cutting edges, while the third is a large flake tool with a convex distal cutting edge (Fig. 17). Despite their morpho-structural variability, these tools share a similar logic, combining a robust prehensile unit (TFUp) with a single, well-defined transformative edge.

Overall, the techno-structural organization of the unit F toolkit highlights a high degree of flexibility in tool conception. Rather than reflecting standardized tool forms, the observed variability results from the anticipatory integration of natural blank volumes, surface morphologies, and fracture planes from the earliest stages of tool conception. Cutting edges are organized through the selective exploitation of pre-existing convexities, cortical-natural surfaces, and fracture planes, allowing multiple functional configurations to emerge without the need for extensive shaping. This flexible techno-structural logic reflects a dynamic tool design adapted to both, raw material constraints and functional requirements, and underlines the capacity of the Kalinga toolmakers to integrate natural volumes into coherent and efficient tool systems (see SOM SI-1.2 for detailed techno-structural descriptions of small and macro-tools).

3.3. Knapping experiment data

Here we present some results from experiments on raw materials from the 'Cobble Terrace' (Fig. 1). One of the main issues is

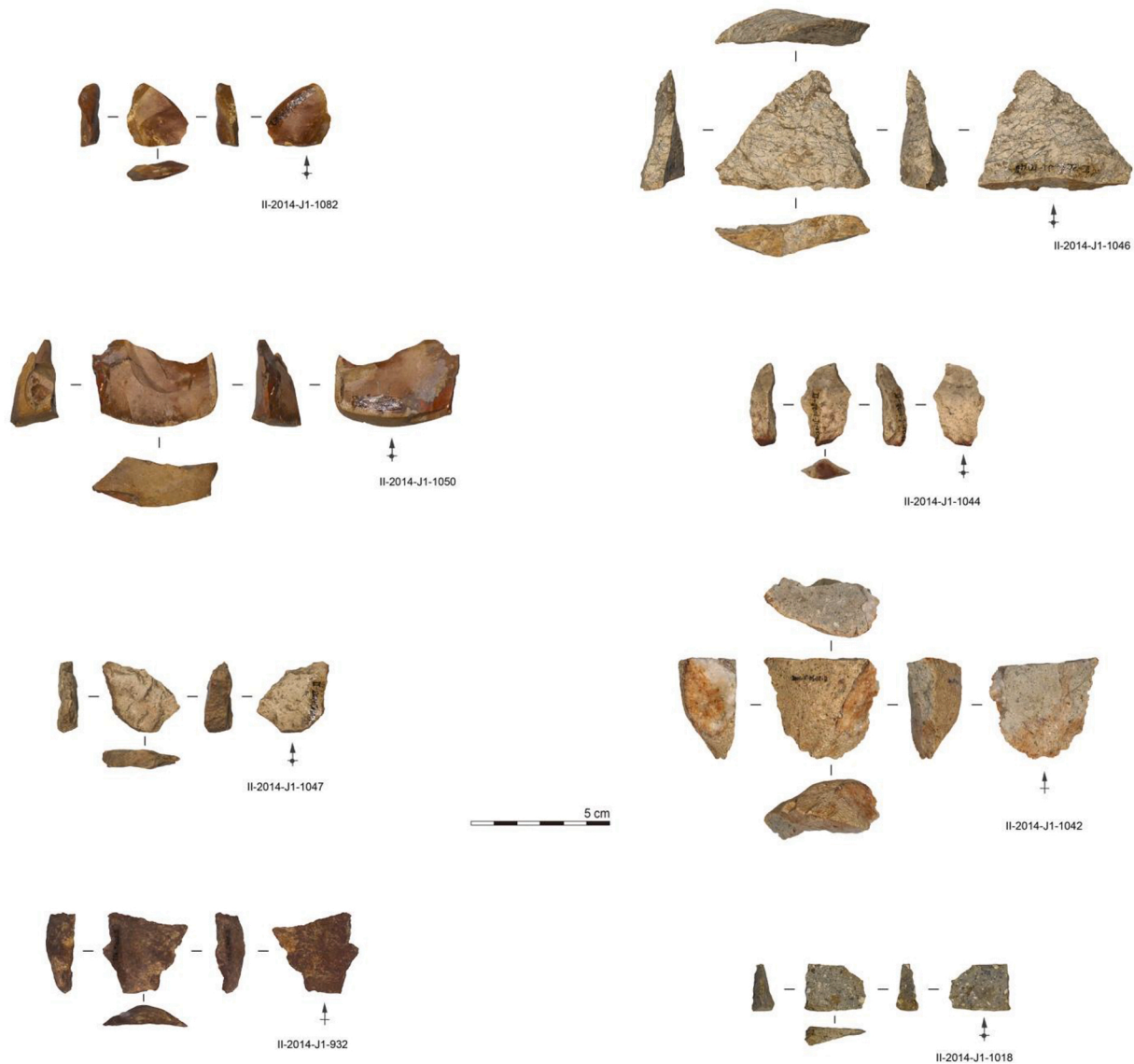


Figure 10. Example of the different flake categories from the Kalinga assemblage. Oval flakes (n°1082 and 1050); convergent flake (n°1046); irregular flakes (n°1044 and 932); divergent flakes (n°1047 and 1042); parallel flake (n°1018). Arrows indicate the flaking axis with and without butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

that direct freehand percussion and bipolar-on-anvil percussion techniques can produce morphologically and technically similar flakes (Mourre, 1996; Gurtov and Eren, 2014). The aim is therefore to illustrate the diversity of products from these two techniques in order to compare them with the stigmata observed on the archaeological material from Kalinga site. Below, we detail in separate paragraphs the selection of the used blanks; the selection of used hammerstones; the selection of anvils; initial removals by percussion on an anvil, and some observations made during the application of the both techniques. Finally, through a selection of three experiments, we present the dimensional, morphological, and technological characteristics of the cores and flakes.

Characteristics of the experimental materials and some observations during the experiments

Selection of the blanks – The blanks used for the experimental knapping were selected from geological samples collected from the ‘Cobble Terrace.’ Most of the blanks are quartzites, except for one volcanic breccia and one sandstone. About half of the 24

selected rocks are rounded cobbles ($n = 13$), while the others are prismatic ($n = 6$), parallelepiped ($n = 3$), or polyhedral ($n = 2$). The mean dimensions of the blanks were $120 \times 93 \times 63$ mm, with the largest measuring $210 \times 125 \times 85$ mm and the smallest measuring $80 \times 74 \times 46$ mm.

Selection of the used hammerstones – All of the 16 hammerstones selected for the experiment had oval shapes and surfaces covered by the same iron-manganese crust as observed on the other cobbles. Most of them ($n = 13$) had fused fissures. The mean hammerstone dimensions were $105 \times 75 \times 58$ mm, with the largest measuring $160 \times 130 \times 100$ mm and the smallest measuring $65 \times 56 \times 35$ mm. Their lengthening index is 1.4 with a carination index of 1.3, which matches with the general indexes obtained for the whole geological assemblage. Their average weight is of 781.5 g, with a range of 200 g–1250 g. These differences in volume between the hammerstones are consistent with the diversity in volume of the blanks selected for the experimental knapping. Overall, the ‘lightest’ cobbles were used for direct



Figure 11. Two lateritized metaquartzite flakes from a bipolar-on-anvil percussion. Numerous areas of percussion marks are visible. Arrows indicate the flaking axis without butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

Table 2
List of the flakes according to their technical type.

Technical category	Total
First flakes	12
Semicortical flakes	34
Noncortical flakes	27
Débordant flakes	6
Total	79

Table 3
Synthesis of lithic tool groups from unit F of the Kalinga site.

Technotypes of tools	Total
N°1: tools with a rectilinear mesio-distal cutting edge	3
N°2: tools with a denticulate lateral cutting edge	4
N°3: convergent tools	3
Total	10

freehand percussion, while the ‘heaviest’ cobbles were used mainly for bipolar-on-anvil percussion.

The initial hypothesis was that volume and weight (mass) of these quartzites (ortho and meta) were proportional. We observed that the size and morphology of the hammerstones were

important when knapping on anvils, but above all their weight and density.

After several unsuccessful knapping attempts with direct freehand percussion, most probably due to the impact resistance of quartzite, especially of metaquartzites, and based on our

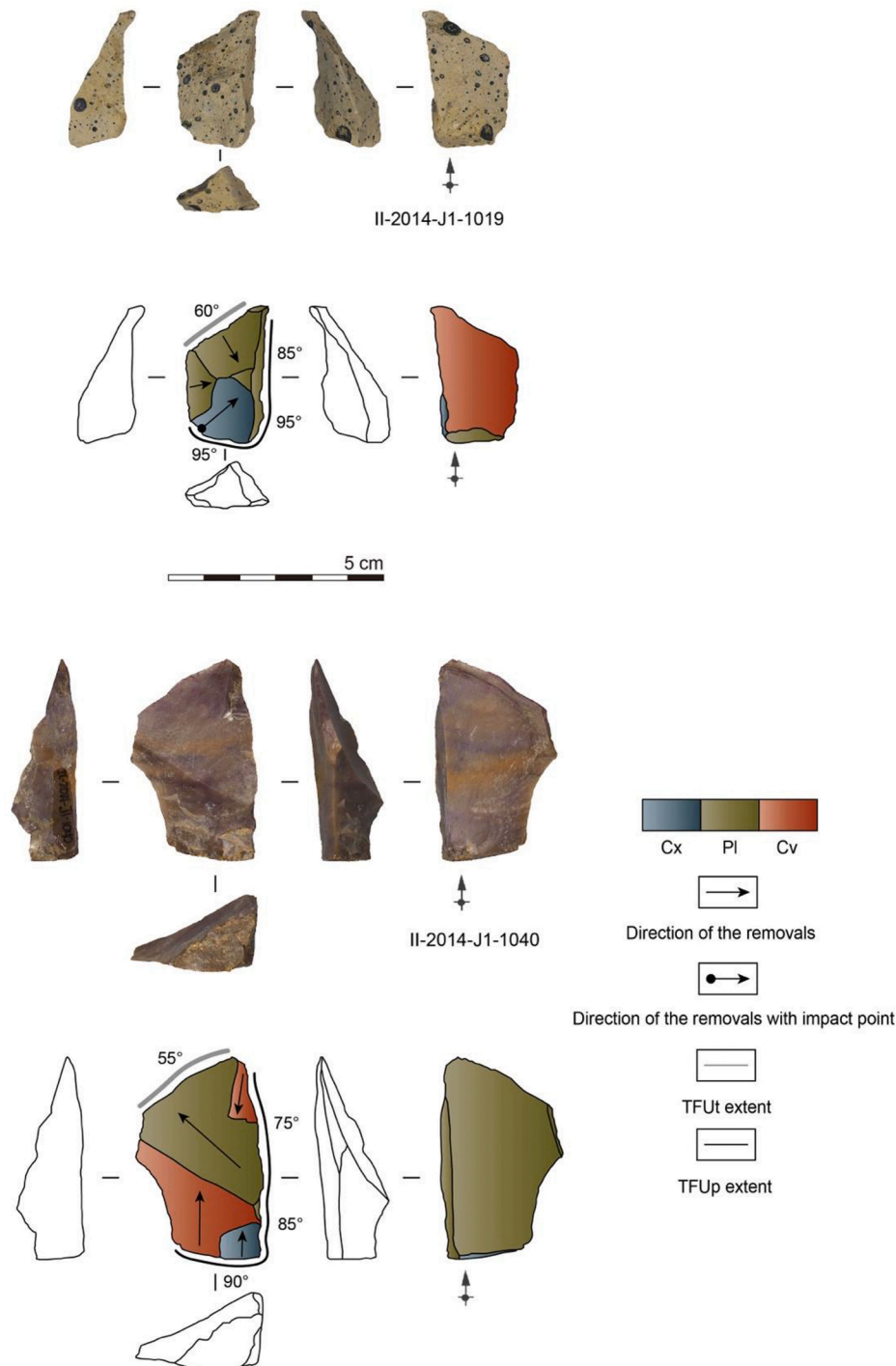


Figure 12. Small flake tools with a rectilinear mesio-distal cutting edge (technotype n°1). Cx, convex; PI, plan; Cv, concave. Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

observations made on the excavated assemblages, we decided to use percussion on an anvil as it was the only effective way to fracture/open the blanks and obtain the initial flake/s.

Selection of anvils – The impact resistance or toughness of the rocks required the use of an anvil in all cases to remove the initial/first flake. After testing several anvils, two (E1 and E2) were selected for the experiment although only E1 proved to be suitable for the production of flakes, thanks to its polyhedral shape and flat surfaces adjacent to convexities. These flat surfaces resulted in a

more stable handling of the pebbles/cobbles on the anvil when applying the bipolar percussion technique.

Technological observations

Initial removal by percussion on anvil – We observed that 54.6% of the cobbles had some natural external breakages, resulting in more or less planar or flat surfaces that could be used as striking platforms. These surfaces were more effective than rounded outlines, which, when resting on the anvil, poorly bounced back the transmitted energy. About 45% of the selected

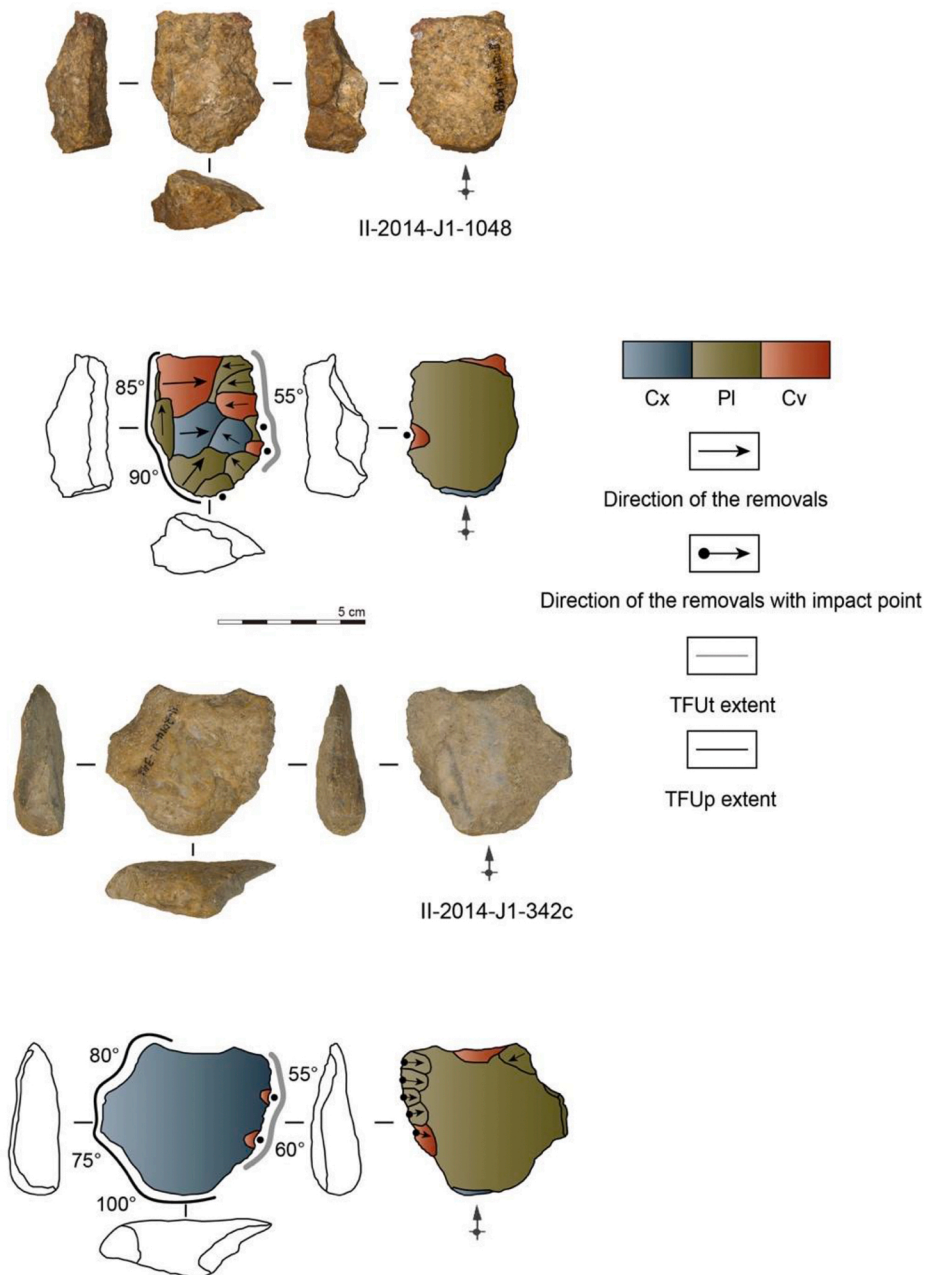


Figure 13. Small flake tools with a denticulate lateral cutting edge (technotype n°2). Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

cobbles were polyhedral, therefore displaying multiples faces including planar surfaces adjacent to convexities.

From the beginning of the anvil experiments, we observed a possible relationship between the difficulty of the breakage or the knapping and the main characteristics of the used rock. This appeared to be related to the peripheral iron deposits (≈ 5 mm) and the numerous alterations, cracks, and impacts observed on the surface and in the groundmasses of the metamorphic, partially or totally lateritized quartzite samples. During testing, we observed possible relationships between the presence of this iron crust and the number of strikes required to successfully break the cobble. In all single cases, the first two impacts only resulted in crushing and breaking the external iron crust, which prevented direct contact between the hammerstone and the

quartzite groundmass and the energy to propagate through it. We further observed that fragments approximately three millimeters thick from the iron or lateritic layer were removed by these two impacts. These fragments were very sharp and well suited and resistant for cutting. Sometimes, the third knapping movement did not detach a flake but instead prepared the crack, which allowed the fourth percussion to easily transmit the energy through the groundmass and detach a flake. The breakage can also be guided or limited by the welded cracks naturally present and numerous in the groundmass.

