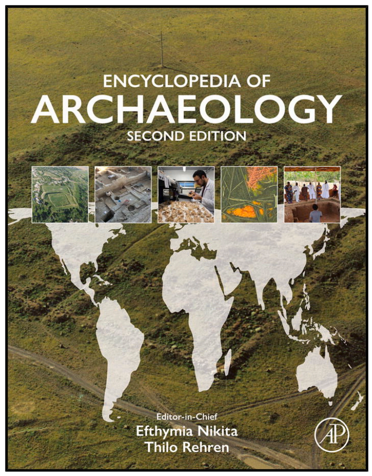

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Chipped Stones and Debitage Assemblages

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Key Points

- Basic principles of knapping
- Brief history of stone tool investigation
- Main features of stone tools
- Present approaches to stone tool assemblages
- Future approaches

Glossary

Bladelets Blanks with parallel or convergent edges, usually with a triangular or trapezoidal cross section, that, when complete, are at least twice as long as they are wide, and are less than 50 mm in length and/or 12 mm in width. These can be removed from prismatic cores or thick end scrapers.

Blades Blanks with parallel or convergent edges, usually with a triangular or trapezoidal cross section, that, when complete, are at least twice as long as they are wide, and more than 50 mm in length and/or 12 mm in width.

Blank Any piece of rock intentionally extracted from a core. When complete, it possesses a platform that corresponds to a small part of the striking platform of the core where it was struck. This platform usually shows a small scar on the exact point of impact. Blanks have a dorsal face on which cortex, scars previously removed, or both can be seen, and a ventral face that corresponds to the interior of the core through which the shockwave of the strike cut the rock. At the intersection between the platform and the ventral face there is a small belly (hence the name ventral face), which is called the bulb; its presence is strong evidence that the piece was no accident.

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Burin spalls Blanks with similar metrical features as bladelets but usually thicker, often with a triangular or trapezoidal cross section, and necessarily extracted from burins.

Chips Elements smaller than 10 mm. In most cases they are debris resulting from knapping, but sometimes, particularly when nodules are very small, they have extremely good quality, or in some cultures, they were intentionally produced to be used as barbs.

Chunks Debris resulting from knapping; it has various sizes and shapes but cannot be linked to one of the above categories.

Configurated tool A tool made by extensively shaping of a nodule, cobble, pebble, large flake or fragment.

Core Nodule, cobble or pebble with blank scars created by its use as a source of blank production. Cores have at least one striking platform where the hammer hit to strike the blanks; this platform is perpendicular or oblique to the respective exploitation surface, the area of the core from which the blanks were removed.

Flakes Blanks that, when complete, are less than twice as long as they are wide.

Nodules, cobbles, and pebbles Nodules of raw material without blank removals.

Points Blanks with features like the previous blanks but that specifically have a pointed shape.

Preparation and maintenance products Flakes produced to prepare a core for the production of blanks (in the first case) or to remove flaws on a core so that it can be further used for blank production (in the second case).

Refitting Method in which the chipped artifacts are conjoined to their original position prior to being reduced.

Retouched tool A core, blank or fragment with one, several or a series of small detachments on at least one edge that were intended to shape or resharpen it.

Abstract

Chipped stone tools are the most abundant remains of human presence in prehistory. Their variability and evolution are due to multiple factors. Some of the most important are the availability of raw materials, which bears on the quality of the toolkits given the resources available in the landscape, and human evolution, cognition, technological development, cultural complexity, and social identity. Because of this and given the heavy dependence of humans on stone tools, toolkits changed rapidly when conditions changed, and remained relatively stable when conditions were stable. After a century of investigation, today's laboratory procedures allow researchers to search, find and pinpoint the main features of these tools across vast regions and, within each region, across time, with great confidence. This is done with such precision that it is frequently possible to know the provenance of each raw material, to infer the function of archaeological sites, and to determine for which tasks each stone tool was used. In this entry, we present an overview of these assemblages and their meaning, and up-to-date ways of studying them.

Introduction

Chipped stones are the result of intentional human action and gave a strong advantage to those using them. The owner of a piece of rock with a sharp cutting edge, of a shape and size adjusted to the hand, had a powerful tool that molded humanity for millennia, ultimately bringing us to where we are today. The study of chipped stones and their related debitage assemblages involves the investigation of many features. These include raw material sourcing, blank production, tool retouching and configuration, as well as artifact recycling and discard.

Raw Material Sourcing

From the countless number of different rocks available on Earth, only some were selected to produce chipped stones. This selection was based on three main criteria: (1) the capacity of the rock to produce sharp hard edges adequate to the tasks at hand, (2) the potential to shape the rocks in a predictable and recurrent way, and (3) the possibility of making tools in shapes and sizes that perfectly fit in the human hand.

The ability to select the rocks that met these three criteria emerged in the earliest archaeological record. Today it is possible to know with confidence where people were collecting their raw materials, since each rock carries specific traits, such as microfossils, geochemical signatures, exotic elements or combination of elements. Consequently, we are able to compare the rocks from which the tools were made with samples collected from their natural source locations to see with which they match and do not match. With this comparison, calibrated according to the action of natural agents such as slopes and rivers, it is possible to reconstruct the territory of acquisition and circulation of the raw materials and, therefore, of the people who carried them.

Blank Production

Mechanics of Chipping

Chipped stone tools are made by knapping, that is, hitting a rock with a hammer in such a way that fragments with specific sizes and shapes are extracted from it. The pebble or cobble from which such fragments were extracted are called cores, and those intentional fragments extracted from it are called blanks.

The recurrent extraction of blanks with predictable sizes and shapes occurs when the knapper understands how each rock behaves during impact. For successful knapping, there are at least four elements that need to be taken into consideration simultaneously—this is what makes it particularly difficult and unique.

