Quaternary International 347 (2014) 133–138

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

A preliminary study on human behavior and lithic function at the Wulanmulun site, Inner Mongolia, China

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ARTICLE INFO

Article history:
Available online 20 May 2014

Keywords:
Wulanmulun site
Use-wear analysis
Tool function
Human behavior

ABSTRACT

The Wulanmulun site, located in southwestern Inner Mongolia (China), is an important Paleolithic discovery in the Ordos Plateau in addition to the sites of Salawusu and Shuidonggou. About 4200 stone artifacts, 3400 fossils, and abundant hunting evidence of hominid were uncovered in 2010. In order to explore stone tool function and human behavior at Wulanmulun during the Middle to Late Pleistocene, we have selected 140 specimens excavated from Locality 1 of Wulanmulun in 2010 for use-wear analysis. The results suggest that 58 specimens retain evidence of use-wear, accounting for 41.4% of the observed samples. Many stone artifacts display use wear, and several show wear from hafting. The working motion was dominated by defleshing and slicing, and the main contact materials were animal substances. Animal processing might have been one of the main working tasks at Locality 1 of Wulanmulun, as numerous animal bone fragments with obvious cut marks and burnt bones were also found *in situ*.

1. Introduction

For archaeologists and anthropologists, human evolution refers to physiological and cognitive development, changes in social behavior, and changes in subsistence strategies. Understanding past behaviors contributes to our knowledge of human evolution. Stone tools, including tools and weapons, are known as a good primary source of information that indicates the development of intelligence, technology, information and adaptability of prehistoric occupants. Due to greater risks caused by the physical conditions in prehistory, hunter–gatherers had to adopt different strategies to cope with climate fluctuations, environmental changes, and constraints on available resources in different areas. In accordance with the concept of *chaîne opératoire* (Schiffer, 1972; Sellet, 1993), every step of the life of stone artifacts including material procurement, manufacture, use, repair, and waste is closely related to "function". Understanding the function and purpose of different tool-kits helps us to interpret adaptive behaviors related to human economy and social changes in prehistory. Currently, the functional study of stone tools can be conducted along several paths: a) We can suggest that the function and design of tools can be inferred in terms of their morphological and technical characteristics by typological or technical-typological analyses; b) Ethnological studies can provide suggestions for the use of various tools; c) The most appropriate or possible function of tools can be suggested through experimental archaeology; d) According to the coexistence of different kinds of evidence, the function of the tool-kit can be understood by its context; and e) Use-wear and residue analysis can provide direct evidence for tool usage.

The Wulanmulun site (39°35.152′ N, 109°45.659′ E), on the left bank of the Wulanmulun River in Ordos, Inner Mongolia, in North China, was discovered in May 2010 by local people. It is considered as another new important discovery of prehistoric culture in Ordos region after the sites of Salawusu (Sjaraosso-gol) (Boule et al., 1928) and Shuidonggou (Teilhard and Licent, 1924) were discovered by the French in 1922 in the neighboring Ningxia Province (Hou et al., 2012; Wang et al., 2012).

The first trial excavation was carried out at Locality 1 by the Ordos Antiquity & Archaeology Institution and soon with the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Adademy of Sciences afterwards. The main part of deposition, with a depth of about 5–8 m, can be divided into eight layers, in which seven archaeological layers are recognized according to their

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http://dx.doi.org/10.1016/j.quaint.2014.04.049

