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How depositional environments impact the preservation of micro-wear of quartz artifacts: insights from the Oldowan of the Shungura Formation (Ethiopia)

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& Anne DELAGNES

GLIMPSES OF A PLIO-PLEISTOCENE AFRICAN ECOSYSTEM:
THE LOWER OMO VALLEY, ETHIOPIA

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Quartz artefact from the FtJi3 site (Member F, Shungura Formation). Credits: Aline Galland.

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How depositional environments impact the preservation of micro-wear of quartz artifacts: insights from the Oldowan of the Shungura Formation (Ethiopia)

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ABSTRACT
The function of Oldowan tools is a key aspect of early hominin subsistence in eastern Africa. The rarity of the sites, the preservation of the assemblages and raw materials are limiting factors in the functional study of Early Pleistocene assemblages. The archaeological occurrences from Member F of the Shungura Formation (Ethiopia) have a precise chronostratigraphic framework (2.324 ± 0.020 Ma to 2.271 ± 0.041 Ma), a detailed reconstruction of depositional environments, and artifacts produced mainly from small quartz pebbles that are highly resistant to chemical and mechanical alterations. The studied archaeological material comprises artifacts from 12 occurrences and three environmental contexts (floodplain, point bar, and channel lag). As a baseline for distinguishing taphonomic damage from use-wear, and for assessing the preservation of use-wear in the archaeological record, we characterized macroscopic and microscopic surface alterations resulting from fluvial transport and aeolian abrasion experiments. Despite the good preservation of the lithic assemblages at a macroscopic scale, variations were observed at a microscopic level corresponding to the depositional environment. Understanding the link between taphonomic alterations on quartz and the type of deposits leads to better recognition and interpretation of potential use-wear on these ancient artifacts.

KEY WORDS
Oldowan,
Shungura Formation,
taphonomy,
microwear analysis,
experiments,
quartz.

RÉSUMÉ
L'impact des environnements de dépôt sur la préservation des microtraces d'usure des artefacts en quartz : apport de l'Oldowayen de la Formation de Shungura (Éthiopie).
La fonction des outils oldowayens est un aspect majeur de la subsistance des hominines en Afrique orientale. La rareté des sites, la préservation des assemblages et les matières premières sont des facteurs limitant de l'étude fonctionnelle des assemblages du Pléistocène Ancien. Les occurrences archéologiques du Membre F de la Formation de Shungura (Éthiopie) sont caractérisées par un cadre chronostratigraphique précis (de 2,324 ± 0,020 Ma à 2,271 ± 0,041 Ma), une reconstruction détaillée des environnements de dépôt, et d'artefacts produits principalement à partir de petits galets de quartz, très résistants aux altérations chimiques et mécaniques. Le matériel archéologique étudié comprend 12 occurrences et trois types d'environnements de dépôt (plaine d'inondation, barre de méandre et chenal). Nous avons caractérisé les altérations de surface macroscopiques et microscopiques causées par des expérimentations de transport fluviatile et d'abrasion éolienne, afin de servir comme référence pour distinguer les marques taphonomiques des traces d'usage, et pour évaluer la préservation des traces d'usage dans le registre archéologique. En dépit de la bonne préservation des assemblages lithiques à l'échelle macroscopique, des variations ont été observées au niveau microscopique en fonction de l'environnement de dépôt. La compréhension du lien entre altérations taphonomiques du quartz et le type de dépôts conduit à une meilleure identification et interprétation des traces d'usage potentielles sur ces artéfacts anciens.

MOTS CLÉS
Oldowayen,
Formation de Shungura,
taphonomie,
analyse des micro-usures,
expérimentations,
quartz.

INTRODUCTION

The intentional knapping of rocks during the Plio-Pleistocene is considered to be the pivotal moment that marks the beginning of Prehistory. The Oldowan techno-complex represents the first evidence of a material culture spread across eastern Africa between *c.* 2.8 Ma to 1.5 Ma (Texier 1995; Plummer *et al.* 2023). In the Eastern African Rift System, Oldowan sites are mostly located in fluvio-lacustrine environments, often in close proximity to mineral resources (Rogers *et al.* 1994; Plummer 2004; Schick & Toth 2006). Substantial work has been done on the management of raw materials (Stiles 1991; Harmand 2004, 2009; Stout *et al.* 2005; Braun *et al.* 2008, 2009; Goldman-Neuman & Hovers 2009, 2012; Delagnes *et al.* 2011; McHenry & de la Torre 2018) and the typo-technology of Oldowan assemblages (Chavaillon 1970, 1979; Leakey 1971; Roche & Tiercelin 1980; Toth 1985; Kibunjia 1990; Stern *et al.* 1993; Texier 1995; Semaw *et al.* 1997; Plummer *et al.* 1999; Roche *et al.* 1999; de la Torre 2004; de Lumley & Beyene 2004; Delagnes & Roche 2005; Mora & de la Torre 2005; Stout *et al.* 2010; Gallotti & Mussi 2015; Yustos *et al.* 2015; de la Torre & Mora 2018; Braun *et al.* 2019). The functionality of these early stone tools remains a key question in the study of Early Stone Age assemblages (Isaac 1969; Keeley & Toth 1981; Sussman 1987; Langejans 2012; Mercader *et al.* 2022). However, research on the function of flaked artifacts has been limited. Functional analyses have often been hindered by poor preservation of the assemblages due to differential preservation of raw materials (Beyries 1993; Gallotti & Mussi 2015) and the remobilization of assemblages, mainly by fluvial dynamics (Schick 1986; Petraglia & Potts 1994; Hovers 2003; de la Torre *et al.* 2017; Maurin *et al.* 2017; Delagnes *et al.* 2023). The characterization of post-depositional surface modifications on lithic surfaces is therefore fundamental for the identification of functional use-wear in these ancient contexts.

This article aims to evaluate the preservation of lithic assemblages from the Shungura Formation, a significant Oldowan site complex in southwestern Ethiopia. This Plio-Pleistocene formation is divided into 12 members marked chronologically and stratigraphically by volcanic tuff horizons that span the entire sequence (Bonnefille *et al.* 1973a, b; Heinzelin 1983). The earliest archaeological occurrences in this sequence are located in Member F (2.324 ± 0.020 Ma to 2.271 ± 0.041 Ma; (McDougall *et al.* 2012; Kidane *et al.* 2014) which is characterized by a succession of fluvial deposits (channel lags, point bars, proximal and distal floodplain) from the meandering paleo-Omo River. The lithic assemblages are dominated by quartz artifacts that are well-preserved macroscopically (Maurin *et al.* 2017). However, in order to interpret their function, it is necessary to describe the taphonomic microwear on quartz, an aspect for which there is still limited understanding.

Hominins have exploited quartz from primary and secondary sources throughout the Oldowan period (Leakey 1971; Merrick & Merrick 1976; Texier 1995; Semaw *et al.* 2003; de Lumley & Beyene 2004; Goldman-Neuman & Hovers 2009; Delagnes *et al.* 2011; Gowlett *et al.* 2022; Plummer *et al.* 2023). The greater resistance of quartz to weathering, both chemical and mechanical (Goldich 1938), allows for a broader range of analyses to be conducted on these early assemblages, such as traceological use-wear analyses. Several use-wear analyses have been conducted on Early Stone Age quartz assemblages, including both pounding tools (e.g., Arroyo & de la Torre 2016, 2018) and flaked tools (e.g., Sussman 1987; Lemorini *et al.* 2014; Bello-Alonso *et al.* 2019, 2021). While these studies have provided valuable insights into early hominin behaviors, they often offered limited attention to the characterization of taphonomic wear. The weathering effects of post-depositional processes on quartz materials need to be assessed as they exhibit distinctive characteristics when compared to those observed in other rock types, such as chert. In stark contrast to flint artifacts, which have been extensively studied (Levi Sala 1986; Plisson & Mauger 1988; Prost 1989; Caspar *et al.* 2003; Clemente-Conte & Pijoan 2005; Chu *et al.* 2015; Michel *et al.* 2019), there has been little focus on taphonomic microwear on quartz artifacts. Knutsson & Lindé (1990) conducted a pioneering wind abrasion experiment on quartz tools, which was analyzed using a scanning electron microscope (SEM). Knutsson's research further investigates the different types of weathering in archaeological contexts using SEM (Knutsson 1988a, b). The other experimental work on post-depositional weathering of quartz artifacts focuses on motion-related weathering within the sandy sedimentary matrix (Venditti *et al.* 2016). However, no experiments have yet been conducted to assess the microwear from fluvial transport on quartz materials. In eastern African Plio-Pleistocene contexts, the fluvio-lacustrine depositional environments and the weathering of artifacts after the erosion of their deposit are the main factors that deteriorate the traces of use-wear on the surface of artifacts. The paleo-Omo River was the main agent of sediment deposition and burial of faunal and lithic assemblages in Member F (Heinzelin 1983). The sediments transported by the river had a significant impact on the alteration and preservation of artifacts. It is widely accepted that the energy of a river and the size of the sand grains causes varying degrees of weathering on archaeological assemblages (Schick 1986; Petraglia & Potts 1994; Frings 2008; Chu 2016). That is why we established a specific experimental protocol with a primary focus on fluvial transport. Another experiment focused on aeolian abrasion due to the exposure of artifacts on the surface, before deposition and following the erosion of the surrounding deposits in a semi-arid environment (Heinzelin 1983).