The first of these is that it is necessary to have a relationship between the hammerstone and the core in which the latter, not the former, is the one that will break. Second, it is necessary to apply the correct amount of force because too little will not be enough to chip the core, and too much will smash and splinter it. Third, it is necessary to strike the core at the correct angle. Cores have two main areas. The striking platform is where the knapper strikes with the hammerstone, while the exploitation surface is the area from where the blanks are extracted. The strike is usually done at an angle between 65 degrees and 85 degrees. The harder the raw material of the core, the higher the angle needed (Fig. 1). The fourth factor is the position of the strike, because the strike must be sufficiently inside the striking platform for the blank to have the necessary thickness, but not too far inside, because the stiffness of the core will reflect the force of the strike. This is also what happens if the strike angle is greater than 85 degrees.

The combination of these four elements allows the production of a Hertzian cone, a cone of force that propagates through the rock from the point of strike and removes a fraction of it. In brittle rocks, it creates a conchoidal fracture and a bulb which has a concave surface with concentric waves resembling a shell. Given the above, a conchoidal fracture is the hallmark of intentional knapping and, therefore, is a *de facto* indication of the existence of a stone tool.

Methods and Techniques

To maximize the productivity of cores, different methods of chipping were developed. A method is the conceptual way in which the overall volume of cores is exploited to produce an intended product. Methods can be intensive, extensive or predeterminate. Intensive methods are those in which a large number of relatively small blanks can be produced from the same core. Extensive methods are those in which a small number of relatively large blanks are produced. The predeterminate method is one in which the core is highly prepared to produce just one or a few blanks with very specific shapes and sizes. The methods with which blanks were produced change across time and space. They can also change within the same timeframe and in the same region, according to the quality of the local raw materials, and according to the tasks at hand. There were many specific predeterminate methods, of which the most common were simple, centripetal, discoidal, Levallois (Fig. 2) and prismatic (Box 1). Almost all these methods, but particularly the Levallois and the prismatic ones, involve configuring the core in order to ensure that the blanks to be extracted had precise predeterminate sizes and shapes.

In addition to method, techniques also vary. Technique is in part related to the type of hammer used, which can be hard or soft. Hard hammers are pebbles of very hard rocks such as quartzite, while soft hammers are pieces of antler or hard wood about the length of the forearm. In addition, percussion can be direct, indirect or by pressure. Direct percussion is when the hammer directly strikes the core. Most commonly, this is an active hammer, that is, the hammer is handheld when it hits the core, but it can also be

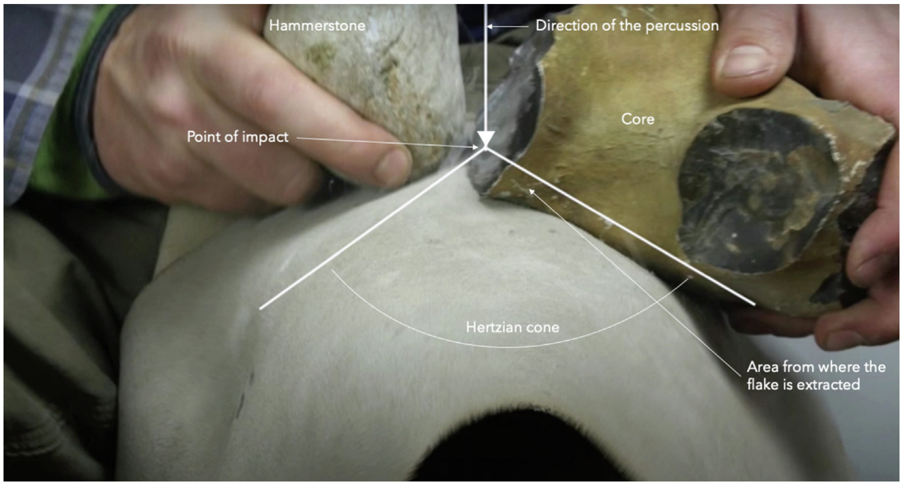

Fig. 1 The exact moment of impact when producing flakes through direct percussion using a hammerstone while holding the core on the leg. Frame taken from the video "Flakes and Spalls-Basic Flint Knapping", freely available at https://rootsvt.com/videos-1/ (https://www.youtube.com/watch?v=N1b_6bGPkvo).