Bipolar on anvil percussion – For the initialization of the flaking sequence, the cobbles to be knapped were struck perpendicular to their horizontal axial plane as this appeared to be the easiest way to obtain flakes during testing. Usually, after the third

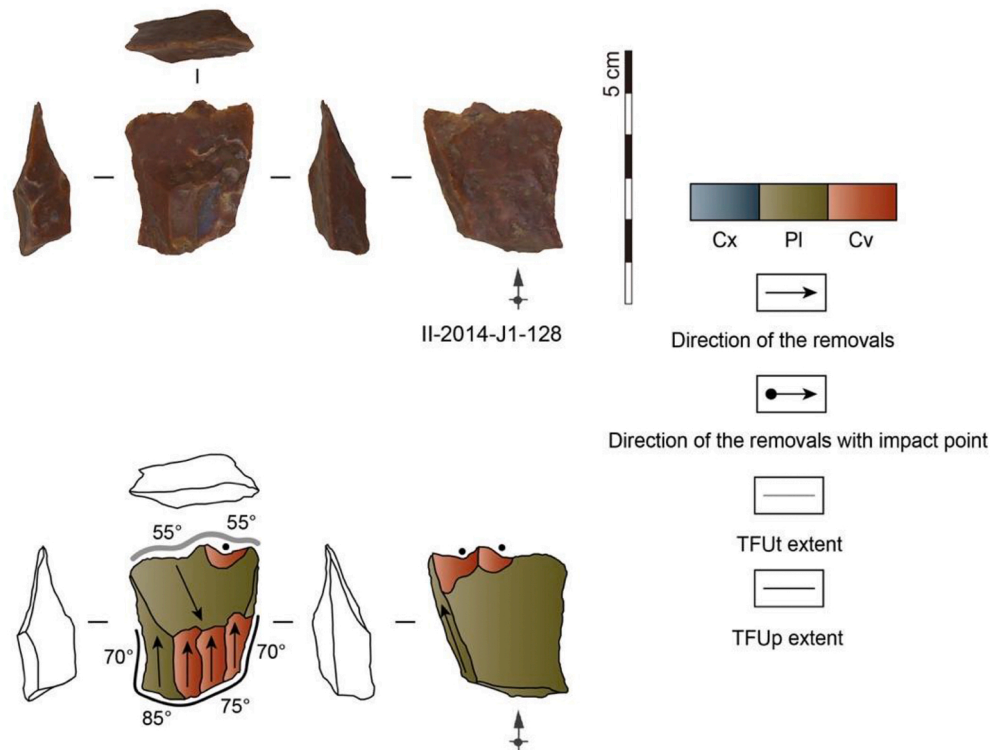


Figure 14. Small tool with a convergent active unit 'beak type' (technotype n°3). Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

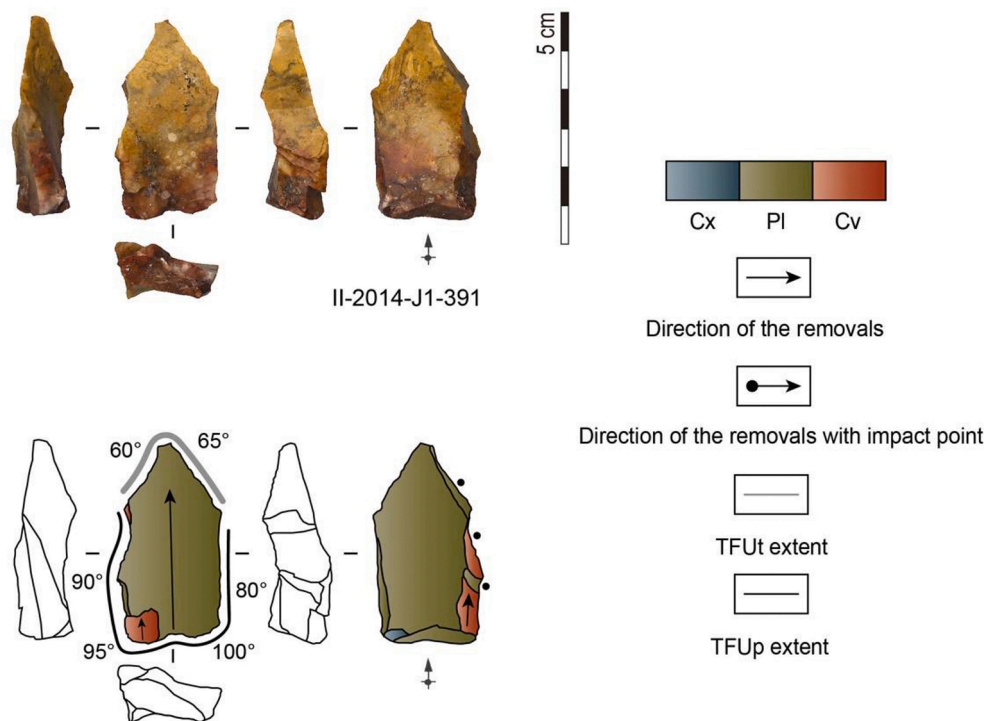


Figure 15. Small tool with a convergent active unit 'rostrum type' (technotype n°3). Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

impact, it was possible to remove a flake. In some cases, the wave of energy followed the welded cracks and produced flakes with a triangular cross section and a butt covered with iron and manganese oxides. In other cases, the wave of energy crossed fissures that

appeared to have been resiliacified. The deep penetration of the iron and manganese oxides into the inner structure of some ($n = 3$) of the stones we knapped required several percussion attempts before succeeding in removing a flake.

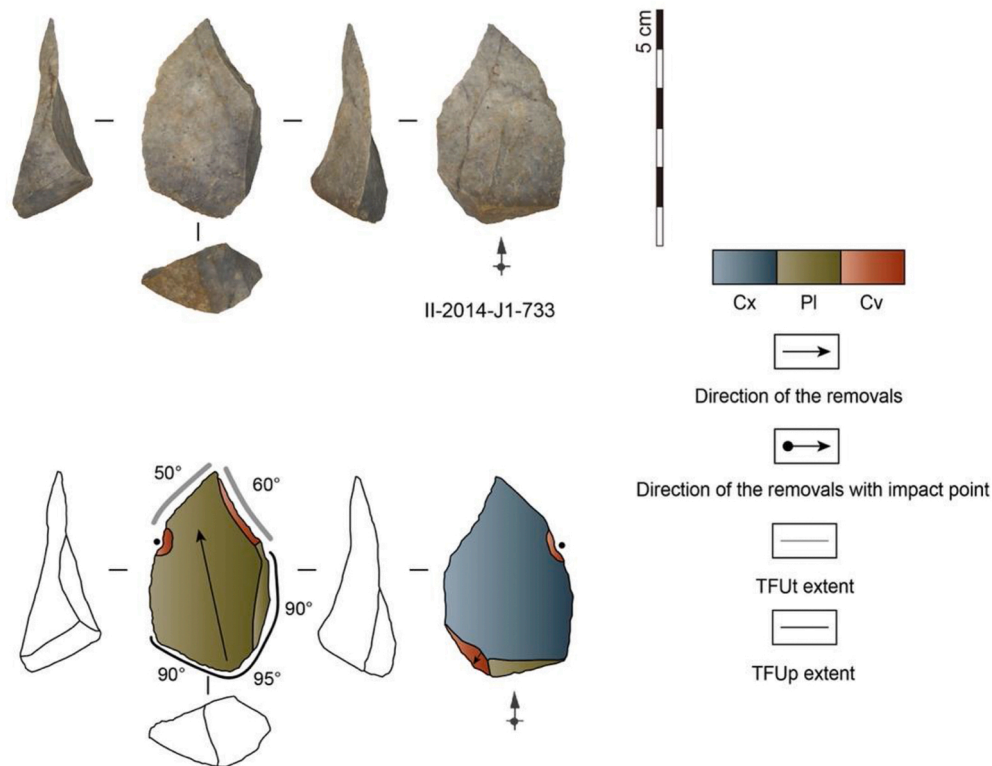


Figure 16. Small composite tool on flake. Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

The development of the wave of energy into a conchoidal removal was often limited by the iron crust. Unsuccessful attempts actually served to create cracks preparing the removal of the flake. Other results of deep lateritization of some of the blanks were (1) obtaining several flakes or fragments of flakes and shatters from a single strike and (2) that the obtained flakes were mostly struck around the periphery of the cores and further required alternating strategies along the reduction sequence.

Direct freehand percussion – This percussion technique was used for the experimental knapping of 9 blanks. As discussed previously, the ovoid morphology and characteristics of the raw materials available in the geological sample of the ‘Cobble Terrace’ make it difficult to use for the initial removal of flakes. This is why this percussion technique was mainly used during the experiment for the production of the second reduction sequence. However, for three of the 24 blanks, direct freehand percussion was the first technique applied. In addition, this percussion is applied with a tangential or oblique gesture compared to the axial or nonaxial gesture used for bipolar-on-anvil percussion (Jaubert and Mourre, 1996; Mourre, 1996; Mourre and Jarry, 2009; Gurtov and Eren, 2014; de Lombera-Hermida et al., 2016).

Some technological and morphological results

Percussion techniques along the reduction sequence – In some cases (8/24), we changed from bipolar-on-anvil percussion to freehand technique within the same reduction strategy. This alternation in knapping techniques was identified on one of the cores excavated at the Kalinga, unit F (n°II-2014-J1-396 – Fig. 7).

Here, we present three examples of experimental knapping:

- A unipolar parallel removal reduction strategy with a bipolar-on-anvil percussion on a parallelepipedal blank.
- A unipolar parallel removal reduction strategy with a combination of a bipolar-on-anvil and a direct freehand percussion technique on a prismatic blank.

- A bipolar parallel removal reduction strategy with a combination of a bipolar-on-anvil percussion and a direct freehand percussion technique on an ovoid blank.

Experiment n°1: (B1)

This first experiment was conducted using a parallelepiped quartzite block (Fig. 20). This block measured 111 mm in length, 84 mm in width, and 68 mm in thickness, with a mass of 1100 g. The block was considered very suitable for knapping, and no abandonment of the flaking sequence was necessary due to the quality of the raw material. Percussion was carried out using a single bipolar-on-anvil technique, producing a total of six flakes (Fig. 20). These flakes have the following average dimensions: 46 mm long, 29 mm wide, and 12 mm thick. The butts are mainly cortical (4/6), and the edges are parallel (3/6), oval (2/6), or irregular (1/6). The angle between the butt and the striking surface is approximately 91°. A few fractures or accidents related to the application of this percussion technique can be observed as two flakes correspond to sired flakes (Fig. 20: n°1 and n°2).

Experiment n°2: (B24) This second experiment was conducted using a prismatic quartzite block (Fig. 21). This block measured 75 mm in length, 75 mm in width, and 57 mm in thickness, with a mass of 710 g. The block was also considered very suitable for knapping as it had no internal cracks and did not require abandonment of the knapping sequence. Parallel unipolar removal was produced using bipolar-on-anvil percussion. Then, direct freehand percussion with a hard hammer was used to rectify the morphology of the striking surface through a removal orthogonal to the main flaking surface. Finally, the flaking sequence was completed with the production of two other flakes using direct freehand percussion. This experiment produced five flakes (Fig. 21) with the following average dimensions: 35 mm in length, 25 mm in width, and 6 mm in thickness. The butts are mainly plain (4/5), while the edges have a parallel (3/5), divergent (1/5), or oval

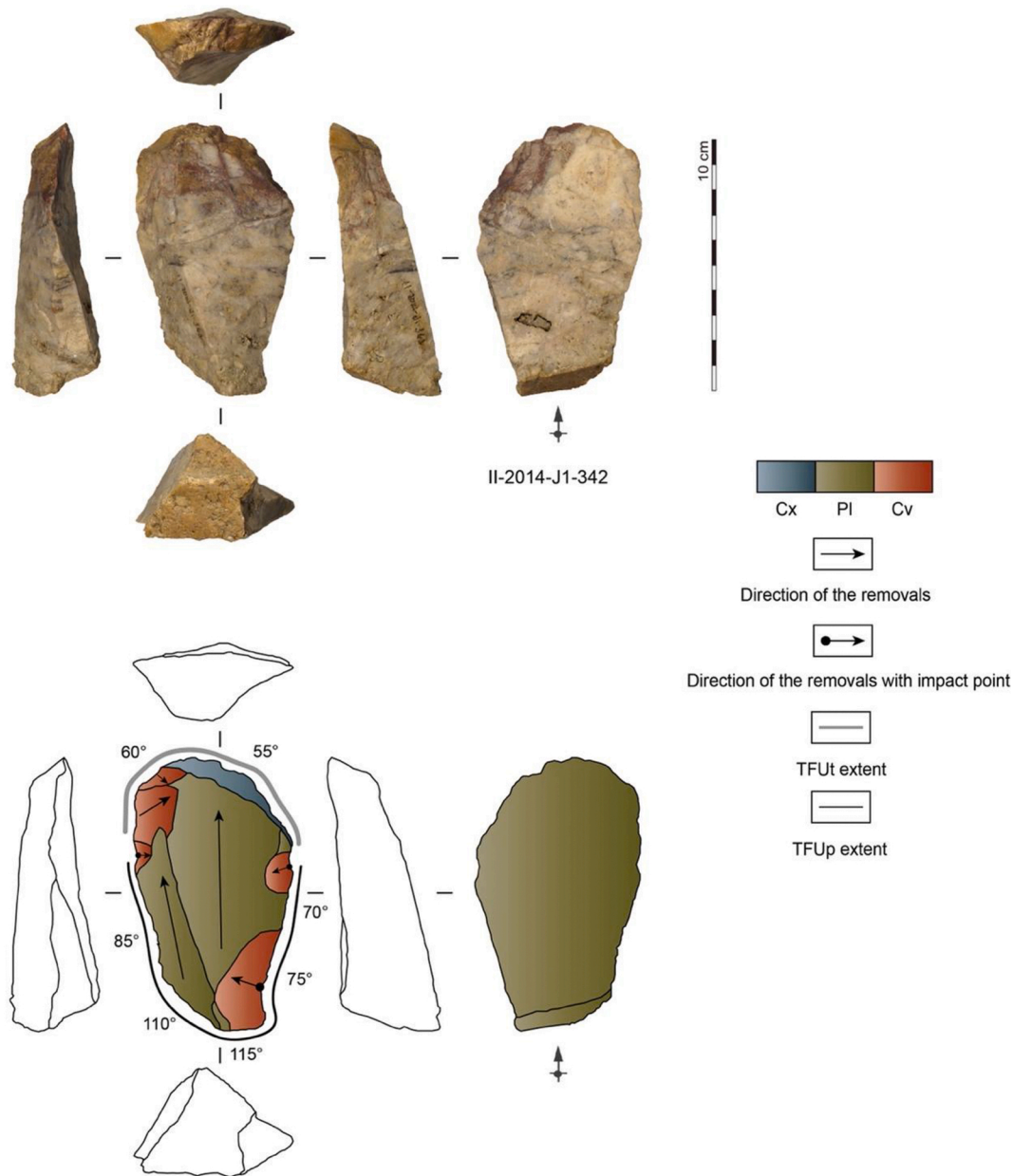


Figure 17. Tool with a convex cutting edge on large orthoquartzite flake. Arrows indicate the flaking axis with butt. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

(1/5) morphology. The angle between the butt and the striking surface is approximately 106° . Some flakes are hinged and have a cortical or semi-cortical back, but no silet accidents or breaks are observed.

Experiment n°3: (B11)

This third experiment was conducted using an ovoid quartzite nodule (Fig. 22). This nodule measured 149 mm in length, 90 mm in width, and 56 mm in thickness, with a mass of 1320 g. For this third experiment, the suitability of this nodule was also judged to be very good, and its quality did not lead to abandonment of the flaking sequence. The flaking sequence was carried out using alternating percussion gestures, beginning with bipolar-on-anvil percussion and followed by direct freehand percussion, with the aim of producing orthogonal removals. A total of 10 flakes were produced with the following average dimensions: 33 mm in length, 40 mm in width, and 12 mm in thickness (Fig. 22). The

butts are cortical (4/10), plain (4/10), or absent (2/10), while the edges are oval (3/10), parallel (3/10), divergent (2/10), irregular (1/10), and déjetés (1/10).

The angle between the butt and the fracture surface is approximately 100° , ranging from 93° for bipolar-on-anvil percussion to 110° for direct freehand technique. A few hinged flakes (2/10) are observed, while the thickest flakes (n°2, n°3 and n°5) were caused by the presence of a welded crack diacase in the nodule.

The experiment produced stone objects similar in diversity to those found at the Kalinga site. The morphological and technological characteristics of the cores and flakes helped us interpret the knapping strategies and techniques used by the toolmakers at Kalinga, in particular regarding the dichotomy between freehand percussion and bipolar-on-anvil percussion, both of which were identified in the assemblage from unit F at the Kalinga site.