A detailed assessment of the integrity of sites, the homogeneity of lithic assemblages and the degree of preservation of tool surfaces are all prerequisites for understanding the activities of the first toolmakers. This paper stems from doctoral research (Galland 2022) and presents taphonomic experiments aimed at understanding the variability of quartz artifact alterations from the fluvial depositional environments of Member F of the Shungura Formation. The fundamental objective of these experiments is not to faithfully reproduce the post-depositional alterations seen on these artifacts, but rather to recognize and differentiate them from the functional use-wear that is the main focus of our research. The end goal is to provide a solid basis for interpreting Oldowan subsistence behaviors in the Shungura Formation.

MATERIAL AND METHODS

Archaeological material

The early Oldowan assemblage from Member F is dominated by sharp-edged flakes knapped from small quartz pebbles (Merrick *et al.* 1973; Chavaillon 1976). These pebbles were selectively chosen from a variety of raw materials available in the area (Delagnes *et al.* 2011). The functional study of these artifacts was first conducted by C. Sussman as part of the International Omo Research Expedition (IORE) in the 1970s. Sussman's preliminary report on 19 artifacts from Member F yielded inconclusive results (IORE archives). She examined a sample from the site complex FtJi 2 (OMO A2) for which each artifact was individually bagged. Thus, the inconclusive results may come from the small size sample, due to "time restrictions and microscope availability" (IORE archives), rather than poor storage conditions. Our work includes material from the IORE and from the Omo Group Research Expedition (OGRE), which has been working on the Shungura Formation since 2006. We selected 12 occurrences of over 100 artifacts located in five major site complexes in Member F (Table 1; Fig. 1). The selection of the archaeological assemblages reflects the diversity of fluvial depositional environments (channel lag, point bar, floodplain) in Member F (Table 1; Fig. 2), which is essential for characterizing the traces of alteration specific to these contexts.

Within Member F of the Shungura Formation, the occurrences located in channel lags are characterized by coarse sand and sand layers in secondary deposits (*in situ* or surface). Seven occurrences were selected in channel lag contexts. The first site complex, FtJi1, has three main occurrences, OMO A16, OMO A17, and OMO A18, excavated by the IORE team in

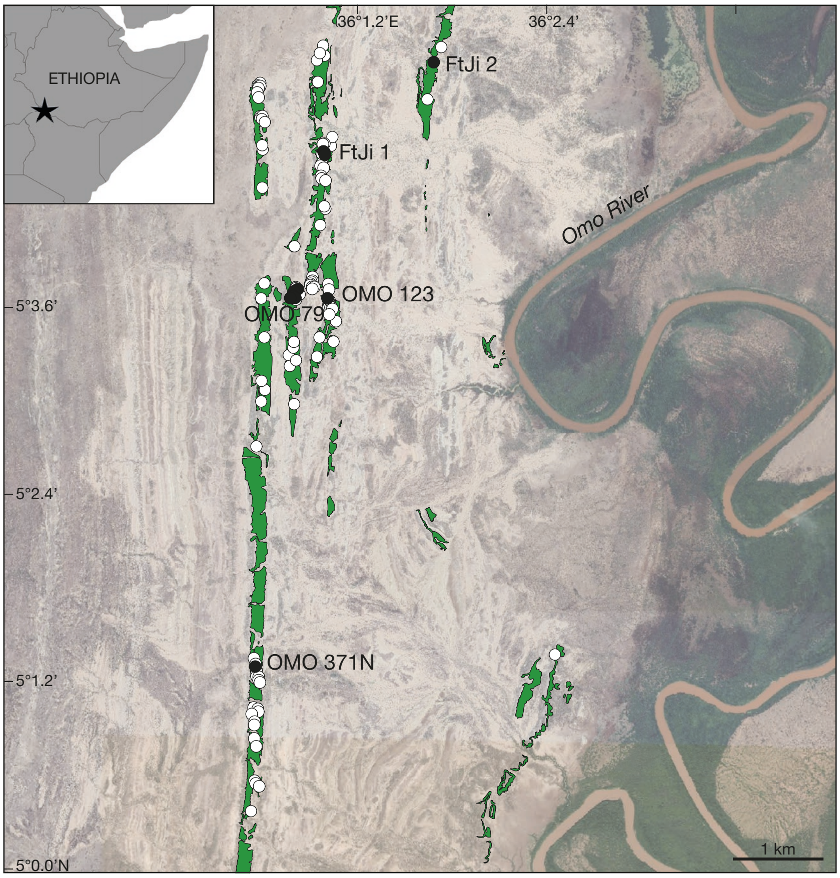


Fig. 1. — Location of selected occurrences (**black dots**) within their site complex in the Member F (**green filling**) of the Shungura Formation, Ethiopia. The **white dots** represent all archaeological occurrences within Member F that are not discussed in this study. Credits: Aline Galland.

Table 1. — Inventory and description of the selected archeological occurrences. Only artifacts longer than 2 cm are included in the analysis (pebbles are excluded).

Site complex	Occurrences	Deposit type	Depositional environment	Number of artifacts > 2 cm	*In situ* artifacts	Surface artifacts	Total number of artifacts
FtJi 2	OMO A2	Silty clay	Floodplain	76	236	128	364
OMO 123	OMO A13	Silty clay	Floodplain	208	1011	241	1252
FtJi 1	OMO A16	Coarse sand	Channel lag	72	299	0	299
	OMO A17	Coarse sand	Channel lag	111	0	206	206
	OMO A18	Coarse sand	Channel lag	65	0	120	120
OMO 79	OMO A42	Coarse sand	Channel lag	62	0	165	165
	OMO A43	Clay and silt	Point bar	47	125	127	252
	OMO A81	Coarse sand	Channel lag	68	0	150	150
	OMO A82	Clay	Floodplain	75	2	318	320
	OMO A112	Coarse sand	Channel lag	57	0	129	129
	OMO A129	Coarse sand	Channel lag	91	0	201	201
OMO 371N	OMO A167	Silt	Point bar	105	199	198	397
Total				1037	1872	1983	3855

the 1970s at the base of a coarse sand layer above tuff F' in the FtJi 1 site complex (Merrick *et al.* 1973). The second site complex, OMO 79, evidences several phases of occupation in the lower deposits of Member F (Delagnes *et al.* 2023). The selected occurrences are OMO A42, OMO A81, OMO A112 and OMO A129, with surface materials collected by the OGRE in 2014; they represent two distinct phases of occupation redistributed in coarse sand deposits (Delagnes *et al.* 2023).

The selected occurrences in point bar deposits are mainly in silty sediments. This includes two occurrences: OMO A43, excavated during the 2018 campaign, representing the third phase of occupation at OMO 79 (Delagnes *et al.* 2023), and OMO A167, excavated in the complex OMO 371N in 2019.

Lastly, three occurrences found in proximal floodplain deposits were selected (no archaeological evidence in distal floodplain deposits was found during the extensive surveys