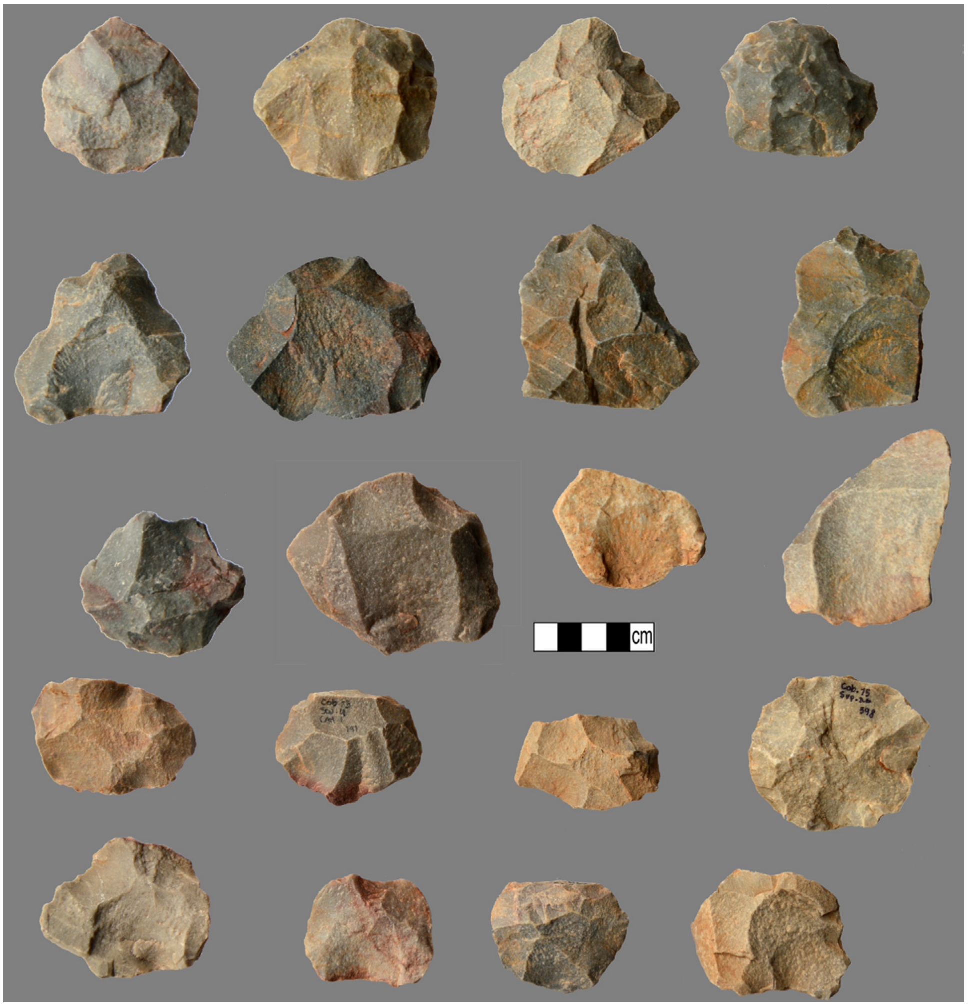

Fig. 2 Diversity of Levallois preferential, Levallois recurrent, discoidal, centripetal and kombewa cores from the Mousterian site of Cobrinhos (Portugal) by 160,000 years ago. Photo by Telmo Pereira.

Box 1 Methods of exploitation

The methods of exploitation had much to do with the relation between the percussion surface of the core (where the core is hit) and the exploitation surface (from where the blanks are extracted).

Simple exploitation involves exploiting the thickness of the core by hitting its largest surface without making any preparation, in order to extract blanks from one of its orthogonal faces.

Centripetal exploitation uses the width of the core by hitting its thickness in such a way that blanks are extracted from its wider surface.

Discoidal exploitation is an upgrade of the centripetal one by still using the thickness to extract blanks from the width but using the negatives of one face as a platform of percussion for the other face. In other words, while in simple and centripetal exploitation there was a hierarchy between the surfaces with one always serving the other, in the discoidal method they alternate. That is, the surface of exploitation became the surface of percussion and vice-versa according to what is the best way to maximize flake production. This permitted at least a twelve-fold increase in the number of blanks from a single core.

Levallois is a pre-configurated method where the core's surfaces of percussion and of exploitation are heavily prepared to extract from its width one or very few flakes, points and, more rarely, blades, with very specific sizes.

Finally, in the prismatic method, the core is also heavily prepared and its thickness is usually exploited to extract flakes, but the most usual blanks for this method were blades and bladelets.

passive, i.e., when the core is a large rock that is thrown against an even larger rock. This method was frequently used from the Lomekwian to the Acheulean, in the former to produce large flakes and in the latter likely simply for the production of any flakes, as the methods and dexterity for knapping were still being developed.

Fig. 3 Extraction of bladelets by pressure. (A) Apparatus: in this case, the core is held between two twigs stuck into the ground, with a boulder holding the back of the core and the crutch behind; (B) Precise positioning of the pointer in the core; (C) Detail of the bladelet taken from the core; (D) Pressure flaking using a different apparatus, with the core being held in a hole in a tree trunk. The knapper in the four images is Pedro Cura and all images were kindly provided by him.

In multiple time periods, a method combining direct active and passive hammers was also used. In this, small pieces of rock were put on top of an anvil and hit with a hammerstone. Using the correct angle, this allows the production of two small sharp flakes, one produced by the direct impact of the hammer and the other produced by the reflection of the impact on the anvil. This method, known as bipolar, did not produce regular blanks, but maximized the use of very small pieces of rocks and pebbles. This was a very important skill enabling the exploitation of abandoned carcasses, widening the radius of action, expanding the number of available food resources, and permitting the occupation of regions where good raw materials were scarce.

Indirect percussion is when the hammer plays an intermediate role, striking a pointer that, in turn, is positioned on a very specific point of the core. This allows the extraction of a blank with a very precise shape. The production of chipped stones by pressure is even more complex than indirect percussion, and only appears in contexts associated with anatomically modern humans. It consists of firmly holding the core and applying high pressure on a pointer that is placed on a specific point of the core (Fig. 3). Depending on the desired blank, this can all be done by hand, or it may require an apparatus that holds the core fast to the ground and a second apparatus in which a pointer is hafted to a kind of crutch, the force being the pressure applied with the torso or abdomen. The main benefit of this method is the reduction of the thickness of the blanks and of the size of the bulb, thus maximizing the number of blanks produced while reducing blistering and accidents caused by impact.

Due to the violent nature of this work, both hammers (regardless the method or technique used) and anvils gain battery marks that tend to be concentrated in specific areas and, because of that, can unequivocally be associated with lithic production and added to the lithic assemblages.

Tool Retouching and Configuration

Retouched Tools

In addition to the use of blocks of rocks as hammerstones and anvils, and the use of blanks as tools per se, lithic assemblages also have artifacts that were made by retouching the edges of blanks and tools that were shaped from a large flake or a nodule of raw material. In the first case, the blank can be easily recognized, but in the second it often cannot. Retouch had two main purposes: one was to resharpen the edges when they become blunt. By doing this, it is possible to extend the life-use of the tool. The second is the intentional creation of a desired contour that could be thinner or thicker, straight, concave, or convex. In the beginning, this may have been a "happy accident" from resharpening, but later it allowed the creation of tools that were more suitable for specific tasks. Consequently, the repertoire of retouched tools greatly increased, but remained repetitive for hundreds of thousands of years worldwide. Among these, the most common are end- and side scrapers, notches, denticulates, and borers, with some diversity within each class. All are domestic tools intended to cut, scrape, and perforate, which have existed since the Oldowan.