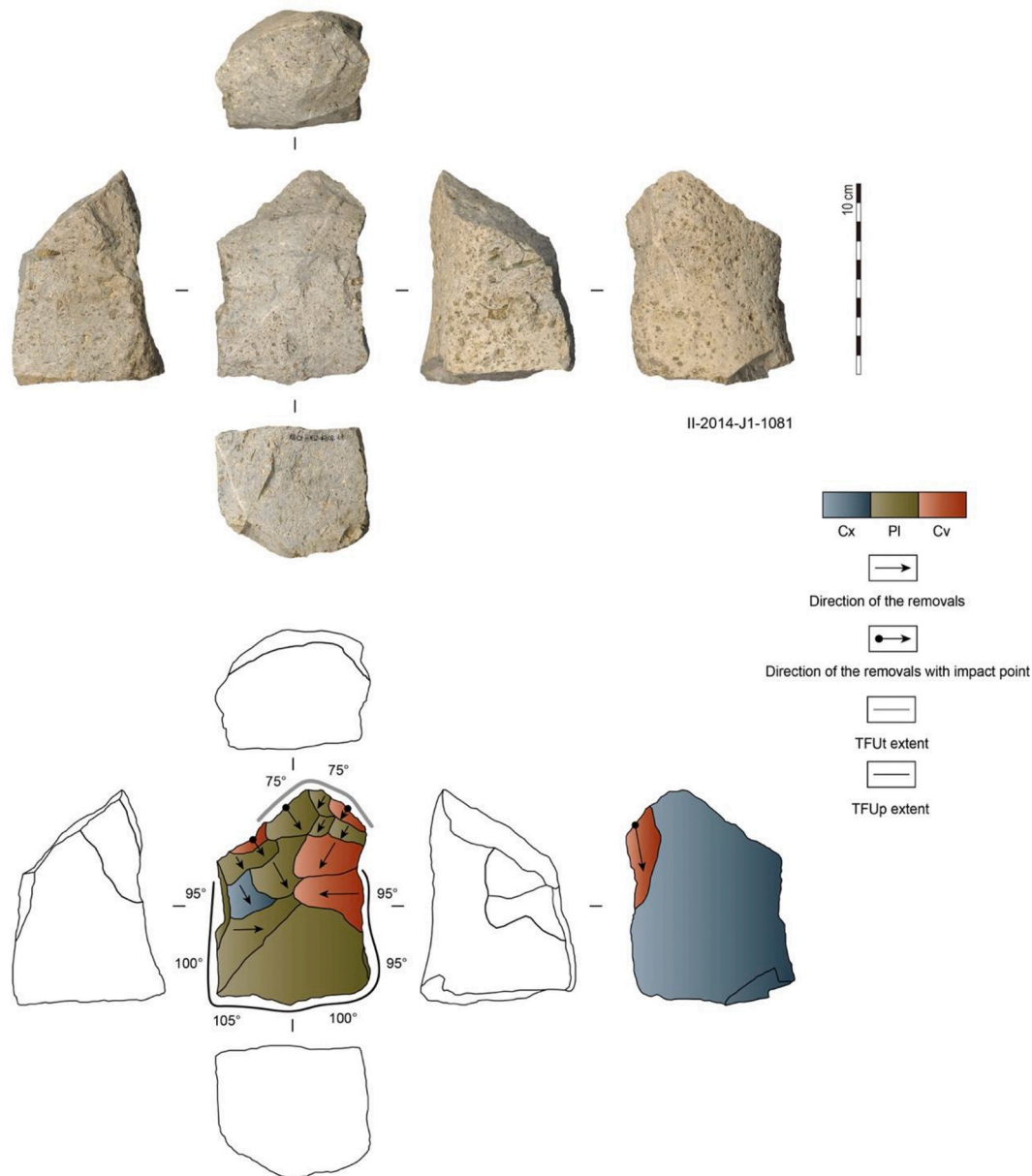


Figure 18. Diacritical and structural sketch of the artifact n°II-2014-J1-1081. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

In addition, small/light and large/heavy hammerstones were used alternatively and/or successively for knapping tests in order to obtain the desired products, regardless of whether the method used, on an anvil or freehand percussion. This alternation generated a variety of stigmata that can be used as a reference for comparison with the lithic material from unit F.

Bipolar-on-anvil percussion resulted in characteristic stigmata such as the presence of a counter-bulb in the distal part of the flakes, an angle close to 90° between the butt and the breaking surface, and the recurrent creation of silet fractures.

Secondly, direct freehand percussion is characterized by the presence of a well-defined cortical or plain butt, an angle greater than 100° between the butt and the breaking surface, and more frequent hinged flakes. While anvil percussion was identified at Kalinga, these passive hammers/anvils were not found during the excavations.

Finally, our experiments have shown that the use of these two percussion techniques within various reduction strategies was sufficient to produce a wide variety of flake morphotypes, some of which yielded a silet flat or a cortical back associated with a potentially functional raw edge.

3.4. Use-wear analysis of selected artefacts

Among the 21 lithic artifacts from Kalinga selected for traceological analysis, seven (one-third) had wear traces that were positively identified as resulting from anthropogenic activities. Four others had traces that could have been produced by some taphonomic agents, and the rest had no or no identifiable traces. Given the limited number of use-related pieces, each artefact is presented individually using their accession number. All were recovered within unit F.

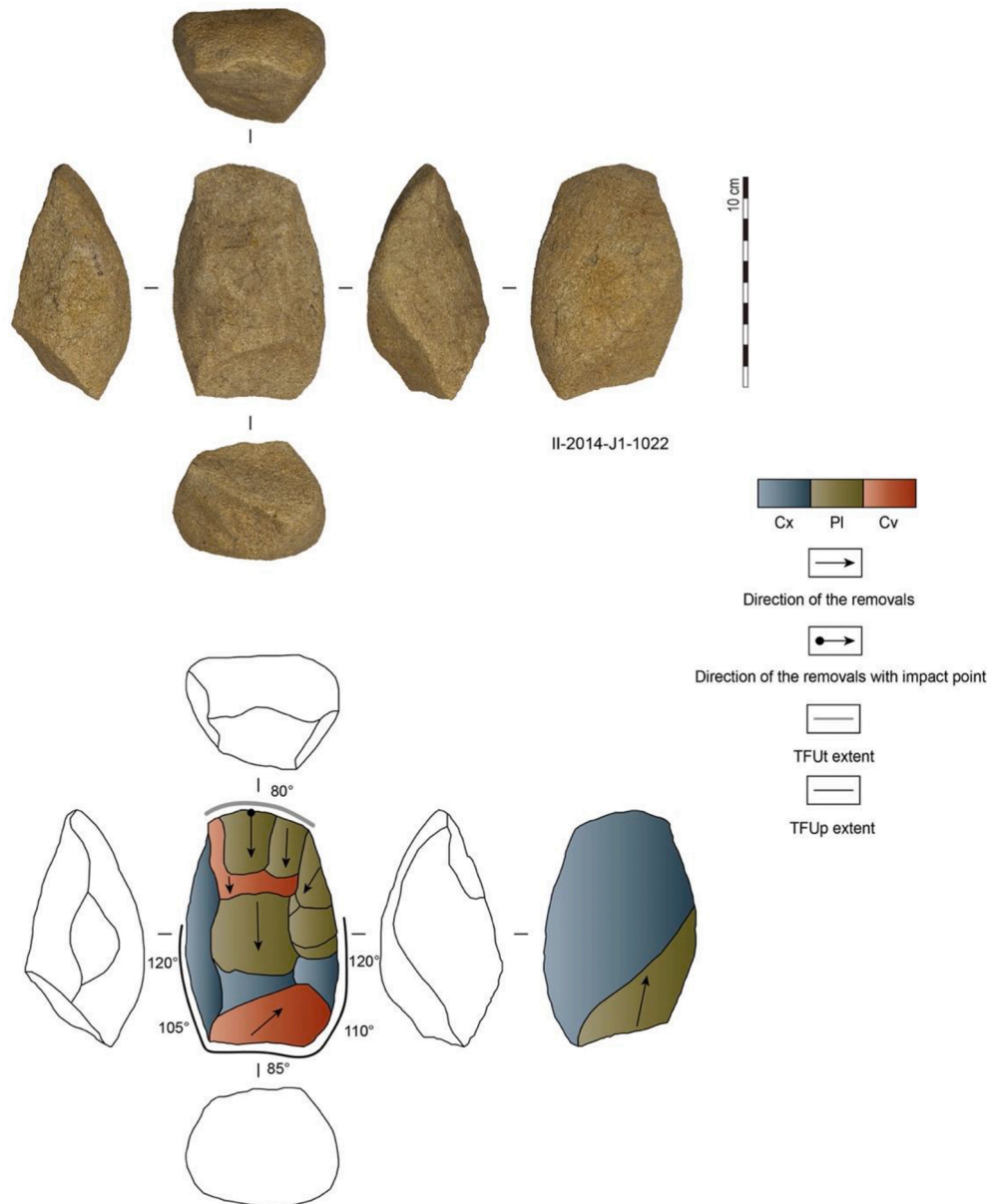


Figure 19. Diacritical and structural sketch of the artifact n°II-2014-J1-1022. (For interpretation of the references to color in this figure, the reader is referred to the Web version of this article.)

The following artifacts displayed identifiable wear traces:

II-2014-J1-391: The lateral edges are mostly without wear traces, and only a few small scars are visible, which appear to be of taphonomic origin rather than use-related. Potentially used areas (PUAs) are the triangular tipped end (PUA I) and one shoulder featuring the only sharp-angled edge on this tool (PUA II). The immediate tip is defined by a shear fracture leaving a slightly crescent-shaped break (Fig. 23A). The edge on the dorsal face shows small but intense scarring with multiple stepped micro-negatives with distal step and distal hinge terminations, similar to a second-edge-row feature (Vaughan, 1985), which abraded the immediate edge and part of the ridge toward the tip (Fig. 23B). A slight gloss also appears along the scarred edge. Using high-power analysis, a bright reflecting polish bevel becomes visible (Fig. 23.1). Numerous striations, longitudinal and across the polish cause a rather rough surface structure with smooth areas in between that exhibit some micropitting (Fig. 23.1).

Slight abrasion also appears on the opposite side (Fig. 23A), together with a thin bright reflecting polish bevel. Short transverse striations appear on the polish surface (Fig. 23.2). Since no further damage is visible on the other two edges of the triangular tip, it is possible that only the tipped distal end was used. The morphology of edge wear and polish suggests a harder organic material, e.g., bone. The limited distribution of the wear traces makes a transversely oriented activity such as engraving more likely than an activity that applied rotation. The dorsal part of the tip appears to have served as the main contact area, with occasional changes toward the ventral side. The PUA II has a slightly denticulated appearance due to several compression ripples on the dorsal face. Some small irregularly shaped scars are visible on dorsal and ventral sides, but their origin remains indeterminable (Fig. 23C, D). Along the immediate edge, a micropolish similar to that observed along PUA I can be observed on the ventral side (Figs. 23.3 and 23.7). This polish is not continuously developed along the edge but



Figure 20. Photographic plate of experiment n°1. Legend is the same as in Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

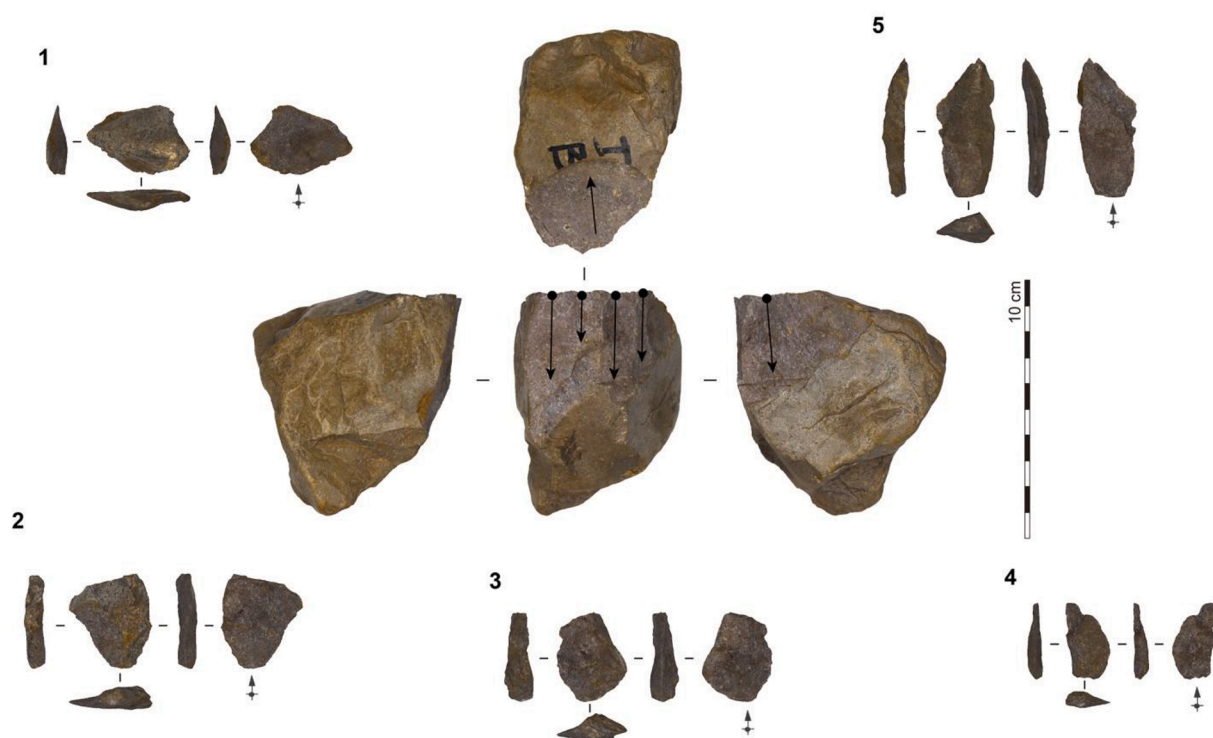


Figure 21. Photographic plate of experiment n°2. Legend is the same as in Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

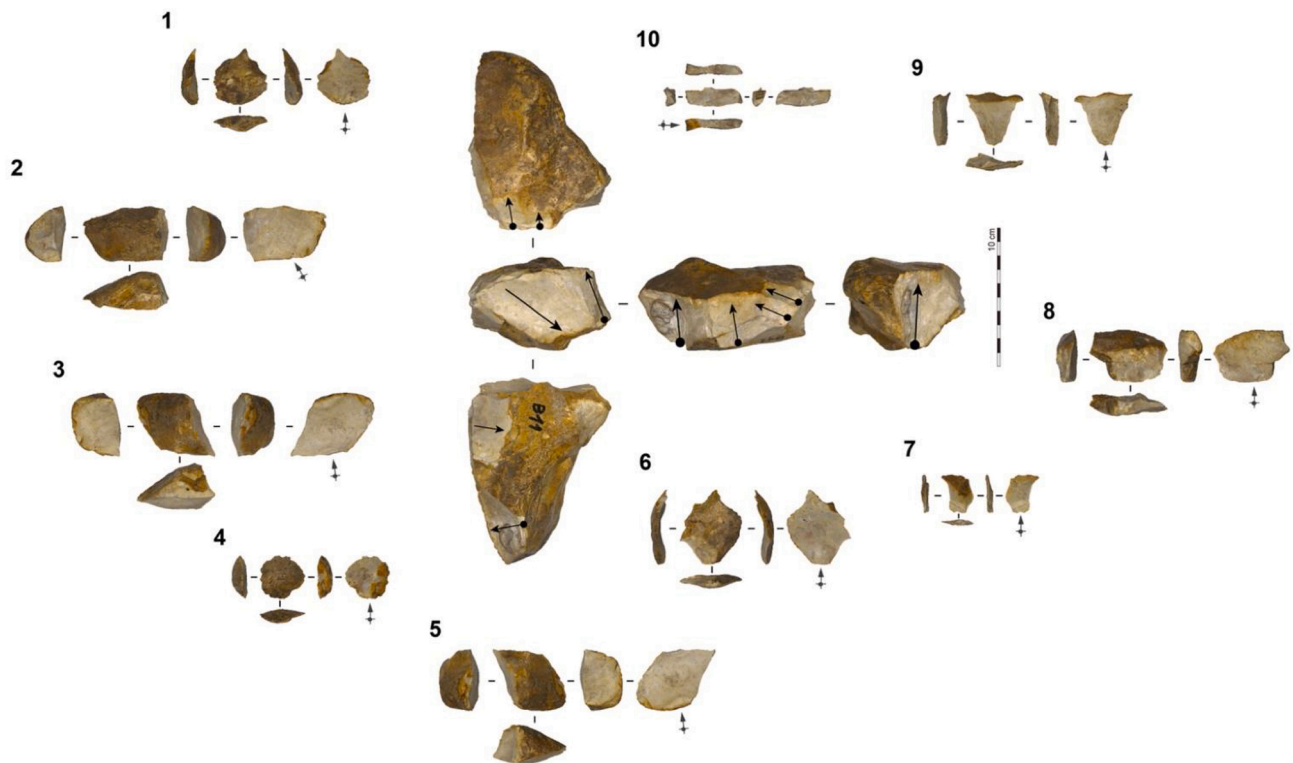


Figure 22. Photographic plate of experiment n°3. Legend is the same as in Figure 4. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

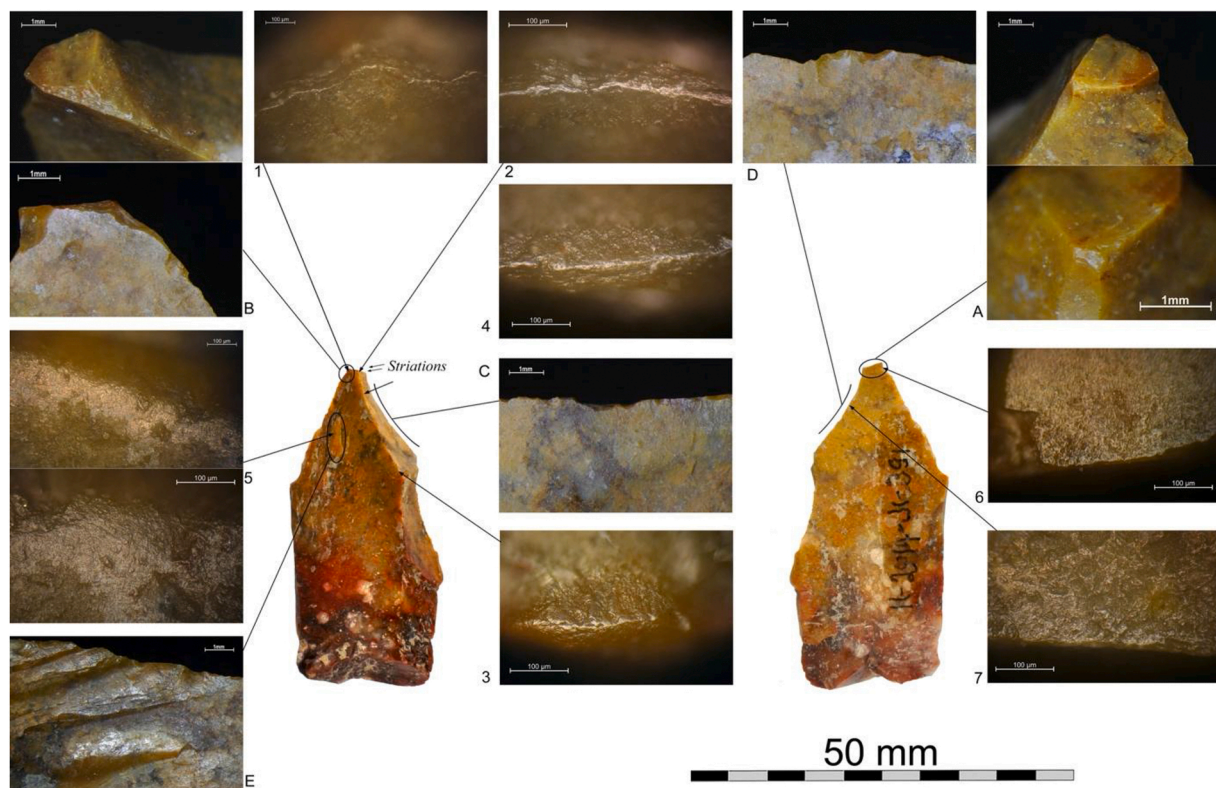


Figure 23. Traceological analysis of the artifact n°II-2014-J1-391. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

appears on the entire area C. On the inner ripple, a slight gloss similar to that observed in area B can be observed (Fig. 23E). High-power analysis reveals a dense but rather weakly developed polish covering the ripple. A few striations can be observed in a transverse direction relative to PUA II (Fig. 23.5). This polish in the interior but somewhat elevated part of the tool suggests a rather shallow working angle when using PUA II; PUA II was certainly used on the same material as PUA I in a predominantly transverse scraping activity and very likely within the same working context. The triangular tipped end bordered by a flat concave edge and the thick back of this tool recalls what Aureli et al. (2016) designated as 'mini-rostrum tool.'