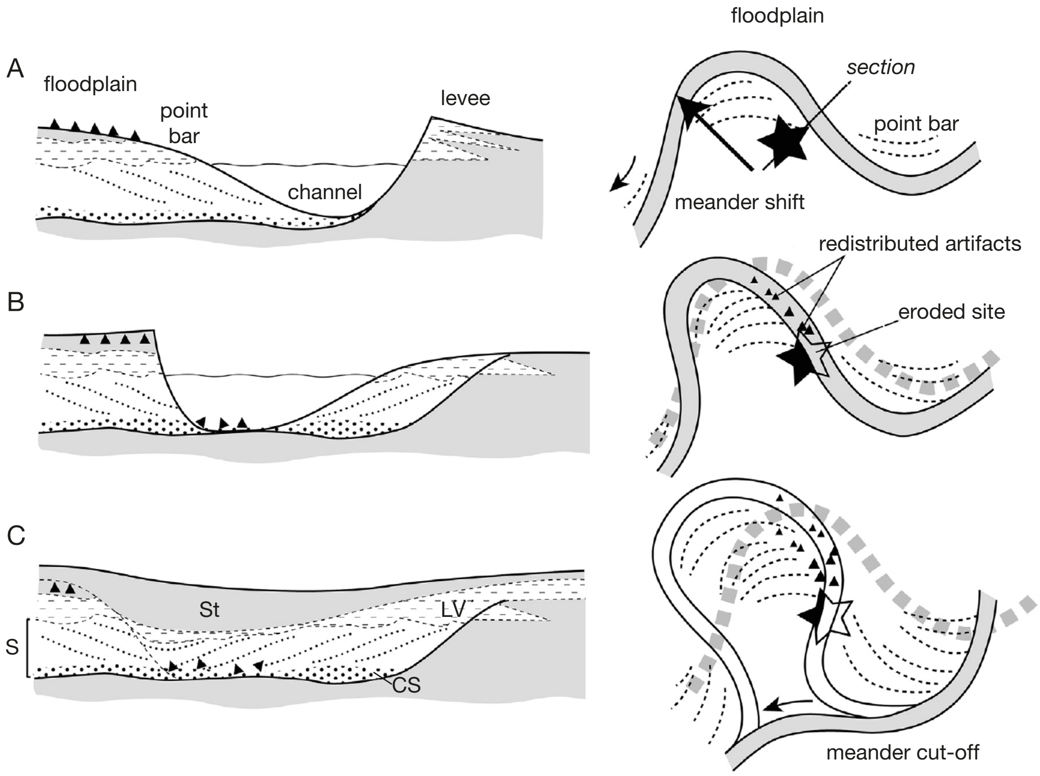


Fig. 2. — Hypothetical site formation process along the paleo-Omo River (**right**, plan view; **left**, cross-section): **A**, main occupation (**black star**) in a meander floodplain; **B**, meander shift, erosion of the site, and transport of the artifacts (**black triangle**) as bedload in the channel; **C**, meander cut-off and burial of the site by flood deposits. Abbreviations: **CS**, coarse sand; **LV**, levee deposits; **S**, sand; **St**, silt. Credits: modified from Maurin *et al.* 2017.

performed by the OGRE prior to 2017; Maurin *et al.* 2017). OMO A2 (site complex FtJi2) was excavated by H. Merrick in 1973 from a silty clay deposit with carbonated concretions, 6 meters above tuff F' (Merrick *et al.* 1973). OMO A82 is considered the fourth phase of occupation at OMO 79 (Delagnes *et al.* 2023). Around 400 m to the west of OMO 79 is the site complex OMO 123, in which OMO A13 is the richest occurrence in Member F, excavated by J. Chavaillon from 1973 to 1976 (Chavaillon 1976).

The complex post-depositional history of Member F sites led to the classification of archeological occurrences according to their "primary" or "secondary" contexts. The notion of primary context refers to the preservation of archaeological remains in their original depositional sediment. In the case of fluvial sedimentation, silty and clayey deposits have been attributed to primary contexts (Fig. 2). Regardless of the nature of the sediments, we assume that all Member F occurrences in a primary context have undergone varying degrees of post-depositional deformation, such as vertical remobilization of pieces by argiliturbation (Duffield 1970; Eswaran & Cook 1988; Eswaran *et al.* 1999), that hinder any attempt at intra-site analysis based on the spatial distribution of artifacts. On the other hand, the concentrations of artifacts found in primary contexts can be used without difficulty to reconstruct the depositional environments where hominins settled. In secondary contexts, artifacts were remobilized by fluvial dynamics that redeposited them elsewhere within the sandy matrix of channel lags (Merrick *et al.* 1973; Schick 1986). In this case, when occurrences are in small concentrations spreading downstream within a single sandy deposit, the transport distance of the remains is challenging to accurately assess, as are the type and location of the original occupation sites.

The positioning of the remains *in situ* or on the surface is another important criterion in the characterization of the occurrences. Tectonics and tilting of the sedimentary deposits of the Shungura Formation have exposed cut fronts along which erosion is active, notably via runoff, wind, and bioturbation. Objects eroding from the tops or slopes of sedimentary hills are sometimes evidence of an occurrence still largely preserved *in situ*, i.e., within the primary or secondary sedimentary deposit (Delagnes 2012). Occurrences are considered *in situ* when one or more artifacts are found either, in place in the sediment, associated with surface artifacts attributable to the same original archeological level due to their distribution (Delagnes 2012; Delagnes *et al.* 2023), or associated by the nature of the adhering sediment (Archer *et al.* 2020). Surface occurrences correspond to concentrations of remains closely associated spatially with the same stratigraphic unit, with sediment adhering to the pieces, and without a preserved archeological horizon. Occurrences associated with recent secondary deposits (e.g., the bottom of present-day ravines or recent sedimentary slumps) are excluded from this research (Delagnes 2012; Delagnes *et al.* 2023).

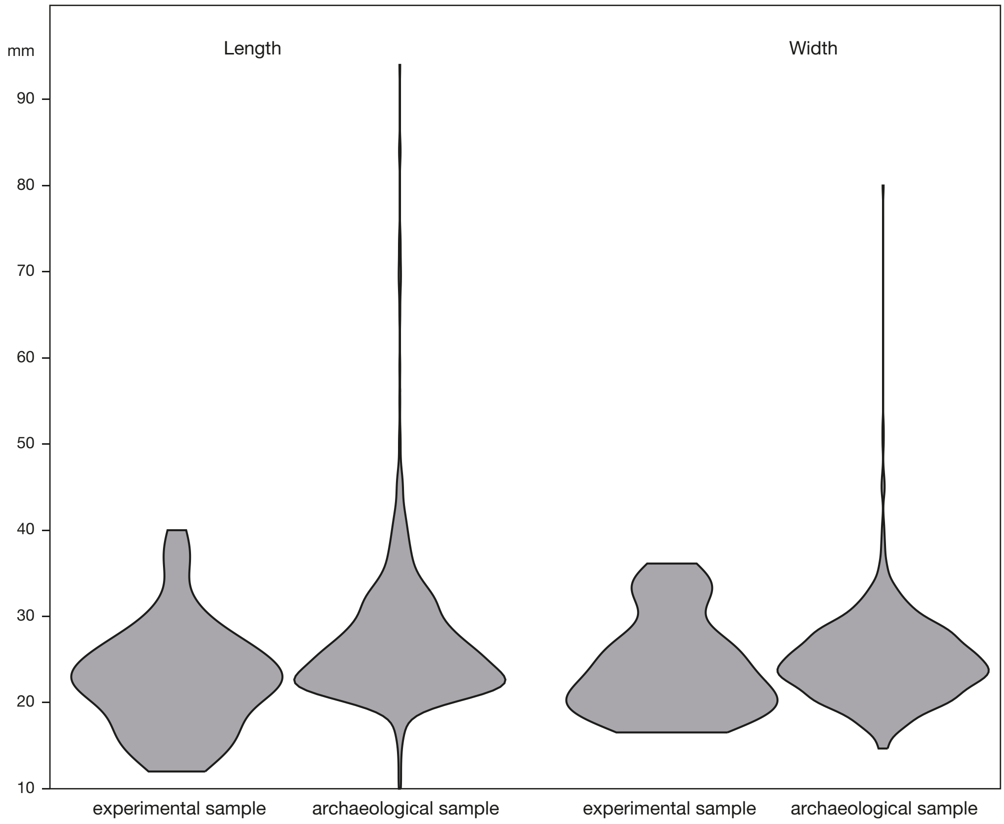


FIG. 3. — Violin plots comparing the distribution of length and width measurements between the archaeological and experimental quartz assemblages. The density plots highlight variation within each sample and allow visual comparison of the morphological characteristics of each sample. Credits: Aline Galland.