Lithic hunting tools that correspond to hafted technology, that is, stone artifacts intended to be placed on the tip of a wooden haft like a spear or an arrow, come in two types. One corresponds to simple pointed blanks extracted from predeterminate cores (sometimes slightly retouched), such as the MSA or Levallois points that appear in the archaeological record ca. 500 ka (Wilkins et al., 2012), or tanged points, such as those from the Aterian. The second type consists of blades and bladelets with heavy abrupt, semi-abrupt or low retouch in one or more edges to create a very precise shape. These tools, called backed tools due to this heavy retouch that makes a "back" to the rest of the tools, appear in the archaeological record by ca. 71 ka (Brown et al., 2012) and represent an important innovative step. They were used alone in the tip of a weapon or combined as tips and barbs in what are known as

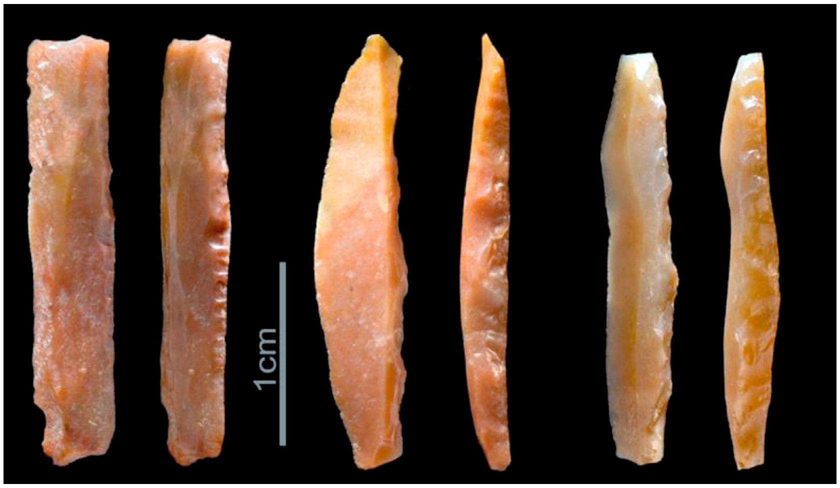

Fig. 4 Upper Palaeolithic backed bladelets from Cabeço Porto Marinho (Portugal) dated from 25,500 to 18,500 years ago (Gameiro et al., 2020).

composite tools. These tool types were diversified by the hundreds across the globe and, at the same time, there is high standardization of each one. Together, this enabled the establishment of regional cultural patterns along with rapid changes in the same region, usually following environmental fluctuations. With their appearance in the archaeological record, it becomes possible to refine the subdivision of each cultural period, of each cultural territory and map the spread of cultural traits across continents (Fig. 4).

Configurated Tools

In some periods and regions, the archaeological record shows the presence of configurated tools. These correspond to tools entirely shaped from a large blank or nodule of raw material. Whereas in the case of retouched tools, it is usually possible to recognize the blank, in configurated tools this is often not the case. Some of the most common configurated tools were the handaxe, the hallmark of the Acheulean that appeared ca. 1.76 million years ago (Lepre et al., 2011), which spread across Africa, Europe and Asia, and lasted until ca. 170 ka in the first continent, 140 ka in the second and 55 ka in the third (Key et al., 2021). Handaxes had a great variety in both exquisiteness of their shaping but also in size and in silhouette. These tools disappeared with the global spread of pre-determinate blanks, particularly Levallois. However, they appeared again in France, at the end of the Mousterian, without any direct relation to the Acheulean.

With the higher ability to control fire, namely through heat-treatment from ca. 164 ka (Brown et al., 2009), it became possible to produce much more exquisite tools, in particular hunting tips. Heat treatment consists of slowly heating fine-grained rocks like flint or silcrete to ca. 350 °C, keeping them at that temperature long enough to destroy the original molecular structure, and then slowly cooling them down. With this process the rock becomes amorphous, meaning its molecular structure will no longer interfere with the propagation of the Hertzian cone. This makes it easier and more predictable to extract very thin and long flakes with a wide angle between the ventral face and the platform (named bifacial trimming flakes), a fundamental process to thinning the tool to make it sharp. Their configuration usually ends with a series of blanks extracted by pressure flaking. Some of the most well-known Palaeolithic bifacial tips are the Still Bay points from South Africa that only occurred in a very narrow time span, dated between 71.9 and 71 ka (Jacobs et al., 2008), the Solutrean points from Southwestern Europe, dated between 22 and 17 ka, and Clovis points from North America, dated from 13.2 to 12.9 ka, but there are many others from across the globe (Fig. 5).

Artifact Recycling and Discard

The first artifacts to be discarded were debris. These are pieces of rock that are jettisoned from the core due to the violent action of knapping. The most common forms of debris are chunks and chips, the former being big and the latter small, including flakes smaller than 10 mm in diameter. It is not unusual for chunks to be recycled according to features such as shape and size, quality or exotism of the raw material, angles and surfaces adequate for specific tasks or the presence of cutting edges. Recycling processes for chunks include their use as opportunistic cores for extraction of a few flakes, bipolar debitage, or being retouched as heavy domestic tools. On the other hand, chips were often recycled as barbs for composite tools because they typically carried very sharp cutting edges. Other artifacts immediately discarded were those resulting from the configuration and maintenance of cores, and are very characteristic (crests, flanks, cornices, etc.).