II-2014-J1-402: This is a fragment of an initial flake from a coarse-grained quartzite pebble that exhibits a denticulated and fairly straight edge (Fig. 24).

Several steep scars and crescent breaks have serrated the edge, and they are predominantly located on the steeper-angled ventral face. The coarse-grained quartzite hampers further analysis and prevents a secure identification of the wear traces. The scars certainly derive from contact with hard matter. While this contact does not necessarily have to be use-related, their rather regular appearance might suggest an intentional contact, except for the single crescent breaks in the middle of the edge, which could result from postdepositional damage, for instance, trampling (Fig. 24A). In addition, some crystals along the potential working edge appear slightly abraded (Fig. 24B). As a potential activity, cutting or sawing through a harder material such as bone can be considered. High-power analysis was not applicable as the coarse-grained structure of the artifact prevents the observation of any developed edge polish.

II-2014-J1-519: The lateral edges are rather thick with a 90° angle, with PUA I being convex and PUA II slightly concave. No significant edge wear is visible with the naked eye. The distal end (PUA III) appears rather blunt due to the right angle of both lateral edges (Fig. 25.1). Diffuse scars with shallow terminations near the tip (Fig. 25.1) might indicate frontal and lateral pressure applied on the immediate tip. This might be use-related; however, the slightly 'fresher' surface of this part of the edge could also suggest a

postdepositional cause. No clearly defined wear traces appear along the lateral edges. The few diffuse microscars observed have formed on the facets of the edge (Fig. 25.2 and 25.3), rather than the adjacent dorsal and ventral surfaces, where only single and less invasive shallow scars with distal feathered termination appear along the medial part of PUA II. A rather interesting feature appears between the edge PUA II and the tip PUA III. Here, a seemingly calcareous deposit has formed, on which clearly deep striations in both longitudinal and transverse directions appear (Fig. 25.1). This deposit could have already been present on the tool prior to its use, due to the absence of carbonates in the environment of the site. In this case, it would indicate the use of the distal end in scraping and engraving activities.

II-2014-J1-674: A large initial/first-split flake of a quartzite cobble, produced by bipolar-on-anvil technique and preserving the natural outer surface (Fig. 26).

The reddish discoloration of the outer surface, in contrast to the yellowish-light brown color of the ventral face, is typical of the lateritization of the cobbles found in the terrace near the site. A few irregular larger removals on the dorsal distal end are not diagnostic of use and are probably the result of retouching or potentially postdepositional processes (Fig. 26A). However, along one lateral edge appears a row of crescent breaks and steep scars with hinge termination (proximal steep and distal hinge). Such scars are typically caused by hard contact materials and may have resulted from longitudinal motion, for instance, sawing (Fig. 26B).

II-2014-J1-676: A small, elongated flake that was probably made by bipolar-on-anvil percussion technique from an ortho-quartzite. Its hinge termination was possibly the result of a silet knapping accident (Fig. 27).

This artifact features what may look like burin negatives along one lateral edge (Fig. 27A) and a frontal step break on a fissure plane (Fig. 27B). No wear traces were observed along the cutting edges. The other edge and much of the dorsal surface are covered by a water-worn natural outer surface. High-power analysis revealed a highly reflecting 'sediment polish,' possibly resulting from a chemical alteration of the surface caused by the interaction with the embedding sediment. This alteration covers the entire

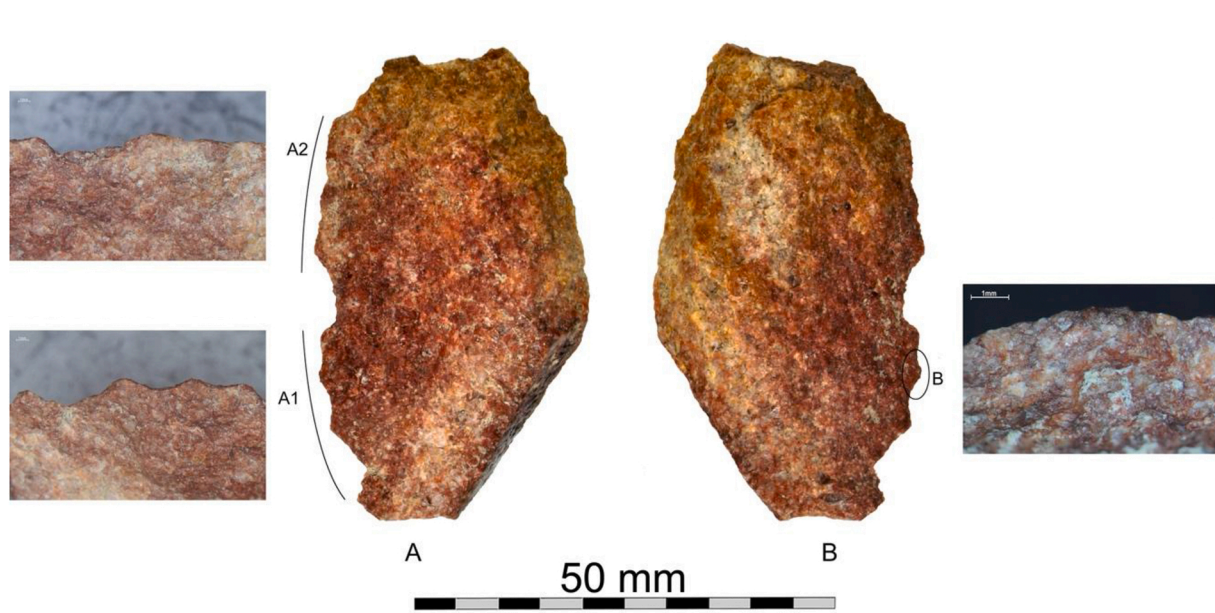


Figure 24. Traceological analysis of the artifact n°II-2014-J1-402. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

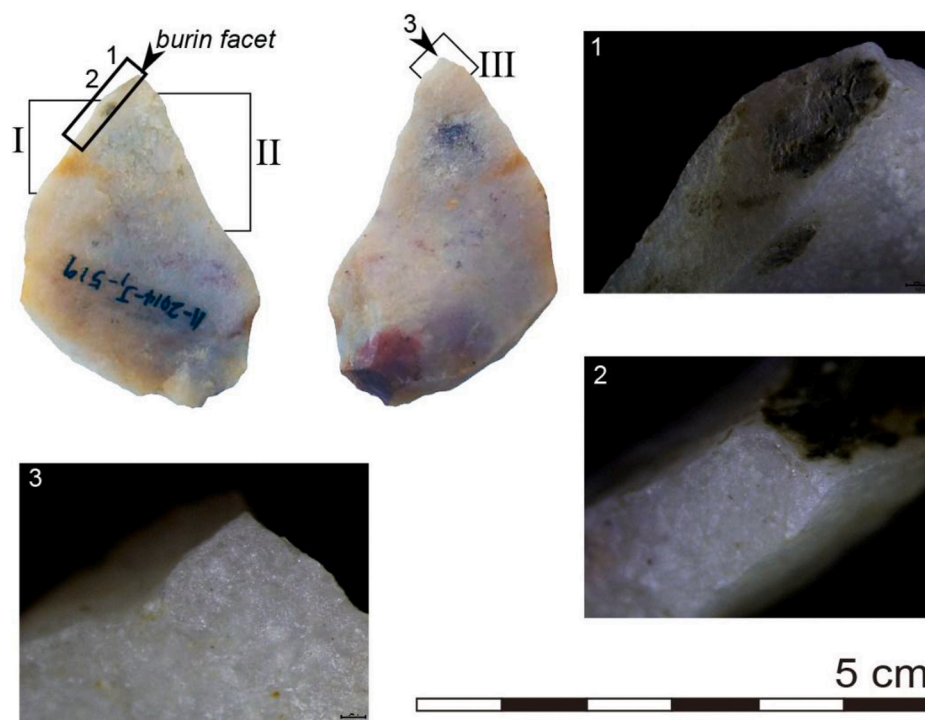


Figure 25. Traceological analysis of the artifact n°II-2014-J1-519. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

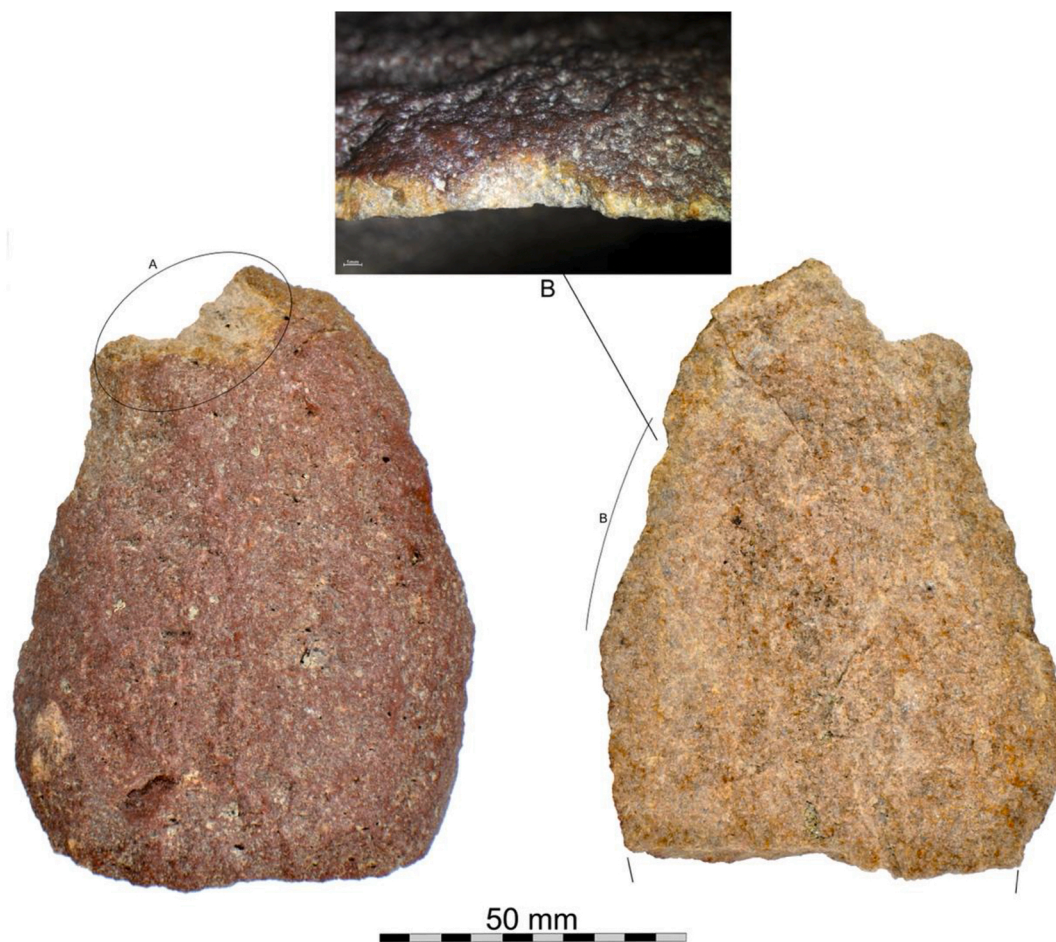


Figure 26. Traceological analysis of the artifact n°II-2014-J1-674. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

surface of the artifact and hampers the analysis (Fig. 27.2). No diagnostic use polish was observed along the lateral edges. Only the immediate tip of the artifact displays small polish spots on elevated parts of the artifact's microtopography. These exhibit a bright reflection and diffuse frontal longitudinal striations with a faint reticular distribution on the dorsal surface (Fig. 27.1) and smooth domed surfaces with micropitting on the ventral side (Fig. 27.3). The traces are too weakly developed to securely determine use, although a contact of the tip with a harder organic material such as bone can be considered.

II-2014-J1-733: Two PUAs in the form of lateral edges are recognized. Both lateral edges exhibit edge scarring suggesting use of this artifact. The PUA I is a steep-angled concave edge located in the pointed half of the artifact. Some larger scars with step termination are truncated by secondary negatives with distal step and distal hinge cross sections, similar to a second-edge-row feature, after Vaughan (1985), suggesting a hard contact material (Fig. 28A). The negatives appear on the steeper dorsal side of the edge.

The convexly curved lateral edge (PUA II) carries, along its distal part and toward the tip, a sequence of crescent breaks and less steep proximal steep and distal feathered negatives provide a slightly denticulated appearance (Fig. 28B), followed by larger and more intrusive scars with proximal steep and distal feathered cross sections in the medial part (Fig. 28C). No second-edge row appears on area B, aside from single microscars on the proximal edge, but the immediate scarred edge appears slightly rounded at 20× magnification (Fig. 28B). On area C, a partial second-edge row with stepped microscars indicates a harder contact material. All negatives are located on the ventral face, suggesting a transversal scraping motion with the dorsal surface acting as the contact surface, but also an activity different from the one found on PUA I. A row of crescent-break microscars appears toward the thick and cortex-covered proximal end (Fig. 28D), in groups alternating from dorsal to ventral. Considering the thin and fragile edge in this part,

this might either be an unintentionally created abrasion or be related to handling.

High-power analysis shows only weakly developed polishes near the tip. A blunt smooth-pitted polish (Vaughan, 1985) with a greasy appearance has formed at the immediate tip on ventral (Fig. 28.1), while a thin, moderately reflecting polish bevel-like accumulation of polish spots with similar texture is visible along PUA I (Fig. 28.2). Applying higher magnification revealed only isolated polish spots with bright reflection and a fluidal smooth surface with a few diffuse micropits (Fig. 28.4). No developed micropolish is visible along the ventral side of PUA II (Fig. 28.3). On the dorsal face, no developed use-wear is observed on either PUA I or II. Possibly, the abrasive contact removed particles of the immediate working edge before polish could develop.

II-2014-J1-765: A trapezoidal flake from a bipolar core made of andesite and displaying unidirectional removals (Fig. 29).

The PUAs are the concave lateral edges. The PUA I possess a slightly concave shape with a V-shaped cross section of the edge. Diffuse negatives with shallow initiation and feather termination appear on both faces, together with a slight rounding of the immediate edge (Fig. 29A–C). These potentially resulted from a scraping activity on a plant material of medium hardness, such as woody vines or bamboo. The PUA II is irregularly concave reduced by several wider crescent breaks (Fig. 29D). These do not appear, however, to be use-related, but rather seem to have been caused by trampling or a similar postdepositional effect.