TAPHONOMIC EXPERIMENTS

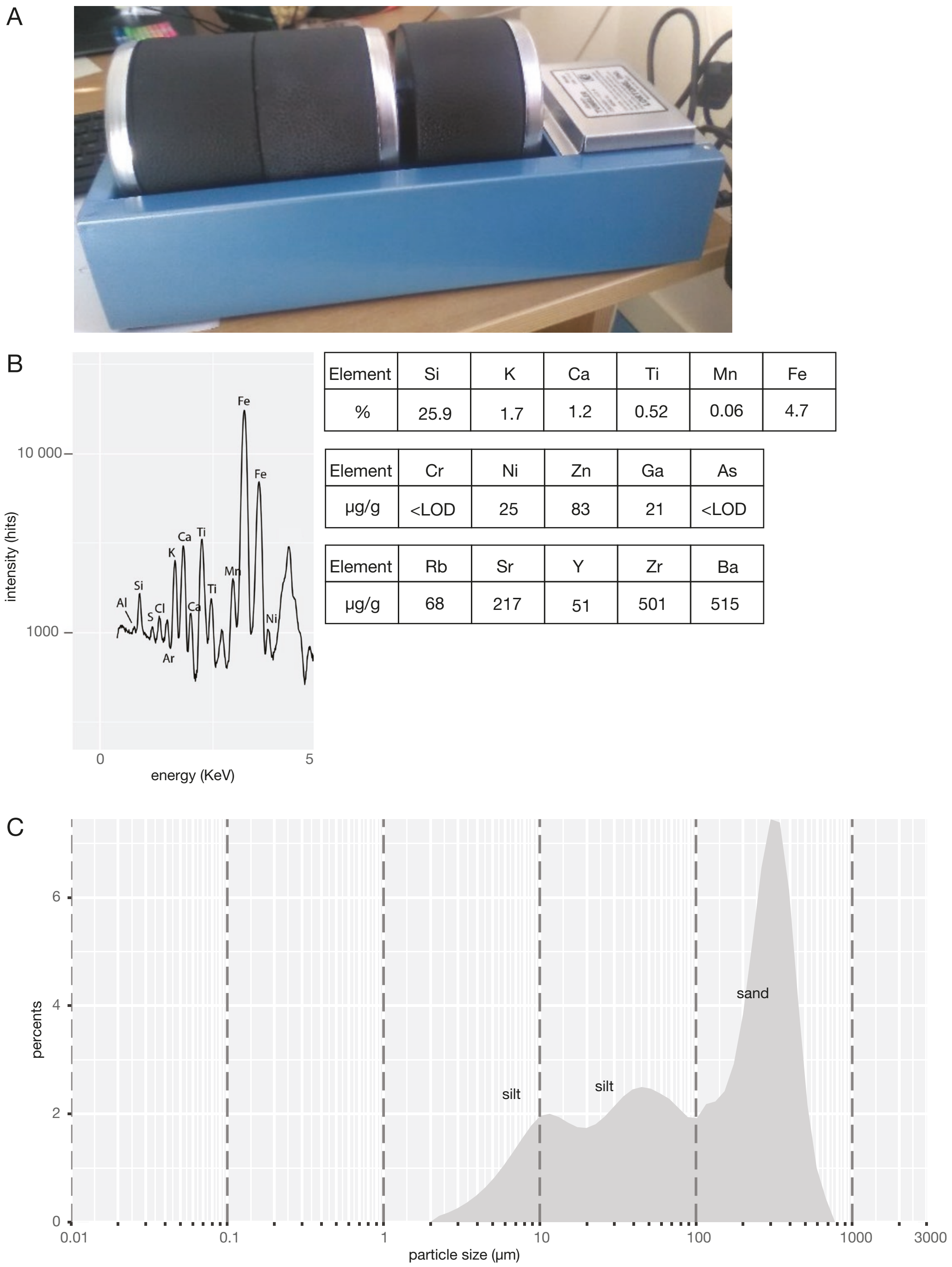
Since the paleo-Omo River was a major factor in site formation processes and that erosion of the deposits caused artifact exposure to weathering, the taphonomic experiments focused on fluvial transport and aeolian abrasion. The knapping of experimental artifacts was the first step of the experimental protocol. The goal was to produce sharp flakes from quartz pebbles collected in the Shungura Formation channel lag deposits. In total, 24 pebbles were knapped, six of which came from Member F. The scarcity of quartz pebbles within Member F deposits (Delagnes *et al.* 2011) led us to use 16 pebbles from Member B that has a similar fluvial depositional environment. The choice of this scarce but local raw material allowed a better morphological comparison with the archaeological sample (Fig. 3). The knapping session involved both bipolar and freehand percussion, and produced 392 artifacts longer than 1 cm, which were given a unique inventory number, stored individually and used in following experiments.

FLUVIAL EXPERIMENT

The second step in the experimental protocol was to better characterize the grain size and composition of the sandy deposits from Member F in order to build an adequate protocol and to understand the impact of this specific fluvial sediment on the lithics. Thus, analyses using a laser particle size analyzer and an X-ray fluorescence spectrometer were performed on sand samples from Member F, collected near the OMO 123 archeological complex. The paleo-Omo River sand collected in Member F is composed mostly of volcanic rocks and very little quartz (Silicon = < 50%) which is due to erosion of the volcanic substrates upstream from the valley (Butzer & Thurber 1969). The particle size analysis showed sand is the main component, with a minor silt component (Fig. 4). The equipment used to reproduce fluvial transport was a combination of three rubber polishing barrels with a capacity of 500 grams each (®Lortone, inc.) and a rotation speed of 60 rpm (Fig. 4). The content ratio was one third sand (100 ml) and two thirds water (200 ml) to obtain a fluid matrix rich in sediment that is characteristic of the Omo river (Zăinescu *et al.* 2023). Then a series of sequential tests were set up to evaluate the development of weathering traces. Abrasion time was established based on data from the available bibliography (according to the synthesis of Chu 2016) at 3 h, 6 h, 12 h, 24 h, 48 h, 72 h and 100 h. Two artifacts for each time interval were used to assess the variability of weathering. Only one artefact was placed inside each barrel in order to avoid breakage caused by the collision of artifacts.

AEOLIAN EXPERIMENT

The aridity of the Shungura environment makes the aeolian alteration of artifacts following surface exposure possible before and/or after burial. This type of experimentation has only been undertaken once (Knutsson & Lindé 1990) on quartz artifacts. It was therefore necessary to establish a protocol adapted to the context of the study. For this purpose, we used



Element	Si	K	Ca	Ti	Mn	Fe
%	25.9	1.7	1.2	0.52	0.06	4.7

Element	Cr	Ni	Zn	Ga	As
µg/g	<LOD	25	83	21	<LOD

Element	Rb	Sr	Y	Zr	Ba
µg/g	68	217	51	501	515

Fig. 4. — Fluvial experiment setup and detailed analyses made on one sand sample from a channel lag deposit in Member F: **A**, equipment used in the fluvial experiment, rubber tumblers (®Lortone, inc.); **B**, analysis by X-Ray fluorescence showing the composition of elements within the sand; **C**, size sorting analysis showing a minor silt component and a major sand component. Abbreviations: **As**, arsenic; **Ba**, barium; **Ca**, calcium; **Cr**, chromium; **Fe**, iron; **Ga**, gallium; **K**, potassium; **LOD**, limit of detection; **Mn**, manganese; **Ni**, nickel; **Rb**, rubidium; **Si**, silicon; **Sr**, strontium; **Ti**, titanium; **Y**, yttrium; **Zn**, zinc; **Zr**, zirconium. Credits: Alain Queffelec et Aline Galland

a closed-circuit sandblasting machine (®Finimac) from the *Centre d'Études Nucléaires de Bordeaux Gradignan* (CENBG; Fig. 5). The air pressure was set at 14 psi, equivalent to 1 bar, and to the estimated pressure on Earth with an average wind speed of 5 m/s (the calculated average wind speed for Shungura (Laity & Bridges 2009). The distance required to obtain this wind speed from the jet to the artifact was then determined as 10 cm, which avoids completely degrading the surface of the experimental flakes. A total of six flakes were placed so that the largest, flattest surface was parallel to the air flow, and two were positioned perpendicularly. We did not have the opportunity to modify the abrasive used by the machine, which is composed of standardized silica sand. The duration of exposure was varied between 1 to 5 minutes. Beyond that time, the force of the machine led to an opacity and smoothing of the experimental flake surfaces which is not seen in the archaeological record.

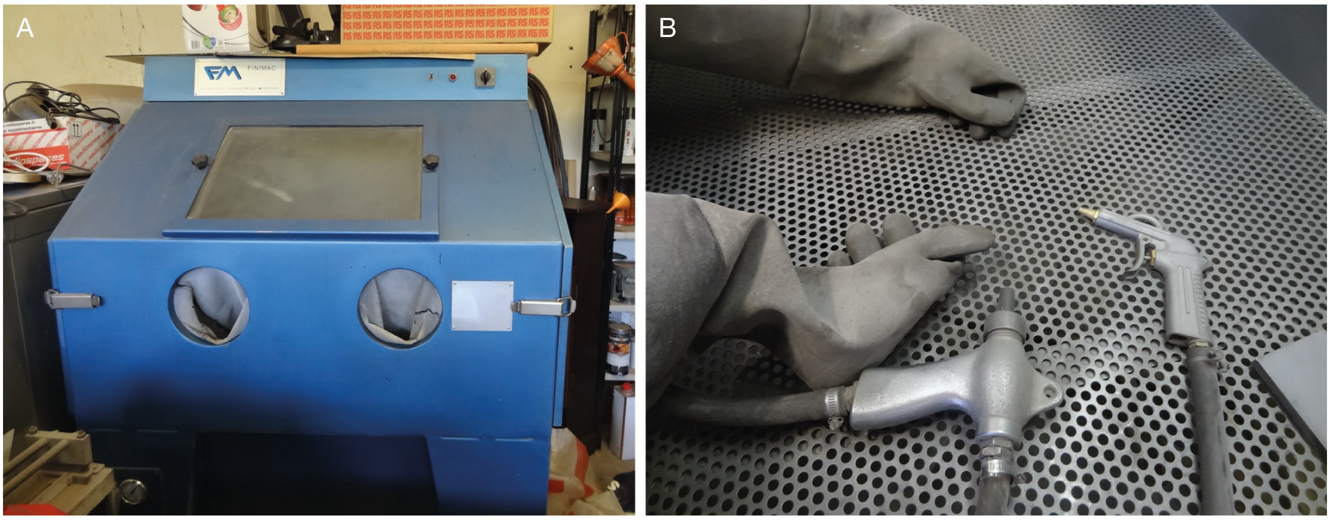


Fig. 5. — Closed-circuit sandblasting machine: **A**, external view; **B**, internal view. Credits: Aline Galland.