Besides these, all other artifacts were recycled, which is more obvious in some cases than others. For instance, some cores, particularly chopper-like ones, were often used as domestic heavy tools for scraping and chopping, hence their name. Blanks produced during the shaping or maintenance of cores were also often recycled by being used directly or retouched. Blanks with blunt edges were frequently recycled. This happens when edges are resharpened to continue the same task, but also when new artifacts, such as

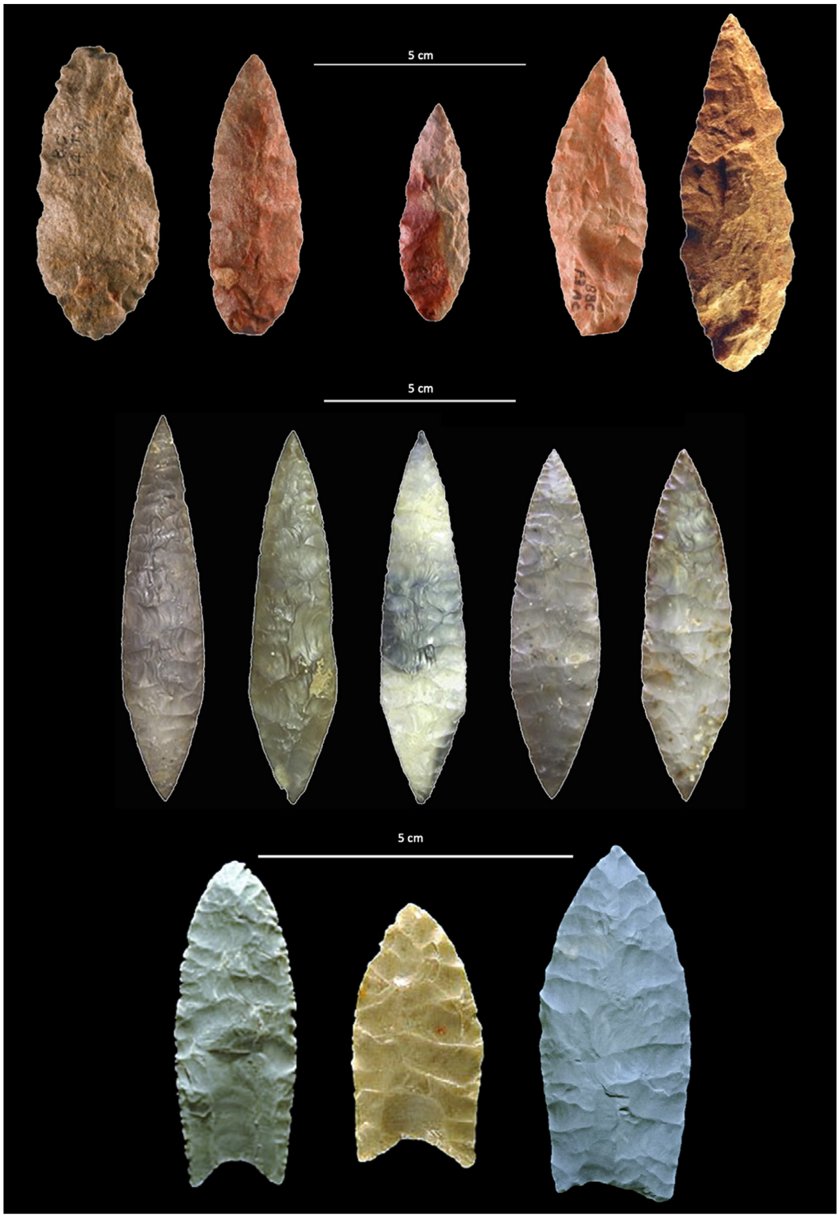

Fig. 5 Diversity of bifacial points from Africa, Europe and America. Top: Still Bay points of Blombos Cave (South Africa) dated from 77,000 to 70,000 years ago (Villa et al., 2009). Middle: Solutrean points from Volgu cash (France) dated between 22,000 and 17,000 years ago (Kilby, 2019). Bottom: Clovis points from Virginia, Arizona and Wyoming (North America) dated between 13,500 and 12,900 years ago (MacLeod, 2018).

end- and side-scrapers, burins, truncations, borers, notches or denticulates, are made. Sometimes the same artifact has a blunt edge and a combination of typical retouches, suggesting several recycling incidents. Another artifact category recycled were hunting tips. Due to the nature of their function, they tended to break on impact. In many cases, this rendered them unusable. However, other times only the most distal part of them broke and they could be reused after some retouch or reconfiguration.

These are the most obvious cases of recycling. In other cases, recycling is not so obvious, and this may carry important interpretative implications. Repetitive recycling leads to the reduction of a lithic's volume, the increase of scars from previous detachments, and changes on the silhouette of the artifact across its life use, in a phenomenon called the Frison Effect (Dibble, 1987). This is important because lithic analysis also includes a morphological dimension (see **Lithic Analysis** section) that is used to infer several facets of the past, including cultural ones. Thus, linking the morphology of artifacts to people's culture while overlooking recycling can significantly bias the accuracy of the final interpretation of those same cultures. Good examples of this were given for Acheulean handaxes (McPherron, 1994) (**Fig. 6**), Mousterian side-scrapers (Dibble, 1984) and Upper Palaeolithic burins (Igreja et al., 2006).