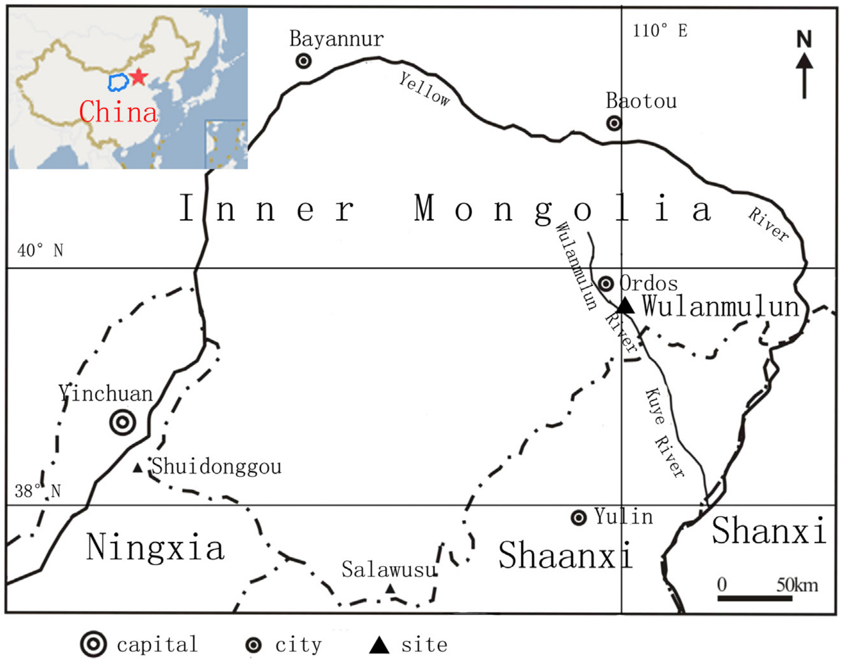

Fig. 1. Location of the Wulanmulun site.

geological context, the mammalian fauna, and stone artifacts (Fig. 1).

More than 1500 stone artifacts were recovered and include various types of cores, flakes, and flake tools. As a whole, the lithic assemblage is the product of a core and flake technology. Single platform cores are very common. Used flakes were obviously needed with longer and rather straight edges that were accompanied by natural or steep backs. Prepared platforms can be observed on few flakes. There was abundant debris produced by flaking cores or retouching. Retouched pieces are mostly made on flakes. There are different types of scrapers with concave, convex, straight, and concave–convex working edges. Denticulates and notches were very much in evidence and can be divided into subtypes. Borers, drills, and various types of points were frequent, and there were some end-scrapers, becs, and burins. Many of these tools could have served more than one purpose (Hou et al., 2012).

A total of 1213 pieces of mammalian bones were obtained from seven archaeological layers. Based on the numbers of fossil specimens, *Coelodonta antiquitatis* are the most numerous species, followed by *Equus przewalskii* and *Megaloceros ordosianus*. Judging by the condition of deciduous and permanent teeth, juvenile *C. antiquitatis* are more numerous than adult ones. The other taxa are mostly dominated by adult specimens or difficult to judge due to the fragmentary and insufficient state of the specimens. The Wulunmulun fauna evidently belongs to the *Megaloceros ordosianus-E. przewalskii* fauna *i.e.* the Salawusu fauna.

Fossils were preserved in a fragmentary condition from parts of teeth, ribs, crania, mandibles, scapulae, vertebrae, and limb bones. Bone tools such as scrapers, points and knives were often made from large mammal limb bones. Cut marks on bones were common and indicate meat consumption. Burnt bones were rare but indicate cooking.

The dating results were given as 70–30 ka by primary OSL and ^{14}C in an earlier report (Hou et al., 2012; Wang et al., 2012). Analysis of sedimentation proves that the site was in a lacustrine situation, but the climate deteriorated into dry desert and no further human activity happened in the final Pleistocene.

The Institute of Zoology, Chinese Academy of Sciences, has identified the ~1000 mollusks collected in the cultural strata. The results show that most molluscs are aquatic gastropods; there are few terrestrial gastropods and bivalves. According to the paleoecology shown by the fossils, we can deduce that the precipitation of Wulanmulun was high, and the environment may have been a warm temperate forest- steppe in the late Pleistocene (Li and Yuan, 2013).

Since 2011, excavations and regional archaeological surveys have been carried out annually. Forty eight Paleolithic localities with stone artifacts and faunal remains have been discovered within the 40 km drainage basin of the West Wulanmulun River (ATWS, 2013). Up to the end of 2012, more than 13,000 stone artifacts, 15,000 fossils mammal and abundant evidence of hominid use of fire were excavated from Localities 1 and 2. An overwhelming majority of the stone raw material is locally available quartzite.