After both fluvial and aeolian experiments, the pieces were cleaned separately in an ultrasonic tank with demineralized water and neutral soap for 15 minutes and then with only demineralized water for another 15 minutes. Afterwards, the surfaces were cleaned with alcohol (90%) during observation under the microscope.

Microwear analysis

The macrowear and microwear data of the selected archeological sample were compared in order to analyze surface alteration across a multi-scale range (Fig. 5). The metallographic microscope Olympus BHM equipped with differential interference contrast was used in the observation of taphonomic wear. The archaeological material stored in the National Museum of Ethiopia in Addis Ababa was observed directly under the microscope without making molds. Non-destructive analyses started with the cleaning of the artifacts using 90% alcohol and ultrasonic cleaning using neutral soap and demineralized water for 15 minutes and with only demineralized water for another 15 minutes. Then 200× and 400× magnifications were used to examine the artifacts from their edges to the central surfaces along the widest surface of each product type. No cortical surfaces were examined. This work focused on the general preservation of an artifact to evaluate the impact of post-depositional processes on the assemblages. To do so we focused on the macroscopic and microscopic abrasion on edges and ridges of the artifacts. What characterizes the microscopic taphonomic alterations is the randomness of their location and orientation on the artifact surfaces and edges which has been mentioned before for other raw materials (Levi Sala 1986; Márquez *et al.* 2001; Burroni *et al.* 2002; Asryan *et al.* 2014; Berruti & Arzarello 2020). We choose to qualify this kind of abrasion as microfracturing because, although the resulting features have a fracture-like morphology, the processes that initiated them, whether mechanical and/or chemical, cannot be confidently determined. This alteration was divided into three levels, both at macroscopic and microscopic scale, based on the work previously done on Shungura, Member F material (Maurin *et al.* 2017; Galland 2022; Delagnes *et al.* 2023; Fig. 6).

RESULTS

Water transport

Due to the high resistance of quartz materials to mechanical alteration, well-developed taphonomic alterations due to sand and water movements can be observed on the experimental pieces after 72 hours (Fig. 7A, C, E).

Microfracturing was evident through more or less continuous irregular pits on the surface of the quartz crystals, and rounding on the ridges and edges (Fig. 8). A clear limit can be seen between the altered edge and the fresh crystal.

We also tested the alteration of experimental pieces in tumbling barrels with silty sediments (Fig. 9) and clayey sediments (Fig. 10) obtained from the sieving of sand samples from Member F. These tests proved productive, as alteration changes according to sediment grain size (Fig. 8). As silt is finer than sand, the well-developed alteration was observed after 100 h in the tumblers. The edges and micro-ridges were heavily rounded, and the crystals were coarsely pitted in the form of circular and/or oval impacts.

The alteration caused by the clay sediment (100 h in the tumblers) is very different from that described above. Edge rounding is highly developed and even shiny, while surface pitting is rare (Fig. 10A-C). There are, however, areas where microfracturing is abundant and continuous, which creates a rough surface on the quartz crystals (Fig. 10D).

Taphonomic wear of archaeological assemblages

The characteristics of the taphonomic wear for each of the three depositional environments in Member F (channel lag, point bar and floodplain) will be described below. While these environments are important to consider, the location

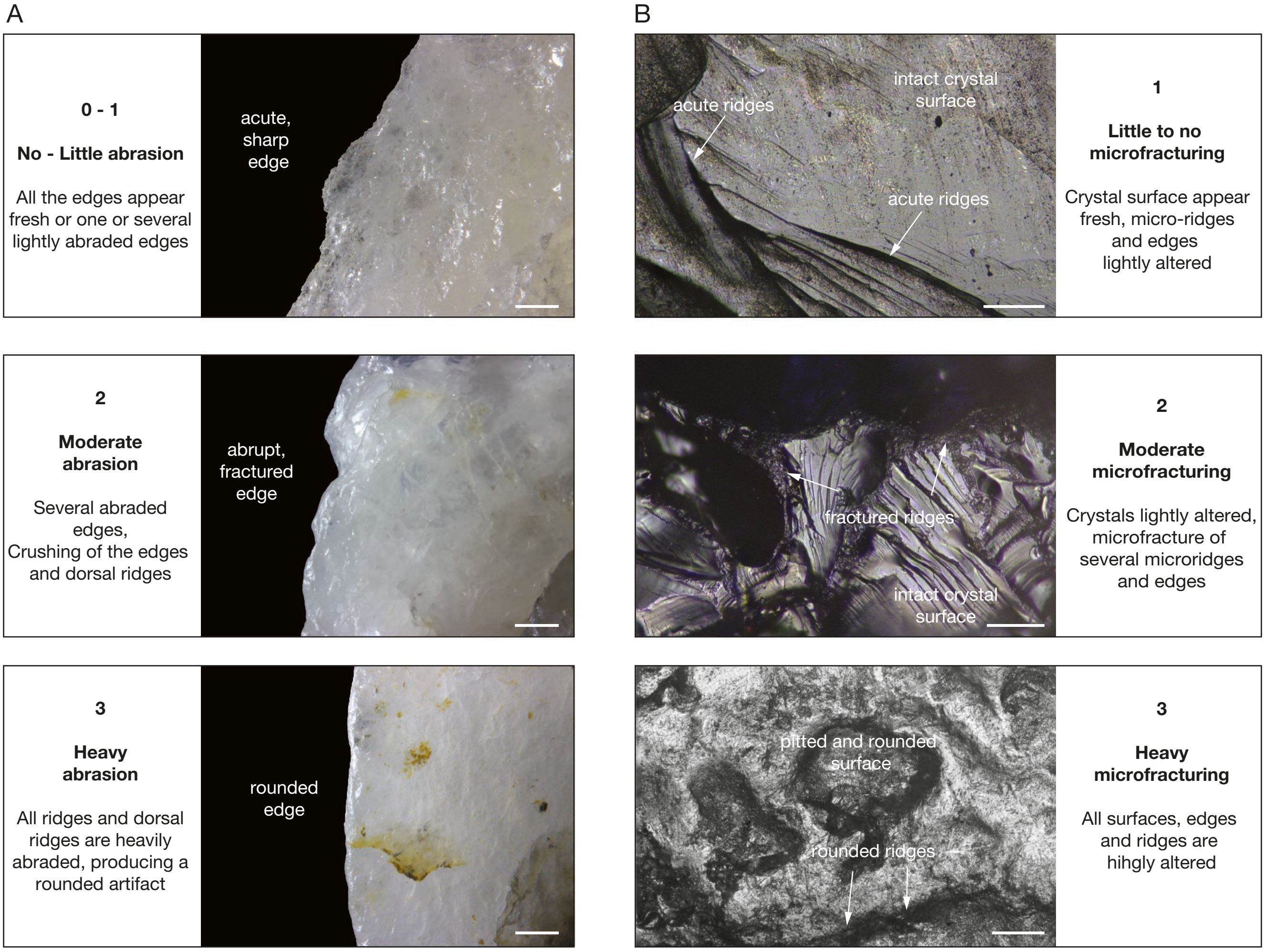


Fig. 6. — Classes of alteration on three different quartz artifacts: **A**, macroscopic surface alterations; **B**, microscopic surface alterations. Description of the alteration levels at macroscopic and microscopic scales. Scale bars: A, 1 mm; B, 100 µm. Credits: Modified from Delagnes *et al.* 2023.

of the artifacts whether on the surface or *in situ* do not show a significant difference when it comes to the intensity of the taphonomic wear.

Occurrences in channel lag deposits

The macroscopic observation of artifacts show that the material is well preserved; less than 5% were highly abraded. This is explained by the strong resistance of quartz to alteration and potentially due to the short remobilization of artifacts in time and space before burial. The relative freshness of artifacts at a macroscopic scale is balanced by the heterogeneity of microscopic surface alterations. Artifacts showing no to little microfracturing represent 48% to 58% of the assemblages, except at OMO A81 where this rate is 68%. However, up to 8% of the artifacts in channel lag assemblages show heavy microfracturing (Fig. 19).

The taphonomic microfracturing characteristic of sandy sediment alteration is observed in the archaeological material. It is distributed on the whole piece, with a light rounding of microridges which could indicate short duration transportation (Fig. 11). This rounding appears alongside coarse and irregular pitting, also equivalent to what was observed experimentally on artifacts transported in sandy sediment (Figs 11; 12).