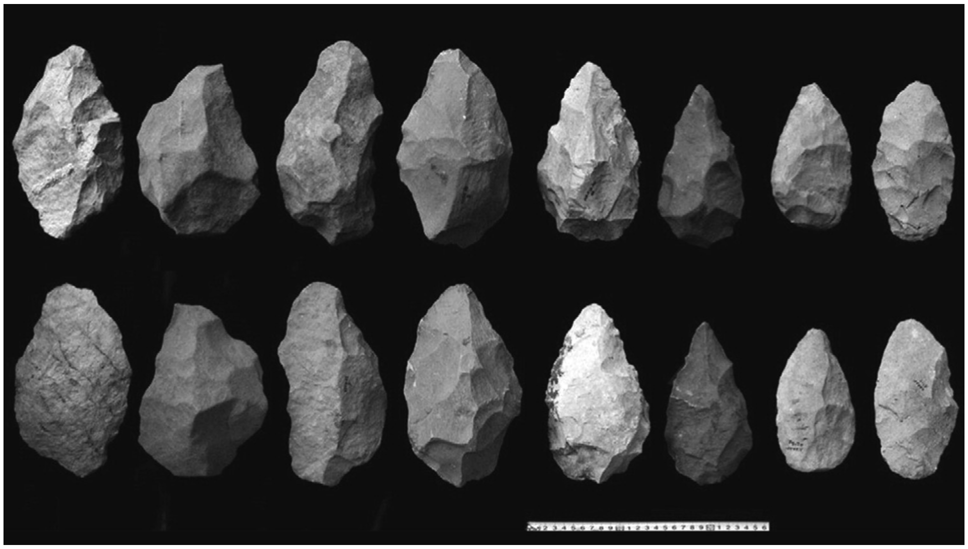

Fig. 6 Chronological evolution between 1.75 and 0.85 million years, or Frison Effect in Acheulean assemblages, at Konso, Ethiopia. Photo from Hodgson (2015).

Recycling can also give important insights into the proximity or distance of raw material sources to an archaeological site, and about their value. The normal pattern is one in which lithics reduce in number, size and cortex, while increasing in curation time (that is, overexploitation and recycling to extend their life-use) as they get further away from the source, in a phenomenon called Distance Decay (Renfrew, 1969).

Overview

Historical Background

Stone tools have been known since the 19th century. Even if their exact age was not known, the oldest ones were immediately considered ancient, considered pre-Diluvian (Boucher de Perthes, 1847) and called Abbevillian due to their discovery in Abbeville, France. However, the discovery of similar tools in Africa changed their name to Oldowan. Today we know that the earliest Oldowan tools date back to 2.6 million years ago (Braun et al., 2019). Despite being crude and simple, the continuation of research and discovery of Lokalalei 3C in Kenya, dated back to 2.34 million years ago, revealed that the Oldowan was already complex (Delagnes and Roche, 2005) and, therefore, unlikely to be the first lithic industry (**Fig. 7**). Furthermore, the discovery of bones with cutmarks, namely in Dikika (Ethiopia) dated to 3.39 million years ago, suggested that some kind of stone tools already existed earlier (McPherron et al., 2010). Finally, the study of tool use by nonhuman primates (Primate Archaeology) (Haslam et al., 2009) revealed that several species, particularly chimpanzees, use rocks to break nuts, but discard them when they break. Because when this happened some chunks gained a cutting edge, one hypothesis is that, at some point in the past, individuals subsequently used that cutting edge. Based on this hypothesis, some researchers looked for stone tools that had never before been recognized and found such artifacts at Lomekwi 3, in Kenya, dating to 3.3 million years ago, that is, predating the Oldowan by 700 thousand years (Harmand et al., 2015). This lithic industry consists of local coarse volcanic raw materials, and was characterized by large irregular flakes and cores, along with pebbles and larger blocks for battering. Despite the differences, these tools had cores with striking platforms, and flakes with butts, bulbs and dorsal patterns—the criteria that define every stone tool regardless of chronology or region.

Lithic Analysis

Evolution of Lithic Analysis

The evolution of lithic analysis was deeply influenced by the societies in which different approaches were developed. From the 19th century to the third quarter of the 20th century, western European researchers focused on the type of the tools (e.g., their morphology) and related each one to artifacts found in the ethnographic record (scraper, knife, borer, point, etc.) in a methodology that became known as Lithic Typology. With this, they wanted to name each tool and establish the chronological and regional limits for their presence in the archaeological record. Through this they were able to determinate the cultures of the past, which is why this period is called Culture-Historical Archaeology (Trigger, 1996). The development of this approach took decades and some of the most important works still used today are by Mary Leakey for the African Oldowan (Leakey, 1950), François Bordes for the Acheulean and Mousterian (Bordes, 1961), and Sonneville-Bordes for the Upper Palaeolithic and Mesolithic (Demars and Laurent, 1992).