The coarse and grainy structure of the flake prevented the formation of developed micropolishes. Only isolated polish spots are visible where the crystal faces were parallel to the ventral and dorsal faces. On the ventral side (Fig. 29.1), a brightly reflected and slightly domed polish formation with micropitting and diffuse striations transverse to the edge of PUA I is present, while on the dorsal side of the same tip, micropolish spots with micropitting and diffuse longitudinal striations appear (Fig. 29.4). Polish spots

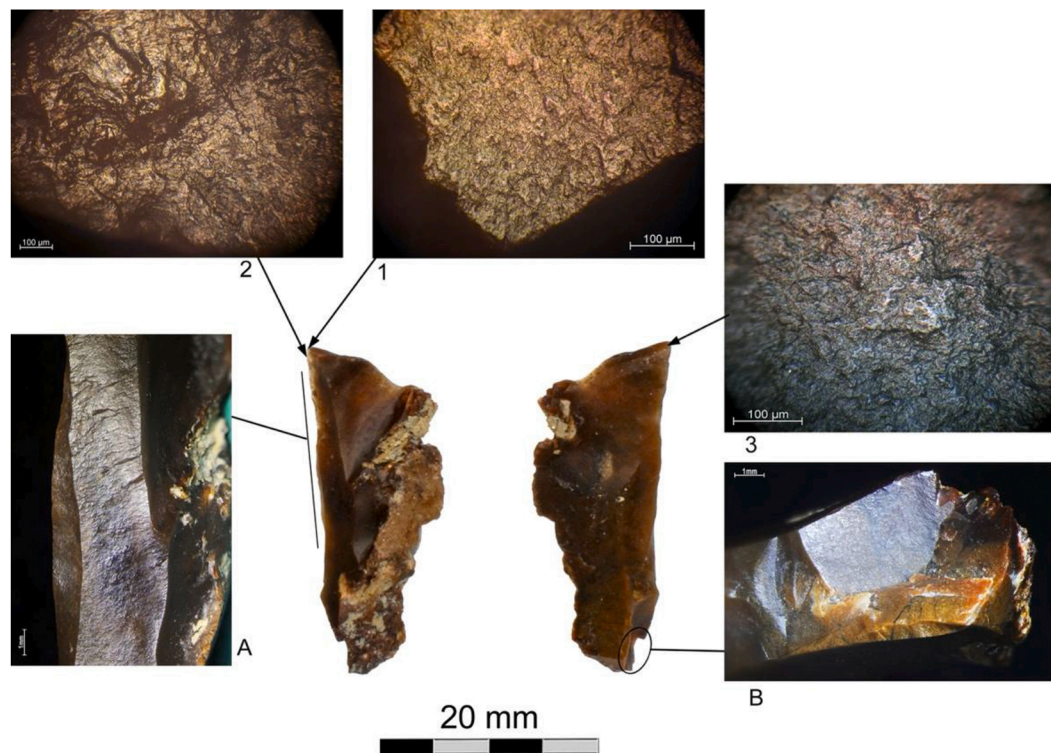


Figure 27. Traceological analysis of the artifact n°II-2014-J1-676. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

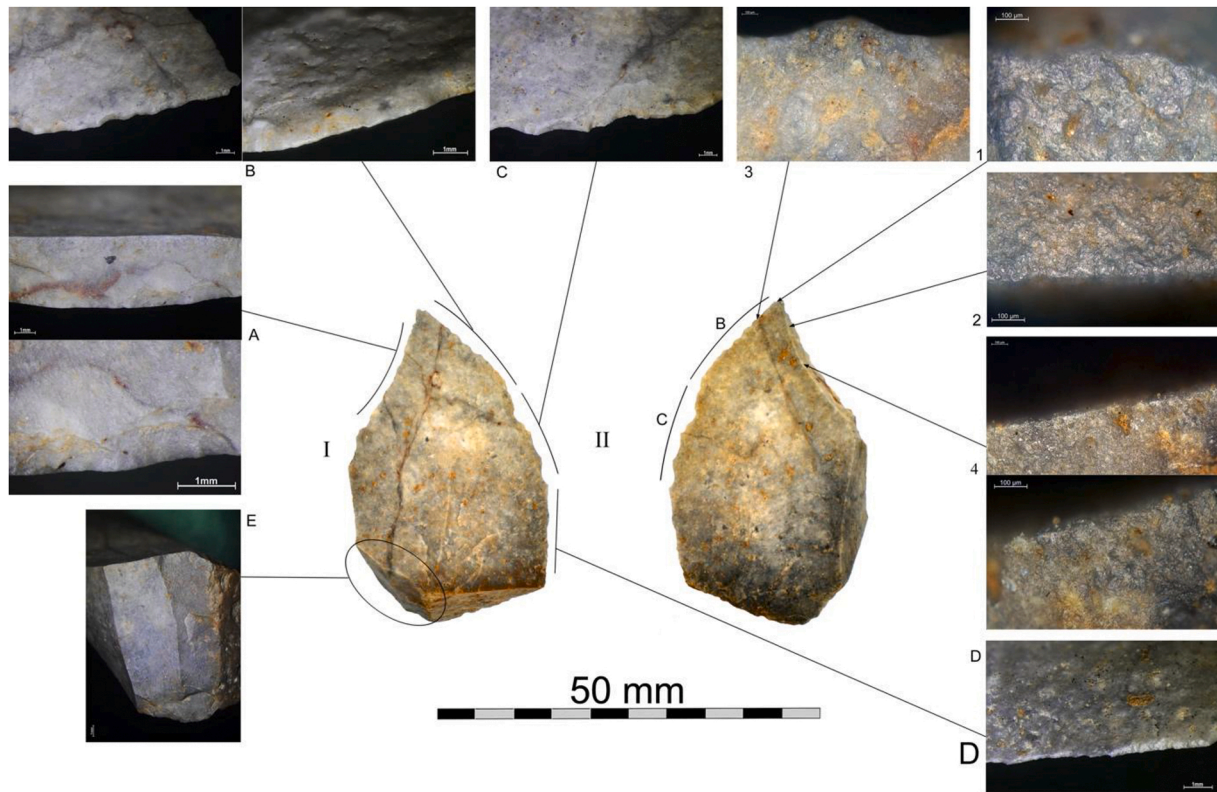


Figure 28. Traceological analysis of the artifact n°II-2014-J1-733. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

that appear along the ventral edge of PUA I (Figs. 29.2–3), and to a somewhat lesser extent on the dorsal side, may indicate contact with a harder organic material such as bone.

3.5. Reassessment of the ancient Cagayan Valley collections in the lights of the Kalinga assemblages

The Kalinga site is located in the Cagayan Valley, which since the first half of the 20th century has yielded numerous series of

lithic artifacts on the surface (Beyer, 1947; Von Koenigswald, 1958). In the 1970s, in response to a growing number of discoveries, researchers from the National Museum of the Philippines, in collaboration with the University of Iowa and Iowa State University, conducted surveys and excavations at three sites between 1971 and 1972 (Fox, 1978; Bondoc, 1980). These research programs led to the identification of more than 60 sites within a geographical area covering approximately 10 km² (Fox, 1978 p. 71). The lithic material is recovered from these sites is currently preserved

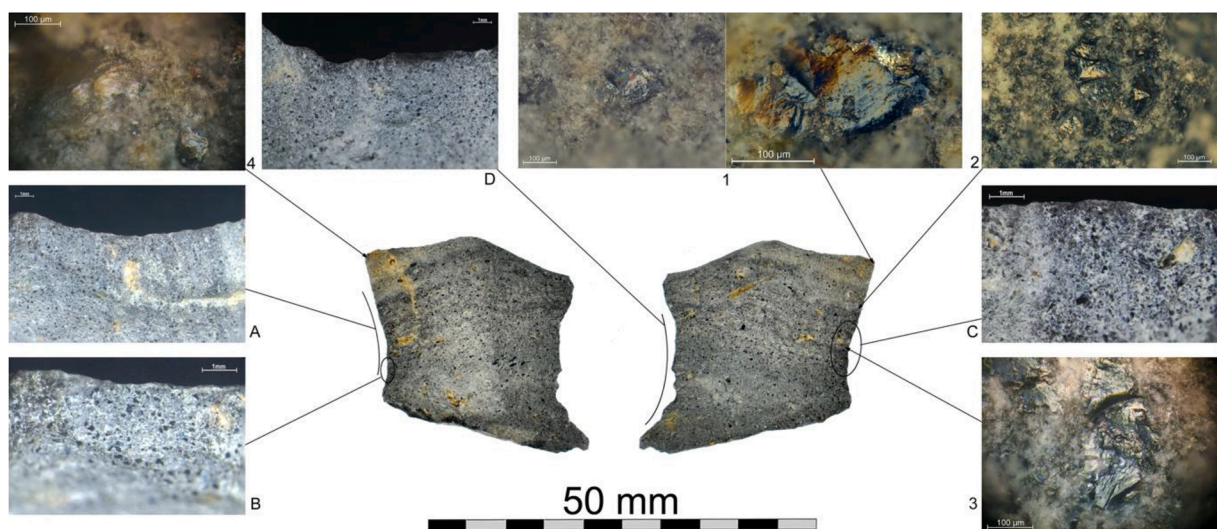


Figure 29. Traceological analysis of the artifact n°II-2014-J1-765. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

in the reserves of the National Museum in Manila and at the National Museum's research station in Peñablanca. The main challenge in re-examining these archaeological collections is to characterize them technologically as accurately as possible in order to compare them with lithic assemblages discovered in situ. Chronologically, recent data indicate that the Clyde site and Espiñosa 4 would date from the first half of the Middle Pleistocene (Lambard et al., 2024).

In this context, we will first describe the main technological characteristics of the excavation sites that yielded lithic material in stratigraphy and on the surface such as the Clyde site, Espiñosa 4, and Madrigal 12. Next, we will provide a summary of the technological data from other sites in the Cagayan Valley.

Clyde site The Clyde site, located a few hundred meters north of Kalinga site, was initially excavated in 2008 in the form of a test pit and trench, which did not reveal any lithic artifacts in situ (Jagou, 2009). Later, in 2019, surface surveys led to the discovery of the remains of a proboscidean tusk, which led to the opening of a new trench in 2022. This operation led to the identification of six lithic artifacts in unit 2, which are estimated to date from between 516 ± 45 ka and 399 ± 40 ka (Lambard et al., 2024).

These objects are mainly derived from volcanic rocks such as lava or metaquartzite cobbles. From a typological and technological perspective, this small series consists of flakes, fractured cobbles, and cores (Fig. 30). The flakes have the following average dimensions: $30 \times 20 \times 1$ mm, with parallel or divergent edges and cortical or plain butts. The average flaking angle is 112° , indicating

the application of direct freehand percussion. None of these flakes are interpreted as tools, although one of them (no. CAR-2022-F3-94) shows a potentially functional cutting edge.

Two cores with alternating orthogonal removals are also included (Fig. 30), as well as a fractured cobble corresponding to a cobble that shows signs of anthropogenic fracture but does not reveal any identifiable production pattern. The technological characteristics of this small lithic series are consistent with the variability documented in unit F of Kalinga, notably through the presence of an alternating orthogonal flaking strategy and the use of a direct freehand percussion.

Espiñosa 4 The Espiñosa 4 site is one of three sites excavated in the early 1970s by members of the National Museum (Fox, 1978). Two flakes were discovered in unit 6 by Fox and Peralta and were interpreted as scrapers. These two objects were also re-analyzed by Johannes Moser, who questioned their anthropogenic authenticity and therefore the reality of any association between the faunal remains and the 'man-made' tools (Moser, 2001, p.133). New dating evidence suggests that these two artifacts are more recent than 623 ± 45 ka (Lambard et al., 2024). It was based on these two flakes discovered in situ, combined with the high proportion of flakes in the Cagayan lithic assemblages, that R. Fox defined the 'Liwanian Flake Industry' in contrast and reaction to the 'Cabalwanian Cobble Industry,' created two decades earlier by Von Koenigswald (1958) (Fox, 1973, 1978, p. 72). Thus, the two flakes from Espiñosa 4 were produced by direct freehand percussion of an orthoquartzite cobble (Fig. 31). Flake n°71-G4-296 is

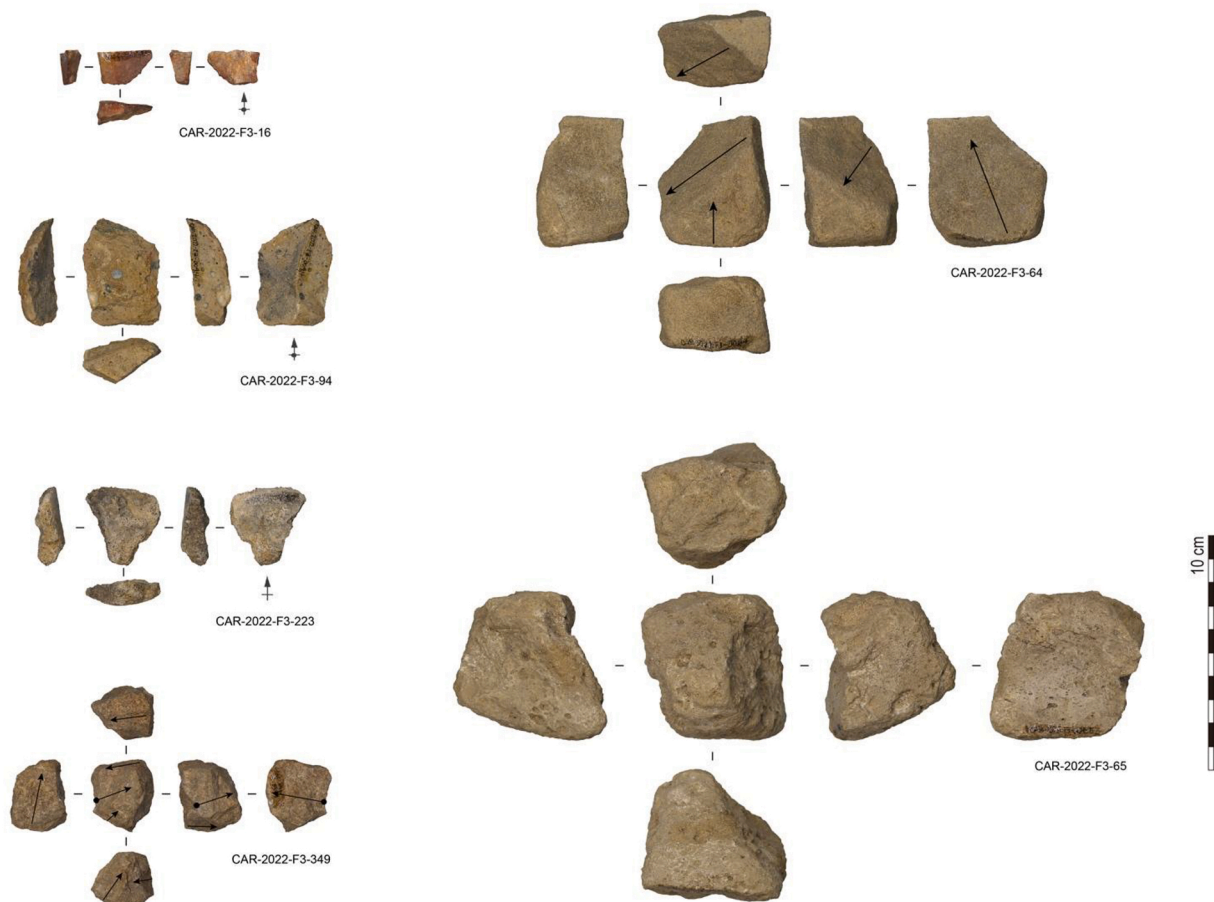


Figure 30. Lithic artifacts from Clyde site. Flakes (n°16, 94 and 223); cores (n°64 and 349); fractured cobble (n°65). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)



Figure 31. 'Liwanian' flakes from Espiñosa 4 collected during the 1970s fieldwork campaigns. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

40 mm long, 42 mm wide, and 13 mm thick, with (sub)parallel edges. The butt is cortical with a pronounced bulb, and the flaking angle is 110° , indicating direct freehand percussion. This is a flake from at least the third generation in the reduction sequence, based on the reading of the negative removals.

A few minor removals can be seen on the left edge, which do not appear to be intentional retouching to modify the morpho-structural characteristics of the cutting edge. The second flake, n°71-G4-295, measures 51 mm in length, 42 mm in width, and 15 mm in thickness, with a similar (sub)parallel edge morphology. It is a flake with a silex break on its right edge, a plain butt, and a pronounced bulb. The flaking angle is 115° , again indicating direct freehand percussion technique. This second-generation flake has a fracture on its distal end and a few microremovals on the left edge. However, even though this edge has functional potential, these removals do not correspond to an intentional retouching phase (Fig. 31).

In addition to these two flakes discovered in a stratigraphic context, the lithic series from Espiñosa 4 is composed of a few surface finds (Fig. 32). These are mainly orthoquartzite and met-aquartzite flakes produced using direct freehand percussion and

bipolar-on-anvil technique. The two cores from this site attest to reduction strategies involving parallel unipolar and alternating orthogonal (Système par Surface de Débitage Alternée (SSDA) type Forestier, 1993) removals. The toolkit consists of two small tools made from flakes and a macro-tool made from a cobble with unifacial removals. Notable is the presence of a large flake (length >10 cm sensu Sharon, 2009, 2010) with a potentially functional neocortical distal edge (Fig. 32), as well as a thick flake made from silicified wood. Overall, based on the two in situ flakes and the surface finds, the production strategies at Espiñosa 4 are similar to those observed in the Kalinga assemblage.

Madrigal 12 The Madrigal 12 site yielded a lithic series ($n = 76$) that was numerically more substantial than the previous assemblages. Most of the artefacts were recovered from a colluvial surface layer located between 5 and 15 cm below the surface (Fox, 1978 p. 81). From a petrographic point of view, the artifacts were mainly produced from orthoquartzite ($n = 44$) or metaquartzite ($n = 20$) blanks, collected in the form of cobbles, probably in the immediate vicinity of the settlement. Flaking is the main production system and is represented by numerous flakes and flake fragments ($n = 58$), as well as a few cores ($n = 4$). The reduction



Figure 32. Lithic artifacts from the Espiñosa 4 site. Large flakes (n°1 and 6); flakes (n°4 and 300); flake tool (n°3); silicified wood flake (n°89). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

strategies are parallel unipolar removals, hierarchical centripetal (radial) removals, or alternating orthogonal removals (Fig. 33). It should be noted that centripetal reduction always begins with the flaking of a thick flake whose ventral surface serves as a striking surface or with the splitting of an ovoid cobble.

Synthesis of the technological characteristics of the localities in the Cagayan Valley The technological study of surface lithic assemblages from the following 11 sites: Espiñosa, Espiñosa North of Pirit, Espiñosa N.R. House, Espiñosa 3, Espiñosa 5, Espiñosa 6, Espiñosa 9, Espiñosa 11, Espiñosa 22, Espiñosa 28, and Madrigal 12 South, provides significant comparative data. Although these series are based on surface collections, they comprise a total of 2969 lithic objects, which provide statistical information on the major technological, production, and structural features of the human groups that inhabited the Cagayan Valley during the Pleistocene.

This comparative section is conceived as a synthesis, and the data are presented by focusing solely on the most representative characteristics of the lithic assemblages from this area.