Occurrences in point bar deposits

As with the channel lag occurrences, artifacts are well preserved on a macroscopic scale, with a very low proportion of artifacts showing significant abrasion (Fig. 19, see supplementary information (SI) for detailed tables of artifacts at: https://doi.org/10.5281/zenodo.11204868). Microscopically, the lithic assemblages are also generally well preserved, with the proportion of artifacts with little to no microfracturing at over 60% for both occurrences (OMO A43 and OMO A167; Fig. 19). Microwear related to taphonomic alteration is poorly developed compared with channel lag deposits. Crystal edges and surfaces are very well preserved overall, with sharp edges and crystals showing clearly visible technological features (Fig. 13A-C). About 3% of the point bar assemblages are impacted by general rounding and the microfracturing is mostly limited to the edges and ridges (Fig. 13D-G).

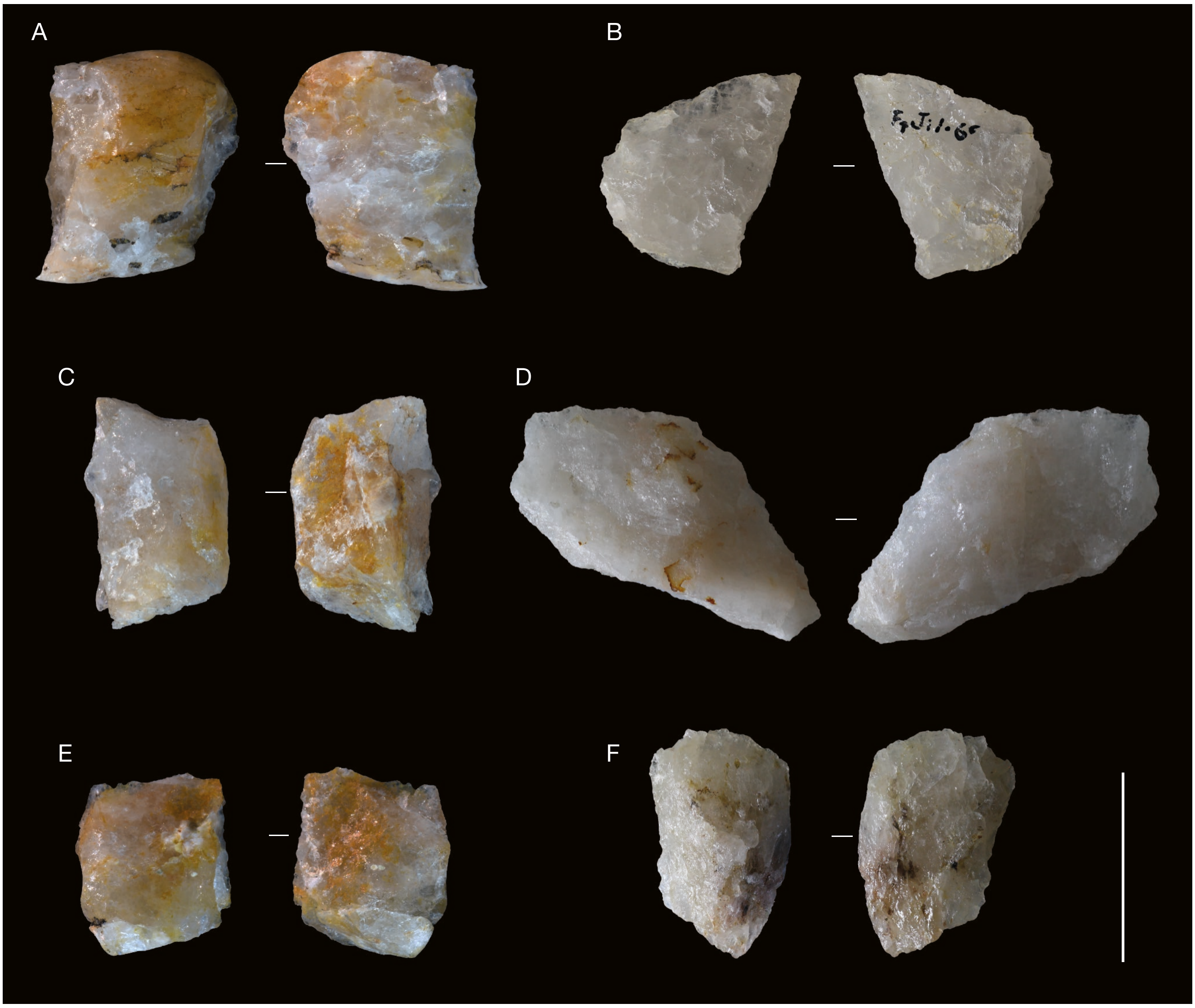


Fig. 7. — Photographs of artifacts used in the fluvial experiment (**A**, **C**, **E**) compared to archaeological artifacts coming from the three main depositional environments (**B**, **D**, **F**). Experimental artifacts: **A**, sand alteration, see Figure 7A, B; **C**, silt alteration, see Figure 8A, B; **E**, clay alteration, see Figure 9A, B. Archaeological artifacts: **B**, OMO A16, channel lag deposit, see Figure 10C; **D**, OMO A167, point bar deposit, see Figure 11C; **F**, OMO A13, floodplain deposit, see Figure 12B. Scale bar: 2 cm. Credits: Aline Galland.

Occurrences in proximal floodplain deposits

Macroscopically, artifacts are well preserved with a low proportion of heavy abrasion (Fig. 19, see SI) and a predominance of sharp edges (Fig. 19, see SI). However, differences in preservation between the proximal floodplain assemblages emerges at the microscopic scale. OMO A82 has the highest microfracturing rate of the entire corpus, with 64% of pieces showing a moderate to high amount of microfracturing. OMO A13 has 43% of pieces with moderate to high microfracturing, compared with 33% at OMO A2 (Fig. 19). These high microfracturing rates can be explained by the predominantly clayey matrix, which was subject to argiliturbation. This process of repeated seasonal swelling and shrinkage of the clays leads to compression of the sediments, which induces the formation of slickensides, and multi-decimeter or sometimes even multi-meter vertical cracks, into which the artifacts can fall (Duffield 1970; Eswaran & Cook 1988; Eswaran *et al.* 1999). Although all three occurrences are located in the same type of clay deposit, argiliturbation must have been more extensive at OMO A82, leading to greater alteration of the artifacts.

The assemblages found in clayey matrices show stronger and more heterogeneous alterations than those found in silty deposits. These alterations are characterized by extensive and continuous microfracturing affecting both the edges and the inner surfaces of the crystals (Fig. 14D, E, H), and strongly altering the microtopography. In clayey deposits, the microfracturing is only present in the upper parts of the microtopography in a coarse, irregular pattern, accompanied by rounding (Fig. 14B, C, F). This rounding can sometimes take the form of a shiny, smooth polish, which is exclusive to this type of sediment (Fig. 15B). Added to this are artifacts with preserved crystals (Fig. 14A), but edges affected by abrupt crushing (Fig. 14G).