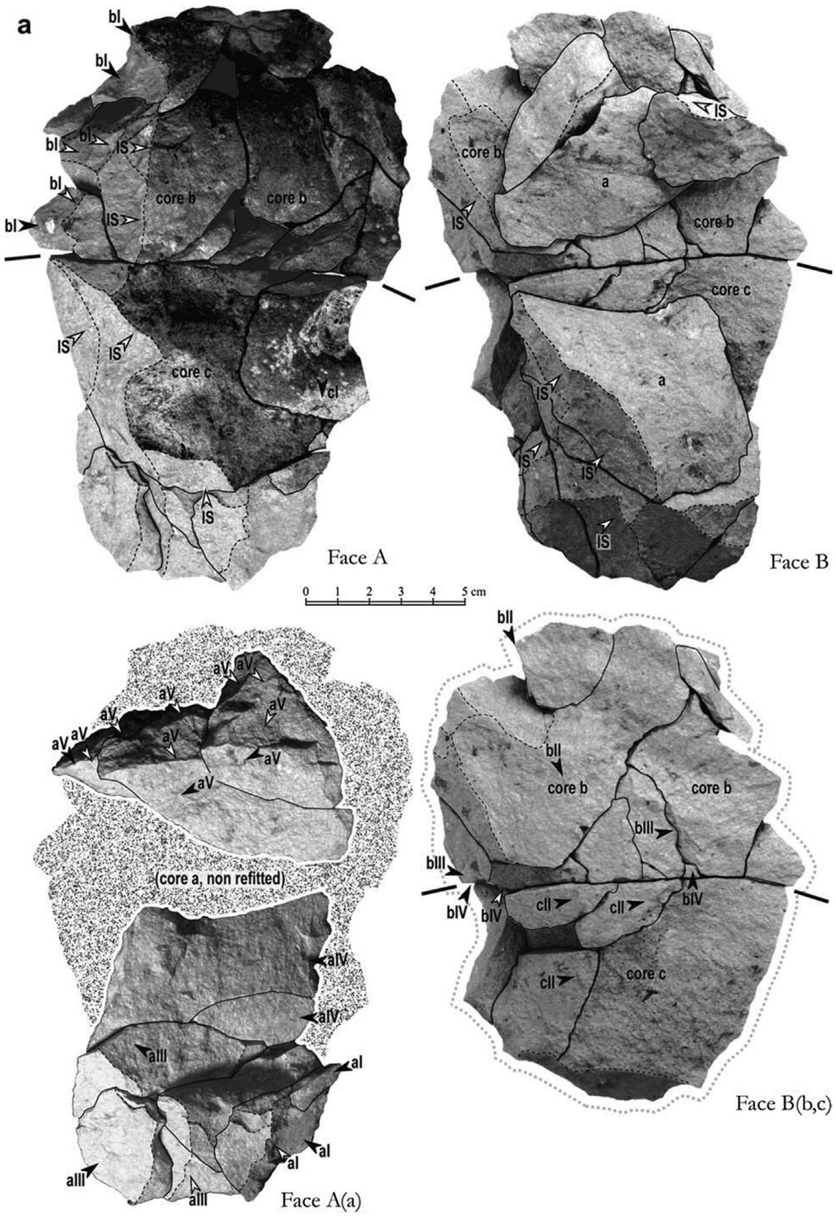

Fig. 7 Oldowan refit from Lokalalei 2C revealing the high complexity of human knapping skills by 2.4 million years ago. Photo from Delagnes and Roche (2005).

Meanwhile, eastern European archaeologists, deeply influenced by the Marxist system, focused on the use of the artifacts. This approach was based on experimental archaeology involving producing stone tools and using them for different tasks. Subsequently, the edges of the tools were observed under the microscope to map, measure, characterize and record the changes and damage caused by each specific task (Semenov, 1957). This became known as use-wear analysis.

In the last quarter of the 20th century, lithic analysis shifted toward Processualism. This approach was first presented by André Leroi-Gourhan (Leroi-Gourhan, 1964). However, the political agenda of Europe between the 1930s and 1940s gave priority to historical-culturalism, and, therefore, it was only after World War II that Processualism gained ground. This was further influenced by North American anthropologists aiming to infer behavior in the past through the study of still existing hunter-gatherer societies (Yellen, 1977; Binford, 1978, 1985; Lee and Daly, 2005). In the last quarter of the 20th century, the Processualist approach also aimed to describe the technological process of lithic assemblage production. This was done through the detailed description of all artifacts from each assemblage to reconstruct the *chaîne opératoires* and reduction sequences (Tixier et al., 1980). Through this it now became possible to place each artifact within the debitage sequence through a theoretical exercise known as mental refitting, but also with real refitting and the conjoining of artifacts (Pelegrin, 1995). Besides that, the Processualist approach also applies use-wear analysis with increasing frequency, allowing awareness about the production and use of chipped stones and debitage assemblages.

Contemporary Approaches

Today, lithic analysis combines the best of all these approaches. This includes raw material studies, lithic technology, lithic typology, refitting, actualistic studies and use-wear analysis.

Raw material studies include destructive and non-destructive methods. Among the destructive but also the most valuable is petrography, which consists of the microscopic observation of thin sections of rocks. Among the non-destructive (or causing only very light disturbance of the surface on a millimetric or sub-millimetric scale) are geochemical methods, namely PIXE (Particle-Induced X-ray Emission), SEM-EDX (Scanning Electron Microscopy - Energy Dispersive X-Ray), XRF (X-Ray Fluorescence) and μ-XRD (micro-X-ray Diffraction).

Lithic technology comprises features such as length, width, thickness, weight, cortex location and percentage, dorsal pattern of the blanks (this is directly related to the surface exploitation of the core), preparation and size of the butt of blanks (which relates directly to the debitage surface of the core), morphology of the blank edges, section and profile, etc. Despite slight differences between handbooks, these progressively converged into consensual jargon understandable to all and protocols that can be used by all, and which can be adjusted to any region, timeframe, or culture. Lithic typology is based on type lists for each region and period, and should be used accordingly, as mixing them is often incoherent. Nevertheless, some types are relatively common across time and space and appear in almost all lists, such as notches, denticulates or scrapers.

Refitting is probably one of the most useful but less used methods for studying lithics. It consists of the conjoining of artifacts in order to place them in their original position before they were struck from the cores. In practice, it consists of a Prehistoric 3D jigsaw puzzle for which we do not know the original shape and the number of pieces, nor do we have all the pieces. Hence, this method can only be used in contexts with very good preservation. Nevertheless, it gives outstanding information about lithic production by placing each artifact in its precise position within the chipping sequence of each core (Boëda, 1994). In addition, it also brings fundamental insights to the interpretation of site formation processes and site organization (Pigeot, 1987; Delagnes and Roche, 2005). Unfortunately, because it is highly time consuming and one is not always sure it will give significant tangible results, it is frequently neglected.