Production strategies – The lithic assemblages at these sites are structured around the exploitation of either metaquartzite or orthoquartzite cobbles, which were probably taken directly from ancient alluvial formations available nearby such as the ‘Cobble Terrace’ formation. In addition to these two main raw materials, volcanic rocks such as lava, andesite, and dacite, as well as some silicified wood elements (Molave tree type?) are also included. The taphonomic aspect of the entire series is quite homogeneous, with some objects showing a medium-intensity patina or gloss that does not affect the global technological reading. The lithic material

from the Cagayan Valley localities differs from the metric composition of ‘classic’ surface series in that it contains a relatively abundant number of very small elements (debris/chunks, flake fragments, etc.) resulting from production activities, measuring no more than 25 mm in length. In this context, it should be noted that these small elements have been systematically collected and incorporated into the collections since the 1970s by researchers from the National Museum. This exhaustive collection, as described in particular by R. Fox and J. Peralta for the Espiñosa 1 site (Fox, 1978), provides a relatively complete typo-technological overview.

Thus, all 11 localities in the Cagayan Valley are characterized technologically by a clear predominance of reduction strategies. The assemblages yield a total of 1595 flakes and flake fragments, representing approximately 54% of the total assemblages studied, as well as 179 cores or core fragments. Before comparing the Kalinga assemblage with those from the Cagayan Valley, a statistical projection using violin plots shows that most of the data are distributed according to unimodal patterns, except for the Espiñosa 11 and Espiñosa 4 sites (Fig. 34). In this context, the comparison of the Kalinga unit F assemblage with these assemblages is therefore valid. Based on the cores (Fig. 35), three reduction strategies can be clearly identified: alternating orthogonal reduction (42%), recurrent parallel reduction (39%), and centripetal (radial) reduction (19%).

The numerous flakes (Fig. 36) have the following average dimensions: 40 mm in length, 35 mm in width, and 13 mm in thickness. Their edges are oval (27%), parallel (25%), or divergent

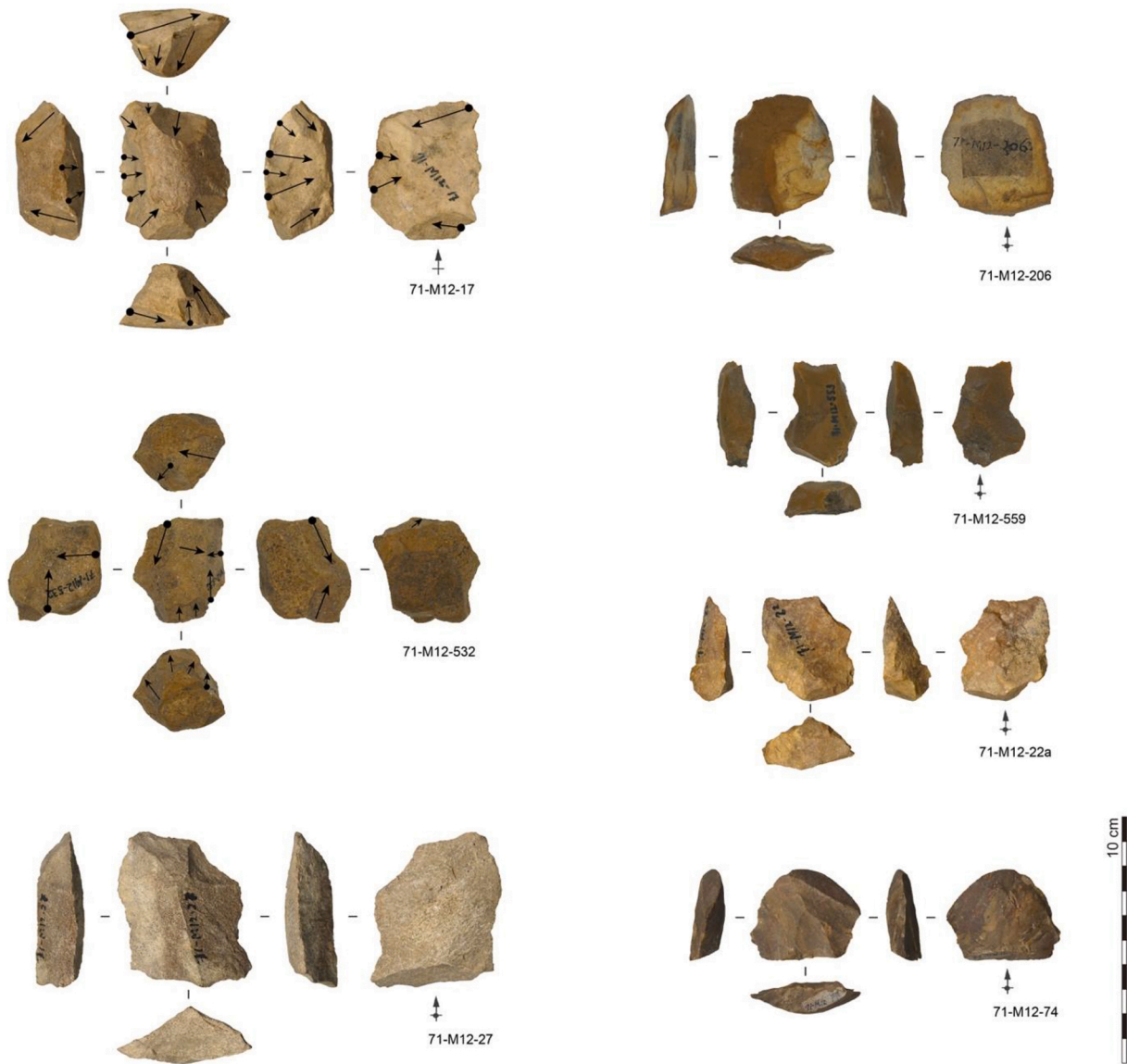


Figure 33. Lithic artifacts from the Madrigal 12 site. Centripetal/radial core (n°17); flakes (n°206, 559, 27, 22a and 74); orthogonal core (n°532). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

(21%), as well as irregular (16%), convergent (8%), and déjetés (3%). The butts are mainly plain (59%) or cortical (30%) and more rarely absent (8%), faceted (2%), dihedral, or punctiform (1%), while the average flaking angle is 110° , ranging from 90° to 125° . These characteristics indicate the use of both bipolar-on-anvil percussion techniques and direct freehand techniques.

The flakes are mainly third- or fourth-generation flakes in the reduction sequence as approximately 68% show 25% or less residual cortex, while 11% are initial or first flakes (Fig. 36). Furthermore, from a morpho-technical aspect, the Cagayan sites yield approximately 30% of flakes with a back, 7% of flakes with a lateral flat surface, 6% of silet flakes, and 6% of débordant flakes. Despite some variations in the production system, undoubtedly linked to issues of statistical representativeness, the technological, dimensional, and morphological characteristics of the series from the Cagayan Valley are very similar to those observed in unit F of the Kalinga site.

In this context, the Cagayan collections are notable for the presence of few large flakes (Fig. 37), characterized by a length

greater than or equal to 10 cm (Mourre, 2003; Mourre and Colonge, 2010; Sharon, 2010). These large flakes ($n = 6$) are only found in assemblages from the sites of Espiñosa N.R. House, Espiñosa 1, Espiñosa 3, and Espiñosa 9. During the study, no 'giant cores' that could have produced this type of flake were identified (Sharon, 2009). In addition to reduction strategies, shaping is represented by 25 objects. Shaping is only unifacial, and the removals are partial, convergent, or peripheral (Figs. 39 and 40). The shaped objects are made from both metaquartzite and volcanic rock and have the following average dimensions: 88 mm in length, 75 mm in width, and 50 mm in thickness. These characteristics are also similar to those observed for the shaped objects from unit F at Kalinga.

Tools – The lithic assemblages from surface collections in the Cagayan Valley yield a relatively limited number of tools. In accordance with the conditions under which these surface lithic series were constituted, we decided to classify only those flakes or fragments that had been retouched as small tools. Within this framework, we have identified a total of 75 small tools on flakes or

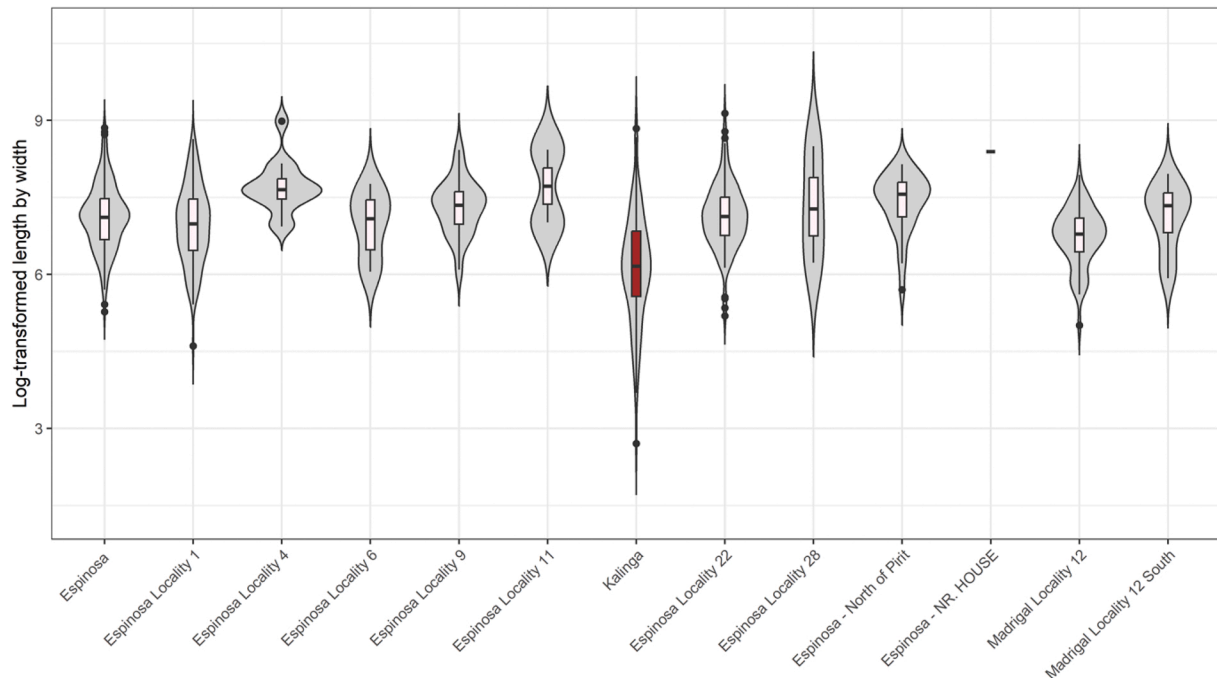


Figure 34. Violin plot representation of the dimensional data of objects from the Kalinga unit F assemblage compared with those from the Cagayan Valley localities. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

fragments for all 11 localities, which represents approximately 2.5% of the assemblages. This observation contrasts with those of Fox (1973, 1978), for whom the ‘Liwanian Flake Industry’ is characterized by a large number of retouched flakes. These small tools from the Cagayan Valley (Fig. 38) mainly consist of tools with denticulate or concave cutting edges in frontal delineation, associated with lateral backs, flat sides, or thick butts and bulbs (Fig. 38).

The massive tools consist of cobble tools ($n = 25$) and large flakes ($n = 6$). As mentioned earlier, the cobble tools are exclusively unifacially shaped, following short sequences of partial or convergent removals (Fig. 39). These cobble matrices have convex ($n = 17$), convergent ($n = 2$), or denticulate ($n = 3$) active parts. A particular morphological and technical feature is evident in the presence of ‘tongue-like’ edges (Figs. 39 and 40). Among these matrices, six objects are classified as a horsehoof because they are cobbles shaped by successive abrupt removals around the periphery of the cobble, in order to create a convex or irregular active part in frontal view with a plane-type dihedral (Figs. 41 and 42).

Finally, the six large flakes have mainly convex or convergent active parts in frontal delineation, which fit into the morpho-structural variability of massive cobble tools (Fig. 41). The characteristics of the tools from the Cagayan Valley sites are once again similar to those from unit F of the Kalinga site. The predominance of small tools with denticulate edges is similar to that seen in Kalinga, while the morpho-structures of the macro-tools are also quite equivalent. However, it is important to point out that no horsehoofs or picks were observed in unit F at Kalinga. This greater diversity of tools within the Cagayan localities assemblages may simply be explained by the smaller number of artifacts in the Kalinga assemblage.

4. Discussion: The Kalinga lithic assemblage in the context of Southeast Asia Early Paleolithic hominin behavior

The Kalinga site yields two lithic assemblages within archaeo-stratigraphic units F and Y. Unit F, the richest one, dated to

709 ± 68 ka by combined U/Th and ESR methods, attests to the association of an almost complete but disarticulated carcass of *N. philippinensis* with lithic artifacts (Ingicco et al., 2018, 2020; Antoine et al., 2021). Unit Y, on the other hand, is dated by ESR to between 365 ± 39 ka and 273 ± 20 ka (Lambard et al., 2024) and has yielded a small lithic series composed essentially of knapping debris or chunks. The nearby Clyde site delivered another small lithic assemblage dated to between 516 ± 45 ka and 399 ± 40 ka (Lambard et al., 2024). In this context, the discussion is developed by focusing specifically on the assemblage from the older unit F of Kalinga. The global technological analysis of this assemblage (Semenov, 1964; Tixier et al., 1980; Inizan et al., 1999; Boëda, 2001) enabled us to identify four main reduction strategies aimed at producing small blanks, which were used either unmodified or retouched. These four strategies were implemented using two percussion techniques: freehand direct percussion with a hard hammer and bipolar-on-anvil percussion. These percussion techniques are logically linked to the petrographic (especially for the lateritized pebbles and cobbles) and volumetric characteristics of the available raw materials, which were collected in the immediate environment of the site, probably on an ancient alluvial formation such as the ‘Cobble Terrace.’ The exploited raw materials mostly occur in the form of (sub)ovoid pebbles or cobbles of metaquartzite and orthoquartzite, as well as volcanic rocks such as dacite and andesite. Among all the products resulting from the production strategies, 14 blanks were interpreted as tools including 12 flakes and 2 shaped objects. The shaping of these two cobbles was achieved through partial unifacial convergent removals. Some tools displaying common morpho-structural characteristics could be grouped into categories also referred to here as tool technotypes.

4.1. Technological behavior at Kalinga in the Early Paleolithic of the Philippines

At Kalinga, from a detailed taphonomic analysis, it has been suspected that the tools were used to butcher the rhino carcass (Ingicco et al., 2020). It has been documented on several occasions

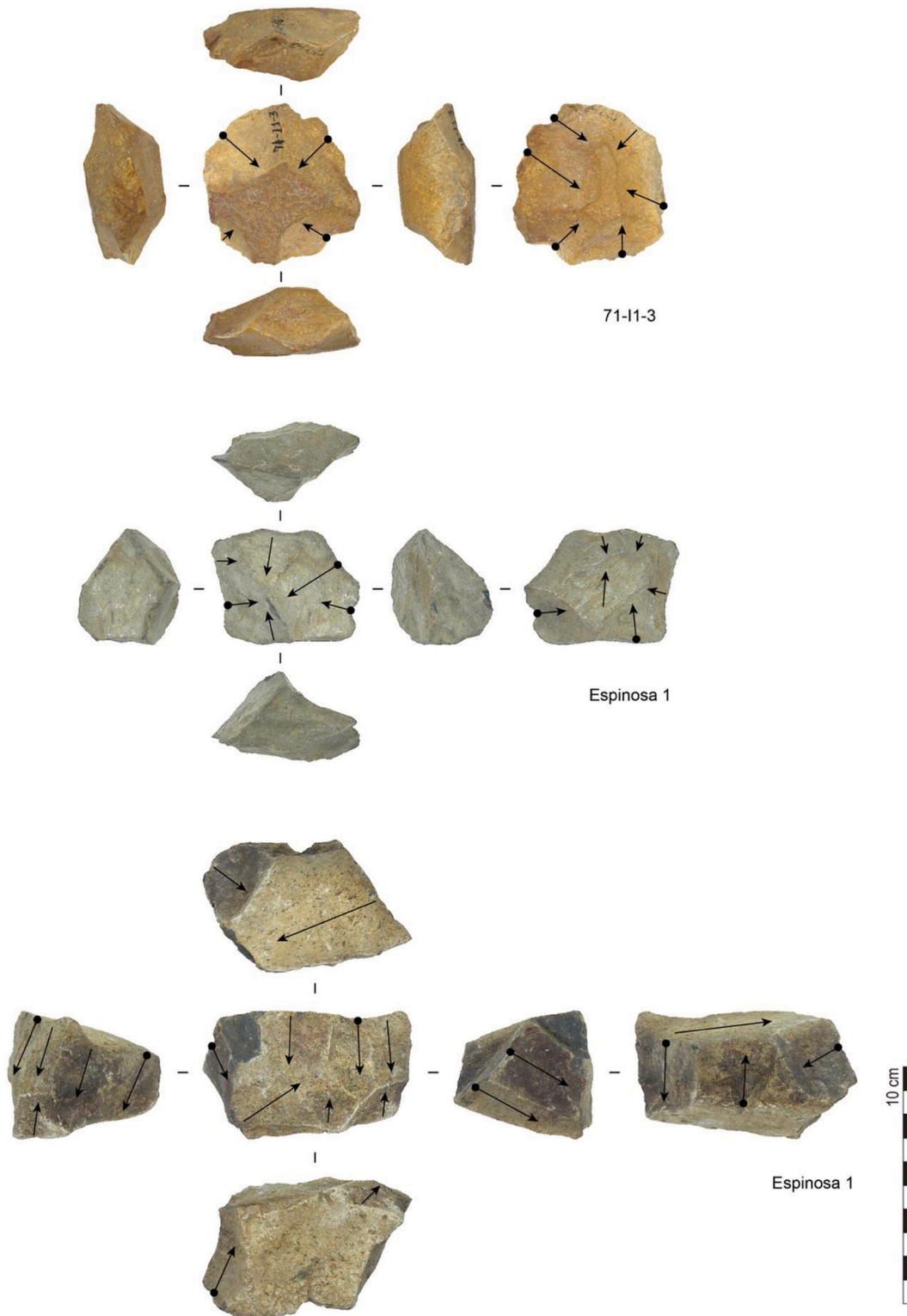


Figure 35. Examples of the main reduction strategies identified in the Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

that small stone artifacts with no retouches are very efficient to butcher very large games (Schick and Toth, 1993; Starkovich et al., 2020). Although weakly developed in general, seven artefacts from Kalinga out of 21 have wear traces. Artifacts knapped by freehand (n° 391, 519, 676, 733, and 765) were used on hard material such as

bone by using the tips of distal ends. Some of the flakes produced by the bipolar percussion (n° 402 and 674) were potentially used for cutting or sawing. It seems that here the production method had an impact on the final morphology of the tools, which were then differently used.