2. Analytical methods and materials

Use-wear analysis was developed to infer tool function on the basis of microscopic traces of wear left on its edge or surface. Since the translation of Semenov's (1964) *Prehistoric Technology*, use-wear analysis has become a principal method for inferring the functions of stone tools in Europe and North America. There are two major techniques for lithic use-wear analysis: the high-power (100–400×) and the low-power technique (5–200×). The former concentrates on the formation and distribution of use polish at relatively high magnifications under either incident light microscopes or scanning electron microscopes (Keeley, 1980), while the latter focuses on traces of edge-damage, microscopic fracturing and abrasion visible at relatively low magnifications under reflective-light stereoscopic microscopes (Tringham et al., 1974; Odell, 1980). After decades of experiments and practices, it has been shown that each use-wear technique has its own particular advantages and weaknesses (Shea, 1987). Because of its convenience, the low-power technique has been employed in several studies in the past two decades and has been proven as a reliable method for interpreting the uses of stone tools (Shen, 2001; Chen et al., 2010, 2013; Zhang et al., 2010).

The interpretations of use-patterns and tool functions can be determined through reference collections, including our own experimental use-wear data (Gao and Shen, 2008; Shen et al., in press), and others' practical research (Odell, 1980; Rots, 2003, 2004; Rots and Philip, 2006; Rots et al., 2010). From numerous experiments, we obtained information of the type of use-damage that were caused by various combinations of tools and established reliable relationships between different tool motions (e.g., chopping, cutting, scraping, boring and drilling) and different contact materials (e.g., wood, meat, hide, bone and antler).

As a part of the research into human behavior and their adaptations in the Ordos region during the Late Pleistocene, we employed use-wear analysis to understand the functions of stone artifacts from the Wulanmulun site. There are two challenges for this study: one is the huge amount of stone artifacts, and the other is that the commonest raw material is quartzite, which is a coarse-grained rock that is too difficult for most researchers to analyze because of the lack of reference experimental data. After previous typological examination, a sample of 140 stone artifacts representing several different tool types, including flakes, scrapers, knives, arrowheads, notches and denticulates, were selected for use-wear analysis from the 2010 trial excavation (Fig. 2). These were all examined by the low power technique with an Olympus SZX16 stereo microscope at magnifications ranging from 8.75 to 143.75 diameters. All wear patterns were photographed using a Nikon EOS 600D digital camera, and measured by Olysim Basic software. Use-wear patterns recorded include micro-fractural scarring and edge rounding, and polish if present. This paper reports the preliminary results of this use-wear analysis in the study season of summer 2012.

3. Results

We use the concept of Functional Unit to count the number of use-wear indications, including traces of prehensile use and hafting (Odell, 1996; Zhang, 2009; Zhang et al., 2010; Chen et al., 2013). According to our analysis, 58 specimens (41.4% of the sample) show use-wear, including certain and uncertain use-wear. Spearheads, scrapers and used flakes show a higher proportion (above 50%) of utilization than notches and denticulates (around 30%) (Table 1).

Table 1
Statistics of use-wear found on observed samples in 2012.

Type	Observed specimens *N*	Specimens with use-wear *N*	Percentage %
Spearheads	6	5	83.3
Scrapers	6	4	66.7
Used flakes	32	19	59.4
Knives	13	6	46.2
Denticulates	47	15	31.9
Notches	33	7	21.2
Others	3	2	66.7
Total	140	58	41.4

Six specimens were found with more than one segment of Functional Unit, in which three specimens displayed both used working and hafting segments. From 58 used specimens, a total of 66 Functional Units (FUs) are therefore found at different locations. Traces of use are commonly found on tips or any likely working edge, while hafting traces are seen on the bottom locations of lateral edges and bases.

3.1. Analysis of used wear: working motions and contact materials

Based on the use-wear evidence, this study can positively determine how some of the stone tools were used. The working motions evidenced on the lithic tools can be divided into four types: vertical, longitudinal, lateral movement, and hafting. From the 58 specimens with use-wear traces, seven types of working motions are identified, including defleshing (slicing), cutting (sawing), piercing, drilling, scraping, engraving, and hafting. Moreover, cutting involved a vertical, one-way movement while sawing is a bi-directional movement, and slicing is an oblique movement. For the working motion of certain use-wears found at Wulanmulun, defleshing (slicing) was the commonest task, followed by cutting (sawing), scraping, hafting, piercing, engraving and drilling (see Fig. 3).

Fig. 2. Some lithic tools excavated from the Wulanmulun site in 2010 (after Hou et al., 2012).