Actualistic studies include two main fields: (1) the ethnographic observation of hunter-gatherer, small-scale agricultural societies and nonhuman primates, and (2) experimental archaeology. The observation of human and nonhuman primate societies allows us to reconstruct the criteria of raw material selection, the process of production of chipped stones and the creation of debitage assemblages, their use, and the names that people give their tools. Ultimately, understanding the lithic assemblages allows us to infer the function of the sites (Burke, 2006). On the other hand, experimental archaeology aims to do the same, but in a laboratory setting. Through experiments, it is possible to isolate, control, and record the variables under study to remove much noise and bias. It also allows the replication of protocols by other researchers, a key element of the scientific method (Marreiros et al., 2020).

Use wear analysis was developed by Semenov with further refinements. It draws greatly from experimental archaeology where the materials, angles, strength and duration of the tasks are highly controlled and recorded to create reference collections. The marks created in each tool during each task are then observed, described and mapped using high-magnification and high-resolution microscopes, and more recently, GIS. These marks are in turn used to interpret the marks on archaeological artifacts to infer their use (Marreiros et al., 2015).

Key Issues

Today, some of the hot topics about chipped stones and debitage assemblages are described below.

Raw Material Studies

High-resolution studies focus on raw materials to assess mobility patterns, territory, awareness about their properties, and grounds of decision making. As explained above, outcrops and archaeological sites are fixed points on the landscape. Hence, the study of the petrographic and geochemical signature of natural sources and of the rocks from which the artifacts were made allows the archaeologist to relate each one to a given location. Through this, it is possible to create a map and understand the regions where people were circulating, and with whom direct and indirect relations occurred. When studying populations prior to anatomically modern humans, and/or for those before the appearance of modern human behavior, this is more important still, because it carries significance about early cognitive abilities (McBrearty and Brooks, 2000).

Value of Lithic Analysis

Research advances bring a growing interdisciplinary working environment to archaeology. Today, the scientific resources available for the investigation of the human past are unprecedented, and unique when compared to other social and human sciences. In this sense, standard lithic analysis can be seen by some as too basic, particularly when compared to the high technology methods used in molecular biology, geochemistry, or absolute dating. Lithic analysis is also much more time-consuming and rarely brings about spectacular results. This is mostly because (a) there are many more lithics than samples to analyze; and (b) there has been much more work done on lithics than the other materials. Despite this, the correct, accurate and detailed analysis of lithic assemblages, covering all the approaches discussed above, is the fundamental pillar for the understanding of human adaptation, behavior, and culture.

Summary and Future Directions

Summary

The invention of chipped stones was the turning point of hominin behavior and probably the major cause of the rise of humanity. Across decades, their study was the only way by which to access the human past. Today, new methods and disciplines widen and enrich as never before the framework of the study of that past. Nevertheless, the study of chipped stones and debitage assemblages remains absolutely fundamental to understanding the behavioral patterns of past human societies. This is particularly evident as it has been repeatedly shown that lithic industries frequently suffered abrupt and rapid shifts in response to climatic events, but remained stable and monotonous during subsequent millennia, until later events mandated again rapid adjustments or change.

The fact that lithics are globally abundant and inexpensive to study allows the training of hundreds of students every year across the world. This is of major importance in order to maintain the constant flow of studies and investigators, even if some end up doing different research as their careers progress.

Future Directions

Time of Invention of Chipped Stones

Likely the most important question today concerns the time and place of the invention of chipped stones. As pointed out above, for almost a century it was thought that the earliest chipped stones and debitage assemblages were the Oldowan, the appearance of which in the archaeological record falls within the Gelasian (2.59 million years ago). However, today the earliest stone tools are the Lomekwian, based on a single site dated to 3.3 million years ago (Harmand et al., 2015).

In a deterministic perspective, some may argue that there are strong possibilities the Oldowan was an adaptive response to the environmental changes of this geological age. In this sense, then, the Lomekwian could have been a similar behavioral response to the conditions of the Piacenzian, which spans between 3.6 and 2.59 million years ago. If that was the case, then it may be expected that Lomekwian industries date back to 3.6 million years. We should also keep in mind that we cannot rule out the existence of an even earlier industry than the Lomekwian, even if one solely composed of battering tools like those used by today's chimpanzees. Possible environmental thresholds for such an industry could be the Messinian-Zanclean transition (at 5.3 million years) or even the Tortonian-Messinian transition (at 7.25 million years); this latter date is a good candidate for the human-chimpanzee split (Langergraber et al., 2012).

Place of Invention of Chipped Stones

In addition to time, the place where chipped stones were first invented is also an unresolved issue. According to current information, most of the earliest technologies appear in the archaeological record in eastern and southern Africa. However, there is a strong bias toward these regions not only regarding chipped stones and debitage assemblages, but for human evolution as well. Yves Coppens' East Side Story (Coppens, 1994) still rules many theoretical models. Nevertheless, it is also plausible that further investigation in Central and Western Africa, and in Asia, may bring new evidence that could shake the status quo. Two good examples of outliers of this model are the very early Oldowan from China, dated to 2.1 million years ago (Zhu et al., 2018), and the central-northern African position of *Sahelanthropus tchadensis*, considered by some to be a strong candidate for the oldest hominin (Brunet et al., 1995).

In other words, despite the overwhelming amount of data from eastern Africa, it cannot be ruled out that the invention of chipped stones could have happened elsewhere. Further elucidation of this fundamental history of humanity requires the investigation of regions left un- or under-explored, such as Central and Western Africa, and older deposits likely ignored as being too early.

Computer Analysis

The increasing development of computers brings great opportunities for the study of chipped stones and debitage assemblages. The widespread use of high-resolution 3D scanning, modeling and reconstruction allows, among many other things, the exact reconstruction of volumes related to the original nodule, core configuration and debitage, blank characteristics, exact quantification of debris, and the correlation between them (Porter et al., 2016).

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See Also: Archaeological Materials: Challenges and Future Directions; Ground Stone Tools and Vessels; Obsidian Sourcing by X-Ray Fluorescence Analysis; Traceology.

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