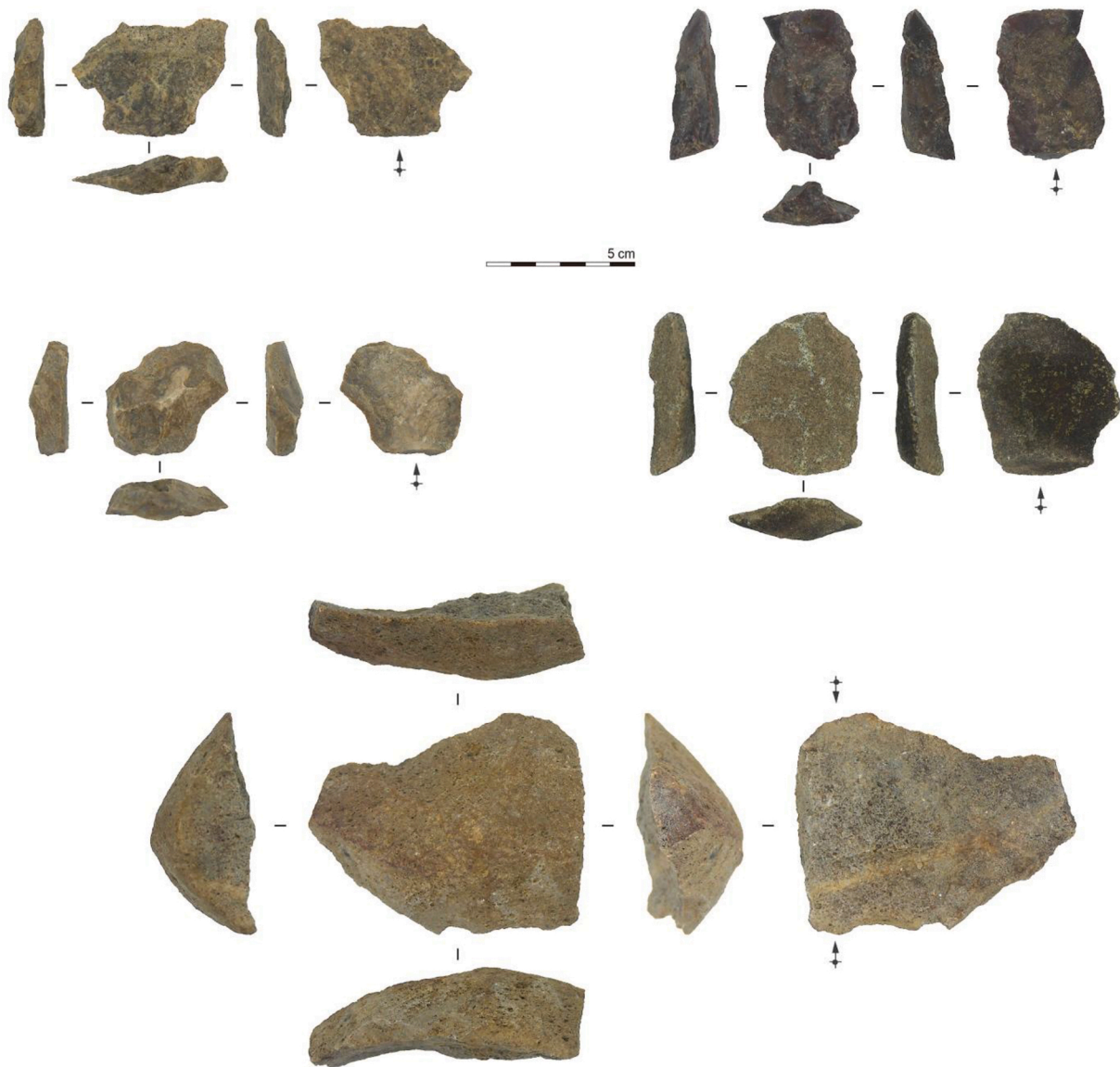


Figure 36. Examples of flake morphotypes from Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

The lithic assemblage of unit F at Kalinga fits, on the scale of the Philippine archipelago, within a set of archaeological evidence chronoculturally classified as belonging to the Early Paleolithic (Von Koenigswald, 1958; Pawlik, 2001, 2002, 2004, 2021; Patole-Edoumba, 2006; Dizon and Pawlik, 2010; Patole-Edoumba et al., 2012; Tiauzon et al., 2020; Ingicco et al., 2022). First, in the regional environment of the Kalinga site, the numerous Paleolithic localities of the Cagayan Valley constitute a primary point of comparison (Fox, 1973, 1978; Bondoc, 1980). The technological re-inspection of approximately 10 of these localities highlights that the assemblages are mainly composed of artefacts resulting from three main reduction strategies: parallel recurrent removals, alternating orthogonal removals, and centripetal (radial) removals. Two main percussion techniques are observed: freehand direct percussion with a hard-hammer and bipolar-on-anvil percussion. These flaking methods and techniques made it possible to produce a diversity of flakes, which may have been used either unmodified or retouched by the hominins inhabiting northern Luzon Island. In this respect, the flakes from these surface localities display

morphometric and structural characteristics very similar to those from Kalinga and are also generally barely retouched. Shaping is also rare among the Cagayan Valley surface localities and is characterized by large unifacially flaked tools with convex or convergent edges, some of which have a 'tongue-like' morphology. It should nevertheless be noted that the production of large flakes (length > 10 cm) is also attested both in these localities and in unit F at Kalinga and may have required the use of direct percussion with an 'anvil/percuteur dormant' (Mourre and Colonge, 2010; Sharon, 2010). All of these characteristics shared between the Kalinga lithic assemblage and those from the Cagayan sites lead us to believe that they may be partly contemporary and therefore reflect the diversity of technical behaviors during the Middle Pleistocene.

Some of these characteristics echo those of the Arubo 1 site, located in Nueva Ecija Province, about 300 km south of Kalinga (Dizon, 1996). This site lies within a fishpond area that also includes a raw material source delivering large chert nodules and other materials, notably silicified wood (Pawlik, 2004). At this site,

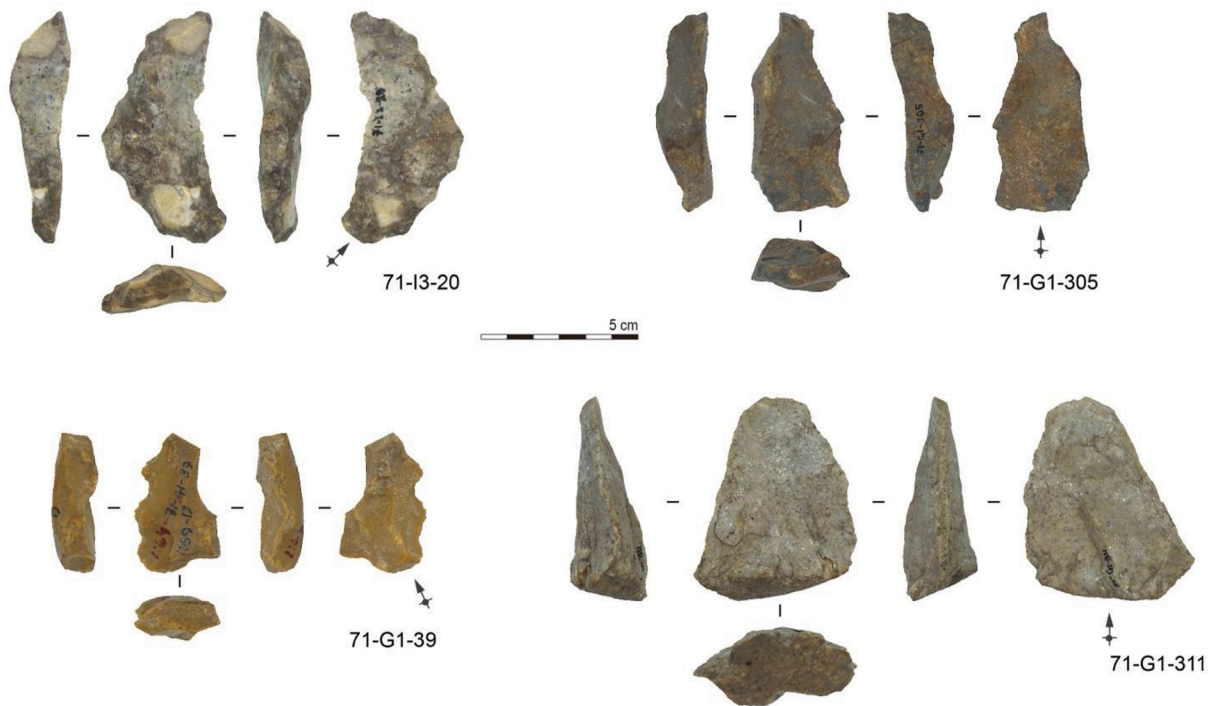


Figure 37. Examples of flake morphotypes from Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

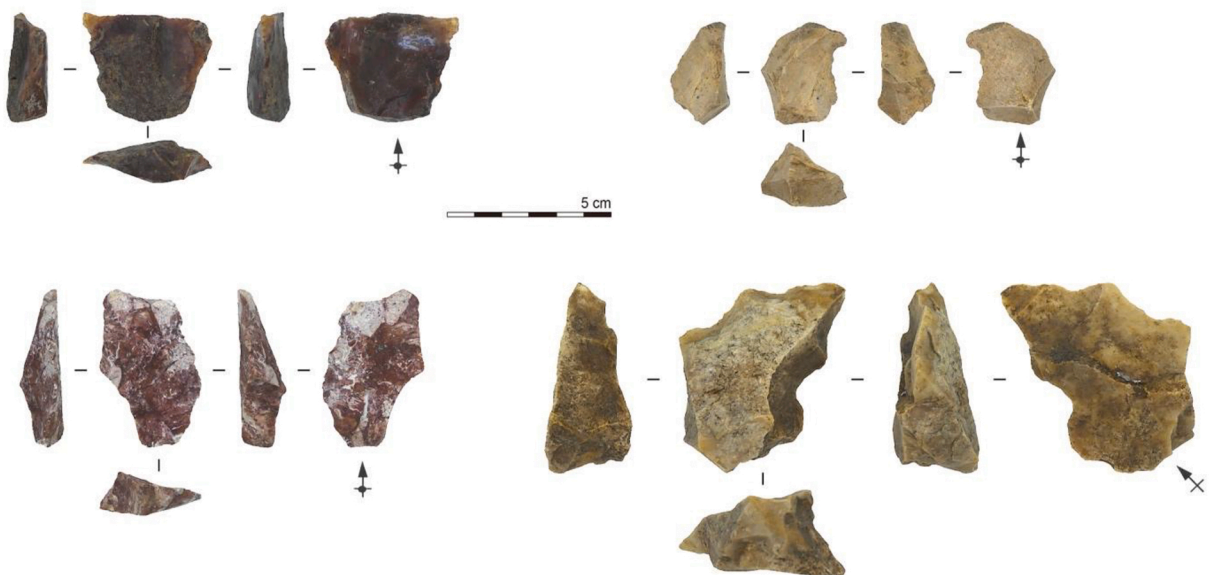


Figure 38. Small flake tools from Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

flaking is also predominant, represented by cores ($n = 5$), bifacial and unifacial core-tools ($n = 4$), and flakes ($n = 9$). The reduction strategies appear to correspond to recurrent parallel and recurrent centripetal (=radial) flaking, often starting from the ventral surface of a large flake (Pawlik, 2005). One of the core-tools corresponds to a horsehoof, quite similar to those identified in the Cagayan Valley surface localities. Three large tools corresponding to a 'bifacial hand axe,' a bifacial cleaver, and a large flake with convergent retouched edges ('pick-type') are associated with this site, although they originate from surface collections (Pawlik, 2009). The bifacially flaked objects have no equivalent in the

northern part of Luzon Island, except perhaps for a bifacial piece discovered in 2008 (Dizon and Pawlik, 2010). During surface surveys conducted around this site, several large cobble tools (choppers) were also discovered.

Further south, on the island of Mindanao, several surface localities in Cagayan de Oro known as Huluga Open Sites were discovered during archaeological surveys conducted in the early 2000s (Neri et al., 2004; Neri, 2006) including a small series of large cobble tools within the sites (Tiauzon et al., 2020). This lithic assemblage consists of 20 shaped objects made from andesite cobbles. Freehand direct percussion was identified as the main shaping technique,

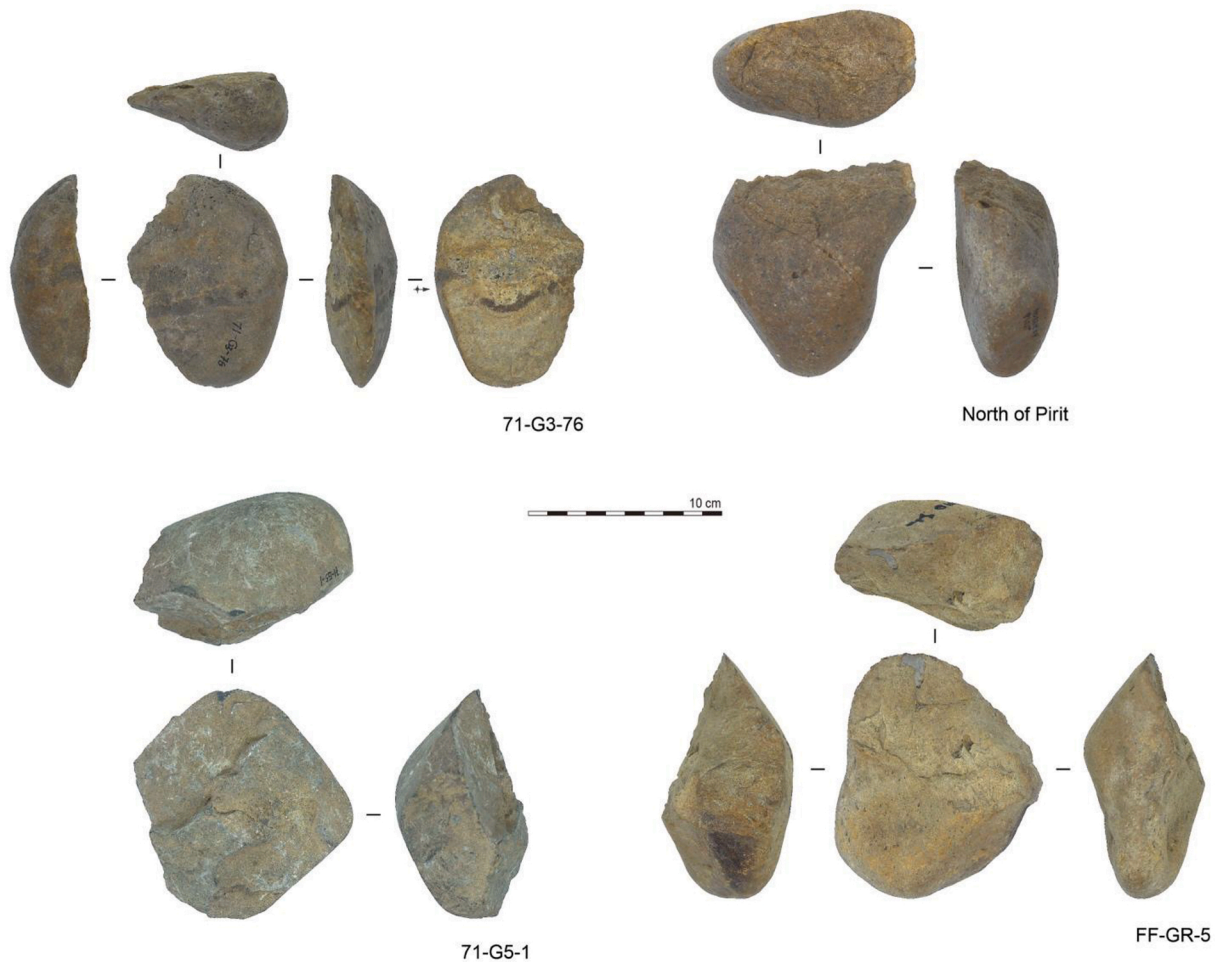


Figure 39. Macro-tools on large flake and cobbles from Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

while the removals are mostly unifacial and convergent-radial (Tiauzon et al., 2020). The large tools produced show active convex or convergent edges, reminiscent of the morpho-structural organization of the macro-tools from the Cagayan Valley.

These data from the global technological study of the Kalinga assemblage and those from the Cagayan Valley localities highlight techno-economic choices oriented toward the production of small blanks of varied morphotypes, used unmodified or retouched, associated with a few large cobble tools or large flakes. The two 'lithic cultures/facies' of this early Philippine prehistory—namely the 'Cabalanian' (Von Koenigswald, 1958) and the 'Liwanian' (Fox, 1978)—defined exclusively and respectively by the presence or absence of cobble tools and small flake tools, should no longer be used as techno-cultural identification. Indeed, the typological habit aiming to target one type of object rather than another—as is the case of the Acheulean defined exclusively through bifaces or hand axes—leads to obscuring the variability and diversity of the technical and economic behaviors of past human groups.