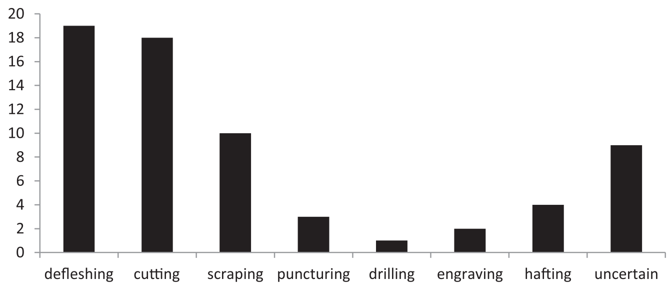

Fig. 3. Working motions identified at Wulanmulun site in 2012.

According to the hardness of the material, contact materials can be divided into several classes: soft botanical substances (e.g. grass, root, tuber), soft animal substances (e.g. flesh, fresh hide), medium-soft substances (e.g. fresh wood, fish scales), medium-hard substances (e.g. dried wood, frozen meat), hard animal substances (e.g. fresh bone, dried hide), extra-hard substances (e.g. dried bone, antler) and hard inorganic substances (e.g. rock). For our samples, the contact materials were mainly identified as animal substances, including flesh, fresh hide, dried hide, and fresh bone with a slight difference in hardness. From a cross-tabulation of working motion and contact material, many use-wears exhibit the possibility of contacting both flesh and bone at the same time. Therefore, skinning and defleshing might have been the main use-tasks of Locality 1 at Wulanmulun.

Specimen OKW-c5 exhibits use-wear in relation to a typical animal-processing tool (Fig. 4). Morphologically, it is a backed knife 46.87 mm long, 28.42 mm wide and 12.56 mm thick. Microscopically, 3 FUs are identified on the tip and top section of both edges. The tip displays a breakage, and a few scattered tiny scars on the dorsal surface. On the left edge, the observed use-wear is dominated by medium-sized scars in a discontinuous distribution on the dorsal surface, and several small scars are found along the edge margins which make those medium-sized scars appear broken from the cross section view. Adjacent to the tip, small-sized scars are continuously distributed with feathered and hinged terminations. Its ventral side exhibits a continuous distribution of medium rounding and tiny scars. On the right edge, edge damage is dominated by light-to-medium rounding and small-sized scars in a continuous distribution, with medium-sized scars occasionally on the dorsal side. The ridge displays medium rounding, and several smashed scars. All scars mentioned above express a single direction.

3.2. Analysis of hafting wear: composite tools

Hafting wear refers to micro-fracture and abrasion traces caused by either the pressures of handling or binding as a way of making a composite tool. If developed and preserved well, this kind of wear can also be identified microscopally as use wear. Identification of hafting wear and prehensile wear on paleolithic stone tools has recently become a research focus in lithic use-wear analysis, although results remain preliminary. Rots and colleagues (Rots, 2003, 2004; Rots and Vermeersch, 2004; Rots et al., 2006) have produced extensive experimental datasets on prehensile and hafting wear, suggesting that hand-held and hafting wear can be reliably distinguished microscopically from use wear, as well as from each other. Their datasets with successful blind tests, showing the formation of hafting wear and positive traces of hafting types and arrangements, have provided valuable comparative data for archaeological interpretation.

In 2004, a simulated experiment of functional study was also conducted in China, and one of us (HC) has participated in the experimental research. Followed Rots' experiments (2003, 2004), 20 flakes were hafted in male arrangement and two flakes in juxtaposed arrangement, and fixed in either parallel-binding or cross-binding methods. According to the experimental results, hafting wear might exhibit small continuous or uneven scarring patterns with very light rounding and weak polish on the base edge of tools, with non-patterned pressure fractures and an uncertain degree of rounding and polish, if any, on the ridge of the surface (Zhao et al., 2008).