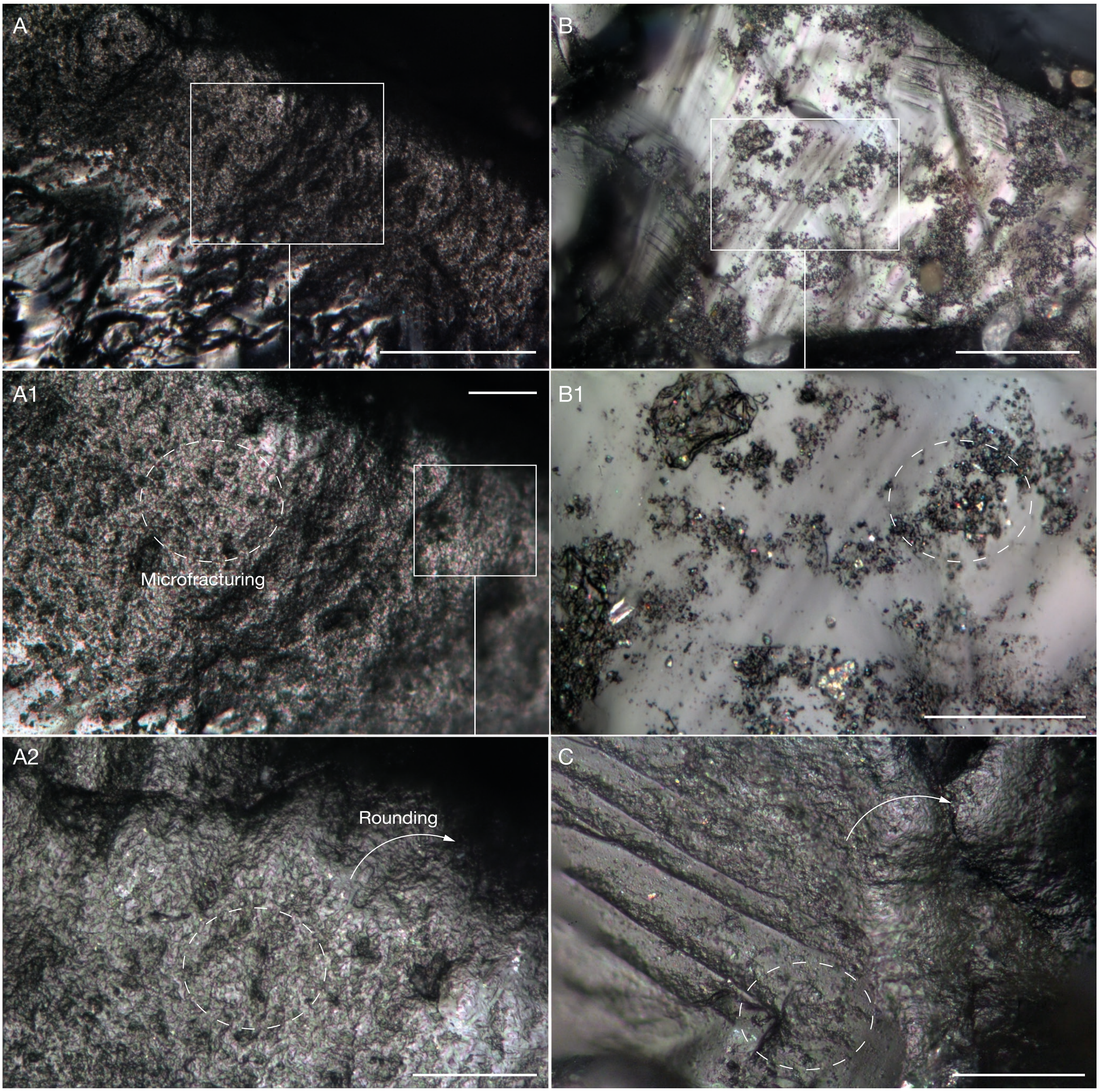


FIG. 8. — Experimental taphonomic wear on two artifacts after fluvial transport (72 h) in a sandy matrix from Member F: **A**-**A2**, show a rounded edge with continuous and pitted microfracturing; **B**, **B1**, scattered microfracturing on a crystal surface; **C**, rounding and microfracturing on the top part of the topography. Scale bars: A, 500 µm; A1-C, 100 µm. Credits: Aline Galland.

AEOLIAN EXPERIMENTS

The traces observed on the flakes were very different according to the duration of exposure to the particle jet. At 1 minute of exposure, the crystals showed no developed microfracturing, and identifiable traces resembled hourglass-shaped impact points on the crystal surface (Fig. 16C). However, after 5 minutes, the surface becomes unrecognizable, and the resultant heavy microfracturing over the entire surface made it impossible to identify the technological and functional characteristics of the flake (Fig. 16A, B).

Aeolian abrasion experiments do not produce wear similar to those found in the archaeological record. The isolated hourglass-shaped impacts produced after 1 minute of exposure are not observed in the archaeological material, and the severe microfracturing of experimental flakes subjected to long exposure has no equivalent in the archaeological record, even when compared to heavily weathered pieces (Figs 17; 18).

The microfracturing produced by aeolian abrasion is rough and continuous across the whole flake surface contrasting with the archaeological alterations which mostly show a generalized

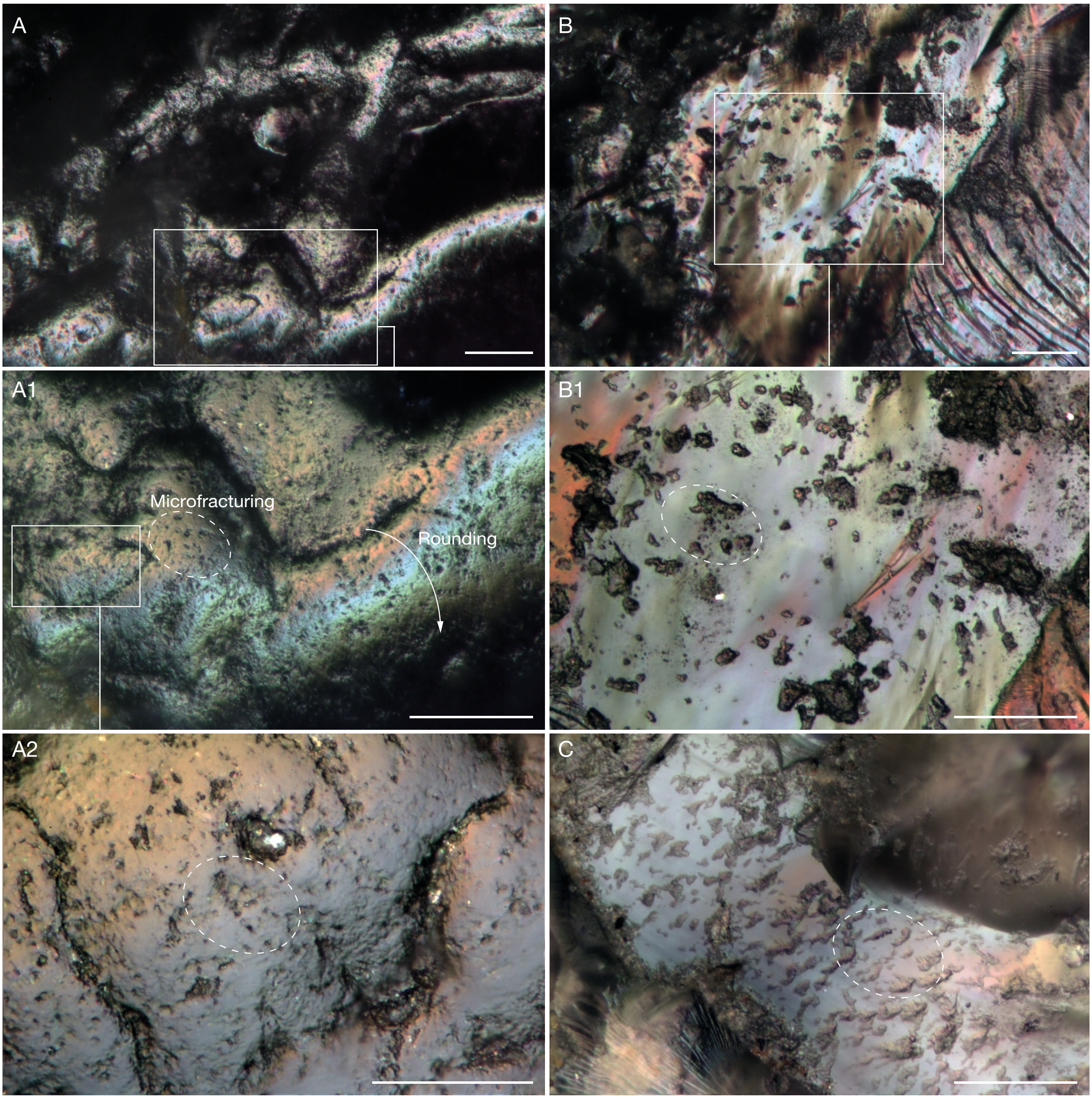


Fig. 9. — Experimental taphonomic wear on two artifacts after fluvial transport (100 h) in a silty matrix from Member F: **A**-**A2**, rounding and circular pitting corresponding to impact marks of the sediment grain; **B**-**C**, pitting of the crystal surface with no rounding. Scale bars: A, A1, B-C, 100 µm; A2, 50 µm. Credits: Aline Galland.

rounding with continuous microfracturing across the ridges and inner surfaces of the crystals.

Synthesis of the results

The taphonomic experiments produced five main results:

1. Fluvial experiments led to the formation of different types of microfracturing, depending on the grain size of the sediment. The coarser the sediment, the more continuous, wide and irregular the microfracturing. Conversely, the finer the sediment, the smaller, finer and more homogenous the microfracturing.
2. The presence of rounding and pitting is consistent in fluvial experiments, with no specific orientation, whatever the particle size of the sediment used.
3. The fluvial experiments using a very fine sediment created a developed, shiny and rounded polish.
4. The aeolian experiment had a very significant impact on the crystals in a very short space of time. The crystals are highly pitted, with no rounding or polish.
5. The fluvial and aeolian experiments carried out did not lead to the formation of striations on the artifact surfaces. From the five types of microwear found on quartz (scarring,