4.2. Technological behavior at Kalinga in the Early Paleolithic of Southeast Asia

Beyond the Philippines, lithic assemblages found in secure stratigraphic contexts of island and continental Southeast Asia are generally rather limited. These include the sites of Calio and Talepu in the Walanae Valley on the island of Sulawesi (van den

Bergh et al., 2016; Hakim et al., 2025), Mata Menge and Wolo Sege in the So'a Basin on the island of Flores (Morwood et al., 1997, 1998; Brumm et al., 2006; Moore and Brumm, 2007; Brumm et al., 2010a, 2010b), the site of Ngebung 2 on the island of Java (Sémah, 2001; Simanjuntak and Sémah, 1996), the locality of Bukit Bunuh (2010) in the Lenggong Valley (Saidin, 2006a, 2006b; Talib et al., 2009, 2020; Saad et al., 2022), and the site of Ban Don Mun in northern Thailand (Zeitoun et al., 2013). In addition to these in situ and dated assemblages, surface collections from the Baksoka (Von Koenigswald, 1936; Keates and Bartstra, 2001; Bakara, 2007) and Ogan (Forestier et al., 2005; Forestier, 2024) Rivers in Indonesia, from the Quaternary terraces of the Mekong River (Forestier et al., 2014, 2025a, 2025b) in Cambodia, from Go Da and Roc Tung (Derevianko et al., 2016, 2018; Kandyba et al., 2021; Nguyen, 2021) in central Vietnam, and from Na Noi Basin (Zeitoun et al., 2012) in northern Thailand are all commonly considered as Early Paleolithic to which we can compare our Philippine assemblages.

Some of these localities have been dated based on the presence of 770–788 ka tektites, notably the Mekong terraces (Saurin, 1963, 1966; Carbonnel, 1972; Saurin and Carbonnel, 1974) and the Go Da and Roc Tung sites in Vietnam (Michel et al., 2024). However, associations of tektites with archaeological material most of the time only indicate a maximum age (Marwick et al., 2022).

In this context, we wish to cross-reference the technological characteristics of the assemblage from unit F at Kalinga with those

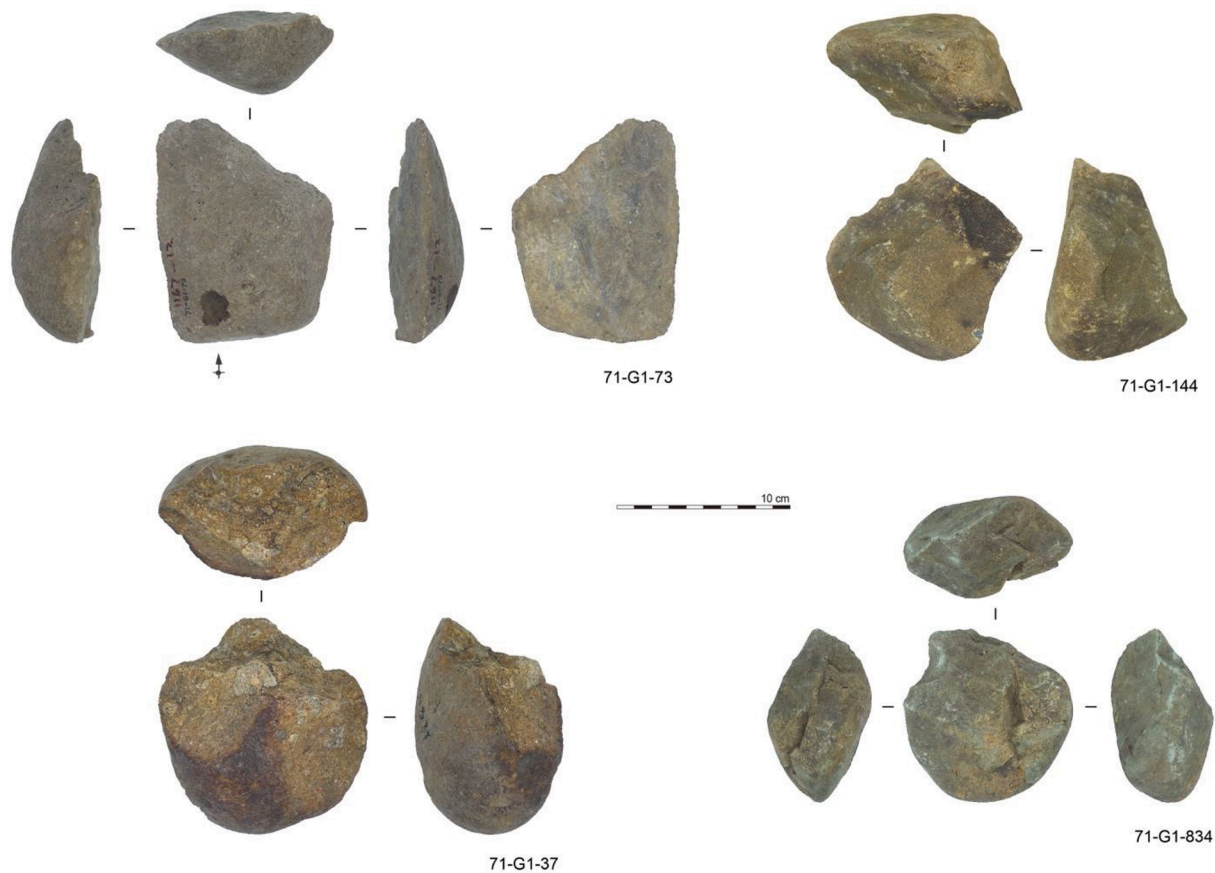


Figure 40. Macro-tools on large flake and cobbles from Cagayan Valley sites. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

of these sites and archaeological indicators of the Early Paleolithic in Southeast Asia (Fig. 43).

The comparison between the Kalinga assemblage and those discovered in situ highlights the presence of shared 'technical invariants' (Geneste, 2010) among sites ranging from Island Southeast Asia to the Malay Peninsula during the Early Paleolithic. Except the Ban Don Mun site (Zeitoun et al., 2013), all assemblages are organized around the exploitation of raw materials collected mainly from nearby or local environments (0–5 km), following flake production systems.

These assemblages are primarily composed of flakes produced using two main percussion techniques: direct freehand percussion, identified at Calio, Talepu, Wolo Sege, Mata Menge, Bukit Bunuh 2010, and Kalinga, and bipolar-on-anvil percussion, identified at Bukit Bunuh 2010 and Kalinga, and suspected at sites in the So'a Basin on Flores Island. The reduction methods are also similar as flaking was mainly conducted through centripetal (=radial) removals, sometimes orthogonal (SSDA-type) or parallel, as seen in the series from Wolo Sege and Mata Menge, Bukit Bunuh 2010, and Kalinga. This geographical distribution of lithic strategies shows no distinctions between continental and insular contexts, nor between continental and oceanic islands.

The 'toolkits' from these assemblages mainly consist of small tools on flakes or chunks, with only a minority showing intentional retouch. However, similarities can also be observed among the toolkits from Kalinga, Flores Island, and the Lenggong Valley as these assemblages all include retouched flakes such as 'pointed-tip,' 'convergent tools,' and 'pointed or notched tools.' These small convergent tools on flakes or chunks are reminiscent of those

documented at Early Paleolithic sites in Western Europe (Aureli et al., 2016; Rocca et al., 2016; Grimaldi et al., 2020; De Caro et al., 2025).

In addition, the production of large flakes (length equal to or greater than 10 cm) is only attested at Ngebung 2 and Kalinga. Some of these sites yielded artifacts resulting from shaping operations, notably Bukit Bunuh 2010, Ngebung 2, and Kalinga. The shaped pieces were produced through short sequences of unifacial removals and, more rarely, bifacial removals. The Ban Don Mun site, comparable with the others only in terms of macro-tools, delivered unifacially shaped cobbles that are technologically similar to those from Kalinga, particularly a distal convex-edged 'tongue-like' tool. Similarly, the Ngebung 2 site includes artifacts classified as 'polyhedrons, spheroids, and bolas' (Cabanès et al., 2022) or horsehoof tools, which so far have no equivalents in stratigraphically secure contexts in Southeast Asia.

Altogether, these data demonstrate that these assemblages share significant technical, productive, and structural traits, with some variations that can be explained by numerically heterogeneous lithic series and differing preservation/archaeological contexts. Site function can also be considered, particularly in light of the very specific context of Kalinga, which represents one of the few butchering sites in Southeast Asia from this period, along with Ngebung 2.

Furthermore, surface lithic assemblages mainly yield macro-objects resulting from cobble shaping or large-flake reduction/débitage. These sites can therefore only be compared to the Kalinga series on the basis of macro-tool characteristics. It is therefore noteworthy that unit F of Kalinga also exhibits unifacially shaped macro-tools made from local raw materials. Given the

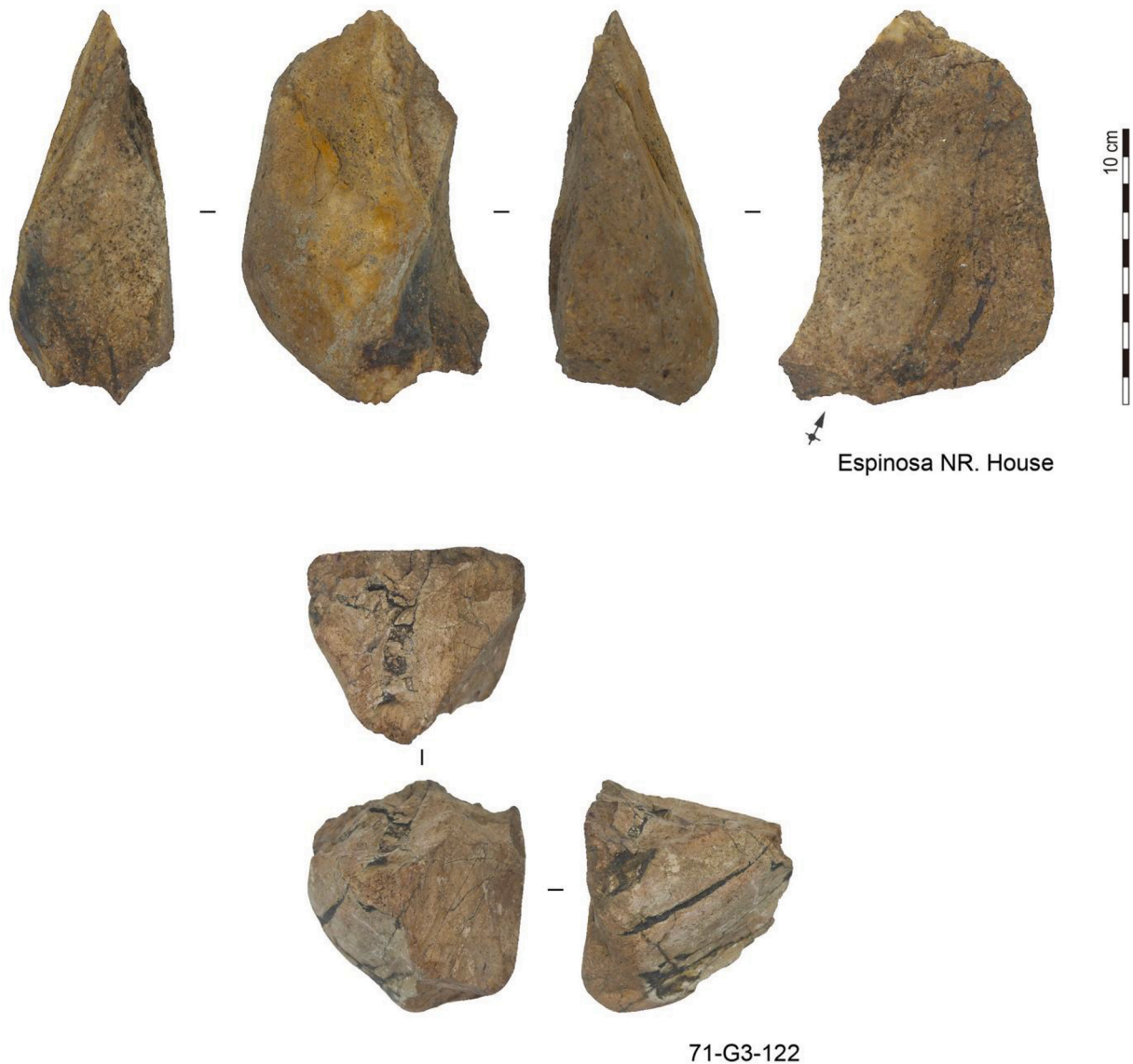


Figure 41. A large flake and a horsehoof from the Cagayan Valley. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

technical, productional, and morpho-structural similarities between the surface lithic series from the Cagayan Valley and that from Kalinga, the comparative perspective can be broadened.

In this context, the production of large unifacially shaped tools, or the more occasional production of large flakes (see Sharon, 2009, 2010), fits perfectly into the diversity of lithic productions represented in these records (Van Heekeren, 1955, 1972; Hooijer, 1969; Bartstra, 1976, 1978; Forestier et al., 2005, 2014; Bakara, 2007; Zeitoun et al., 2012, 2013; Derevianko et al., 2016, 2018; Kandyba et al., 2021; Forestier et al., 2022; Ingicco et al., 2022; Forestier, 2024). From this overview, it appears that the large cobble or flake tools of Southeast Asia from this period are predominantly artifacts with convex active edges, some 'tongue-like' in shape, as observed in the Southern Chinese series from the Bose Basin (Xie and Bodin, 2007; Yuan et al., 2008; Bodin, 2011; Lei et al., 2021; Li et al., 2021a, 2021b; Li and Lotter, 2023), or convergent 'pick-type' tools. The over-representation of these large objects is mainly due to differential preservation contexts, which have erased the finer or smaller fraction, i.e., small flakes. In

this regard, we fully agree with Moore and Brumm (2007), who consider that the dichotomy between 'small flake-tool assemblages' and 'large cutting tool assemblages' in Southeast Asia is merely the projection of a static typological reading. The Kalinga assemblage is structured by the same 'technical invariants' observed in in situ assemblages from Southeast Asia and also shares common traits with surface series, based solely on the three macro-tools. By suggesting a possible (sub)contemporaneity between the Cagayan lithic assemblages and Kalinga, it appears that they share the same technical, productional, and structural characteristics as the surface assemblages across the Southeast Asian region (Fig. 43).

5. Conclusion: The Kalinga site: A new key assemblage to document the diversity of techno-economic behaviors in the Early Paleolithic in Southeast Asia

The technological study of the lithic productions from Kalinga, and, more broadly, the analytical re-inspection of those from the



Figure 42. Two horse-hoofs from the Cagayan Valley. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

surface localities of the Cagayan Valley in the north of Luzon Island makes it possible to provide new and unpublished data concerning the techno-economic behaviors of Early Paleolithic human populations in Southeast Asia. Indeed, the early prehistory of this Eurasian region, built essentially from lithic remains discovered outside stratigraphic contexts, has been characterized as simple, static, sometimes even 'archaic,' in contrast with European and African prehistories (Morris, 1932, 1935; Von Koenigswald, 1936;

de Terra et al., 1943; Movius, 1944, 1948; Van Heekeren, 1948; Heider, 1958; Dennell, 1990, 2014; Bellwood, 1997; Sørensen, 2001; Pawlik, 2009; Lycett and Bae, 2010). East of the late Movius Line, that is, the area outside the 'Acheulean world' (Movius, 1944), lithic productions have generally been confined to a typological dualism between 'core-tool/cobble-tool' industries on the one hand and 'small flake tool' industries on the other hand (Bellwood, 1997; Moore and Brumm, 2007). Within a classification



Figure 43. Map of Early Paleolithic sites in Southeast Asia. Red star indicates in situ assemblages, and black square refers to surface assemblages (sources: Gebco - Bathymetric Data View - WGS 84). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

scheme solely based on the morpho-typology of lithic artifacts, numerous eponymous labels/attributions were coined to distinguish different 'lithic facies' including the Pacitanian of Java, the Anyathian of the Quaternary terraces of the Irrawaddy, the Fingnoian and the Lannathaian of Thailand, the Tampanian of the Perak River, the Cabengian of Sulawesi, as well as the Cabalwanian and the Liwanian of northern Luzon (von Koenigswald, 1936; de Terra et al., 1938; Movius, 1943, 1948; Van Heekeren, 1948, 1949; Von Koenigswald, 1958; Harrisson, 1975; Fox, 1978; Sørensen, 2001). These locally or regionally valid 'lithic facies' served as points of reference and, above all, made it possible to underscore differences at the scale of Southeast Asia, without, however, being explanatory.

Other research has conversely sought to integrate Southeast Asian lithic productions into a global evolutionist model by classifying 'expedient strategies' within modes 1 or 2 of G. Clark's classification (1969). It is quite clear that at Kalinga and in the Cagayan Valley as a whole, neither mode 1 nor mode 2 definitions are satisfactory. Shea (2013) has already emphasized the limits of Clark's evolutionary model.

In this framework, another analytical and interpretative habit was to characterize certain regional assemblages as 'Acheulean' solely on the basis of the presence of bifacially shaped objects (Forestier et al., 2005; Dennell, 2016; Li et al., 2021a, 2021b), thereby raising the major issue of diffusion vs. technical convergence (Nicoud, 2013; Boëda, 2014). The diversity of technical expressions revealed by the technological study of the Kalinga site makes it one of the rare Early Paleolithic sites in Asia to document

human population behaviors from the selection of stone raw materials to their use. It is through the discovery of new sites in secure chronostratigraphic contexts and their exhaustive systematic description that we will be able to move beyond explanatory models directly transposed from European or African prehistories.

Declaration of competing interest

The authors declare that they have no known competing financial interests of personal relationships that could have appeared to influence the work reported in this paper.

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