On the basis of the above references, we identified at least three specimens that retained both use wear and hafting wear, indicating that some tools might have been used as composite tools at Wulanmulun. Specimen OKW 7-32 is a good example of this kind (Fig. 5). It is typologically classified as a used flake, an assumptive functional tool type, with a length of 15.55 mm, a width of

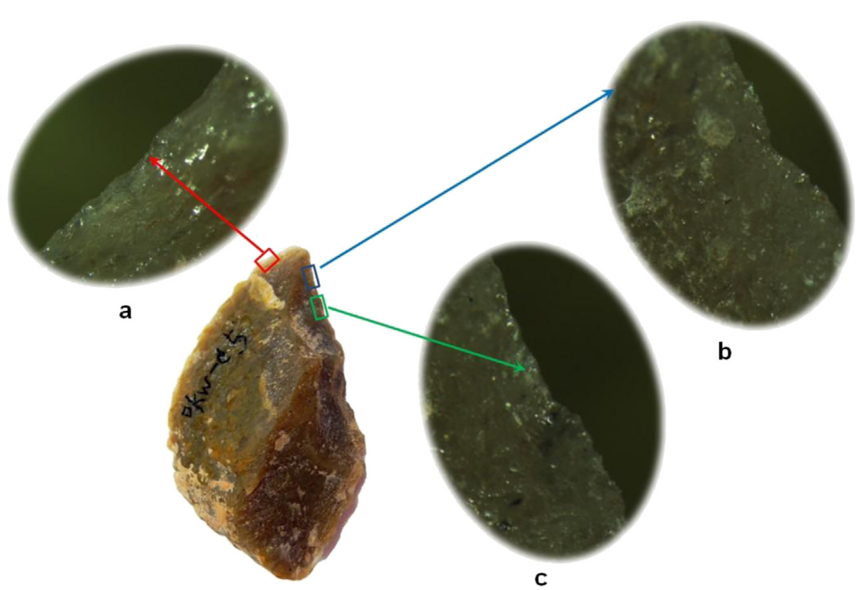

Fig. 4. Use wear (50×) observed on specimen (OKW-c5). (a) Ventral: medium rounding and tiny scars in continuous distribution; (b) Dorsal: small-sized scars continuously distributed with feathered and hinged terminations. (c) Dorsal: medium-sized scars in a discontinuous distribution and several small-sized scars along the edge margins.

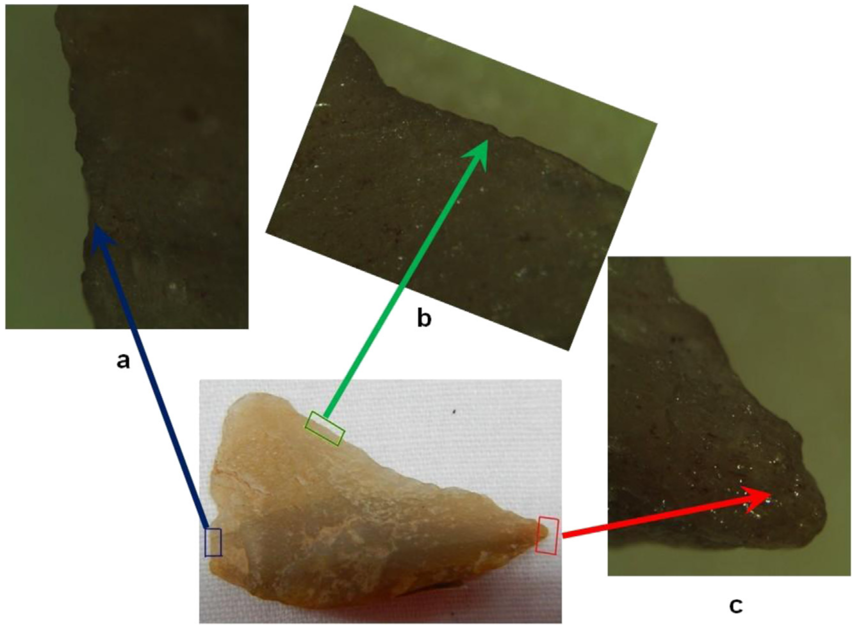

Fig. 5. Hafting wear and use wear (25×) observed on specimen (OKW 7-32). (a) & (b) hafting wears on ventral surfaces; (c) use wear on dorsal surface.

26.40 mm and a thickness of 5.6 mm. Morphological study revealed that its basal part had been modified and thinned for some kind of purpose. According to the microscopic examination, three FUs are found on the base, left edge and tip. The blunt tip retains medium rounding and three scars from the portrait view. On the left edge near the tip, middle-sized zigzag scars are continuously distributed with small-sized scars along their margins on the dorsal surface. At the left edge near the bottom, the use-wear pattern is dominated by light rounding and small-sized scars with feather terminations on the ventral surface. These traces are consistent with binding. At the right edge near the bottom, discontinuously distributed small scars and several "cross-over" shaped scars with no obvious direction are found on the ventral surface. This use-wear pattern seems to have been caused by handling or pressing (Fig. 5).

4. Discussion and summary

Previous use-wear studies of stone-tool function, either by experiments or archaeological analyses are often limited to analyzing only high-quality raw materials, such as chert. This study is a tentative study of use-wear analysis on quartzite artifacts, even though there are no related data for comparison.

In this study, we applied low-power techniques of use-wear analysis to examine microscopically edge damages of 140 stone artifacts from Locality 1 of the Wulanmulun site. The preliminary results reveal direct evidence of tool functions and human behavior, indicating that most stone artifacts were used as tools *in situ*, and some might have been used as composite tools.

4.1. Animal-processing is a main working task at Locality 1 at the Wulanmulun site

The Wulanmulun site is located in the Ordos Plateau of northeastern Asia. The occupants were facing abrupt climate changes and strict resource constraints during the Middle Paleolithic. It is reasonable to suppose that hunting would have been a major strategy for survival by those occupants in North China.

As mentioned previously, the identification of use-wear in the first stage of research indicated that these lithic artifacts have use wear resulting from fleshing (slicing), cutting (sawing), piercing, drilling, scraping, engraving, and hafting (Fig. 3). The overwhelming majority of use wear traces were relevant to animal substances, including flesh, fresh hides, dried hide, and fresh bone. Palaeozoological and palaeoecological research provides us with evidence that animal substances were utilized in this site since fossil animal remains, burnt stones, and combustion features were discovered *in situ*. Some bones also showed cut marks at anatomical parts (e.g. joint blocks). Working tasks at Locality 1 of the Wulanmulun site are determined therefore in combination with evidence of animal-processing, including skinning and defleshing.

4.2. Evidence for the emergence and success of composite tools in North China

It is commonly believed that tools were hafted to enhance functional efficiencies by mechanical principles or were adopted for specific purposes or tasks, e.g. hunting with projectile points. The manufacture and use of hafted tools can thus provide crucial information for technical innovation and adaptive behavior in prehistory. Up to now, researchers have tried to identify the behavior and strategy of using composite tools from use-wear analysis, and experiments.

The technique of making composite tools has been regarded as an important behavioral feature of modern humans by some anthropologists (Klein, 2000; Lombard, 2005). In Africa, Europe, and West Asia, the use of composite tools has been determined at some Middle Paleolithic sites on the basis of multiple researches (Gibson et al., 2004; Lombard, 2005). However, evidence of hafting wear has pushed back the appearance of composite tools earlier and earlier. Use-wear evidences show the existence of hafted tools 200,000 years ago at the 8-B-11site in Sudan (Rots and Philip, 2006), and it is recently reported that the earliest hafted points are 500,000 years old from the site of Kathu Pan 1 in South Africa as (Wilkins et al., 2012).

In China, use-wear analysis has recently been employed to provide new evidence of composite tools. Studies of hafted microblades in the Neolithic site of Shangzhai (Cui et al., 2010) and hafted adzes in the Upper Palaeolithic site of Hutouliang (Zhang et al., 2010; Shen et al., in press) are good examples. Our analytical results suggest that some artifacts from Locality 1 at Wulanmulun might have been made and used as composite tools; these are currently the earliest ones identified in China. The main features of their use-wear are the concentrations of used scars and rounding on the tip or working edges, while hafting wear appears clearly at the bottom or lateral edges near the bottom, exemplified by OKW 7-32 (Fig. 5). This study sheds light on the emergence and subsequent success of composite tools during Middle Paleolithic in North China.

Acknowledgements

This paper was supported by the CAS Strategic Priority Research Program (Grant No. XDA05130203), National Social Science Foundation of China (Grant No. 11CKG001), Provincial Social Science Foundation of Zhejiang (Grant No. G141), NSFC Project (Grant No. 41272033) and Special Fund for Paleontological Excavation of Chinese Academy of Sciences.

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