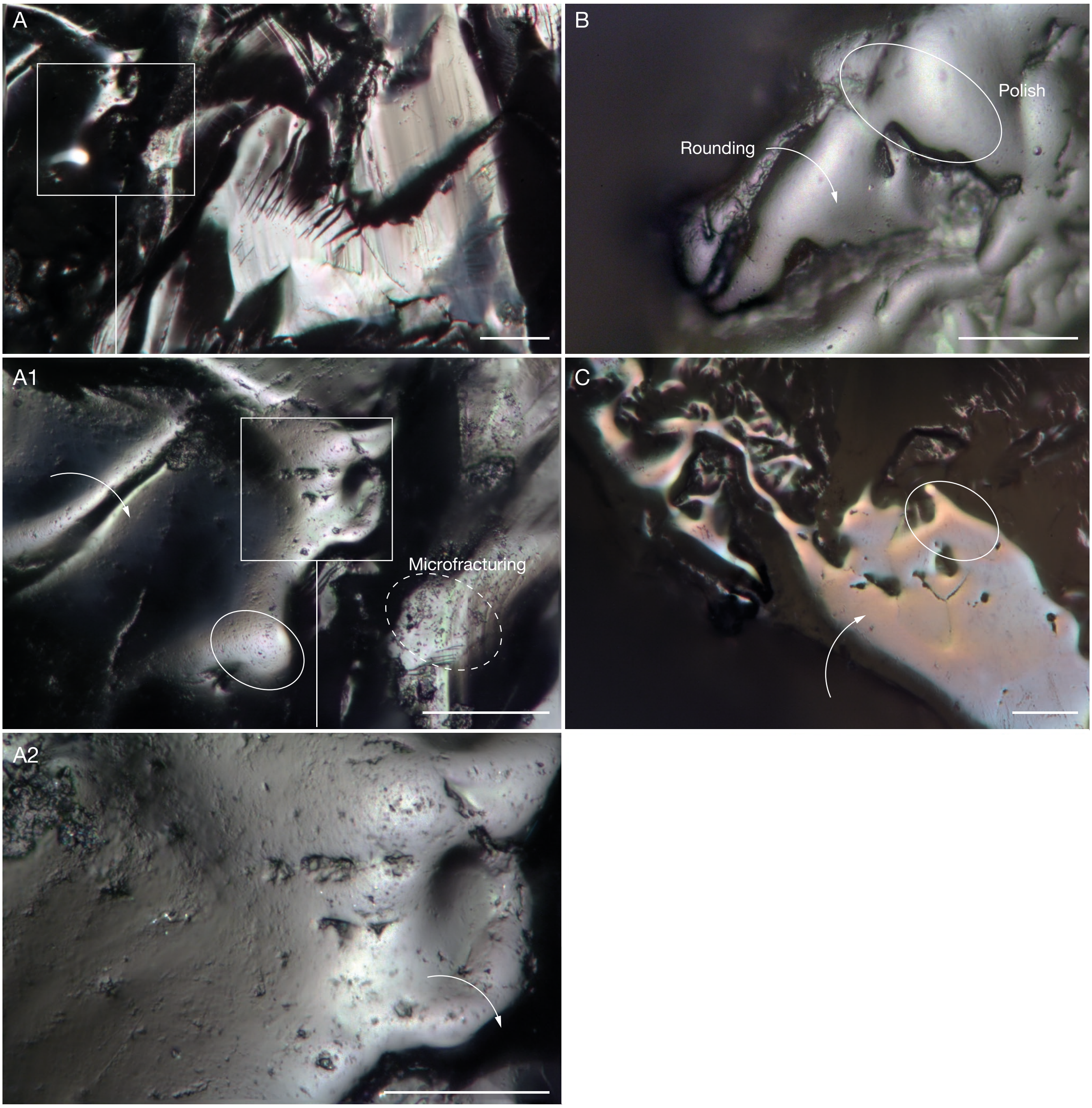


Fig. 10. — Experimental taphonomic wear on two artifacts after fluvial transport (100 h) in a clayey matrix from Member F: **A**-**A2**, developed rounding with scattered pitting; **B**, **C**, heavy rounding, smoothed and bright polish. Scale bars: A, A1, B, C, 100 µm; A2, 50 µm. Credits: Aline Galland.

rounding, microfracturing, polish, striations), striations are the only one absent from our observations. This element is significant in the characterization of use-wear as striations indicate the movement of the action.

To provide an overall comparison of the wear produced by these experiments and the depositional environment in archaeological contexts, a summary table (Table 2) lists the wear morphologies using a semi-quantitative scale that reflects their degree of development: (-) not observed or only present as very weak/highly localized traces, (+) present, (++) abundant, and (+++) very abundant. Striations are linear features on the surface, while scarring refers to small surface detachments. Rounding corresponds to the smoothing and attenuation of edges and microtopography. Polish denotes a smooth, reflective surface modification ranging from weak to well-developed. Microfracturing refers to very small cracks or micro-detachments with a characteristic fracture morphology.

The depositional environments produce specific microwear on the surface of artifacts. In channel lag deposits, the microscopic preservation is moderate (Fig. 19), with the presence of sandy sediment fluvial transport alteration as characterized in the experiments. The alteration observable on

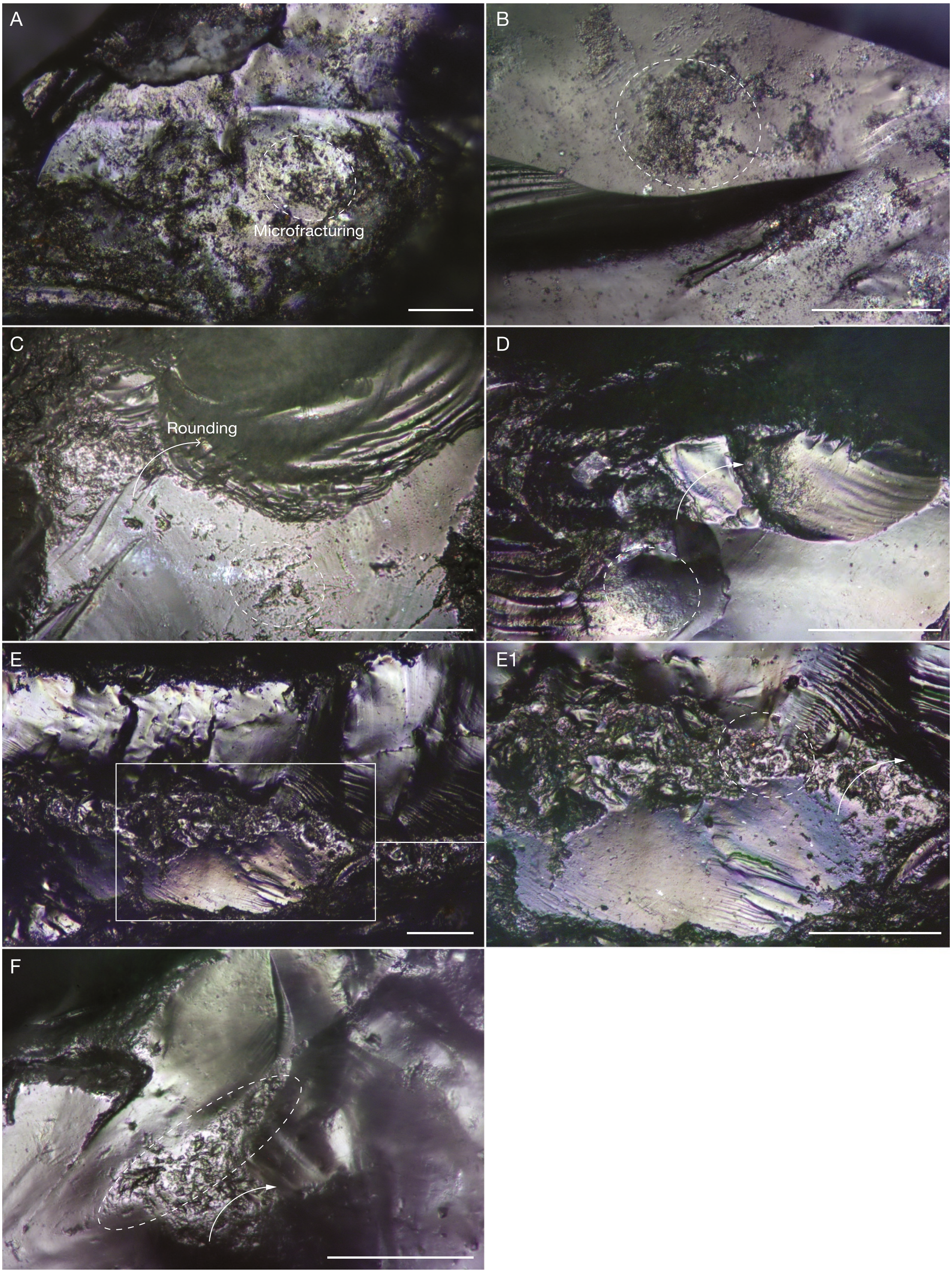


Fig. 11. — Taphonomic wear of archaeological artifacts in channel lag deposits: **A**, **B**, irregular microfracturing on the internal part of the crystals (OMO A16); **C**-**F**, the microfracturing is mainly localized on the top of the topography with light rounding of the ridges (**C**, OMO A42; **D**-**F**, OMO A17). Scale bars: 100 µm. Credits: Aline Galland.

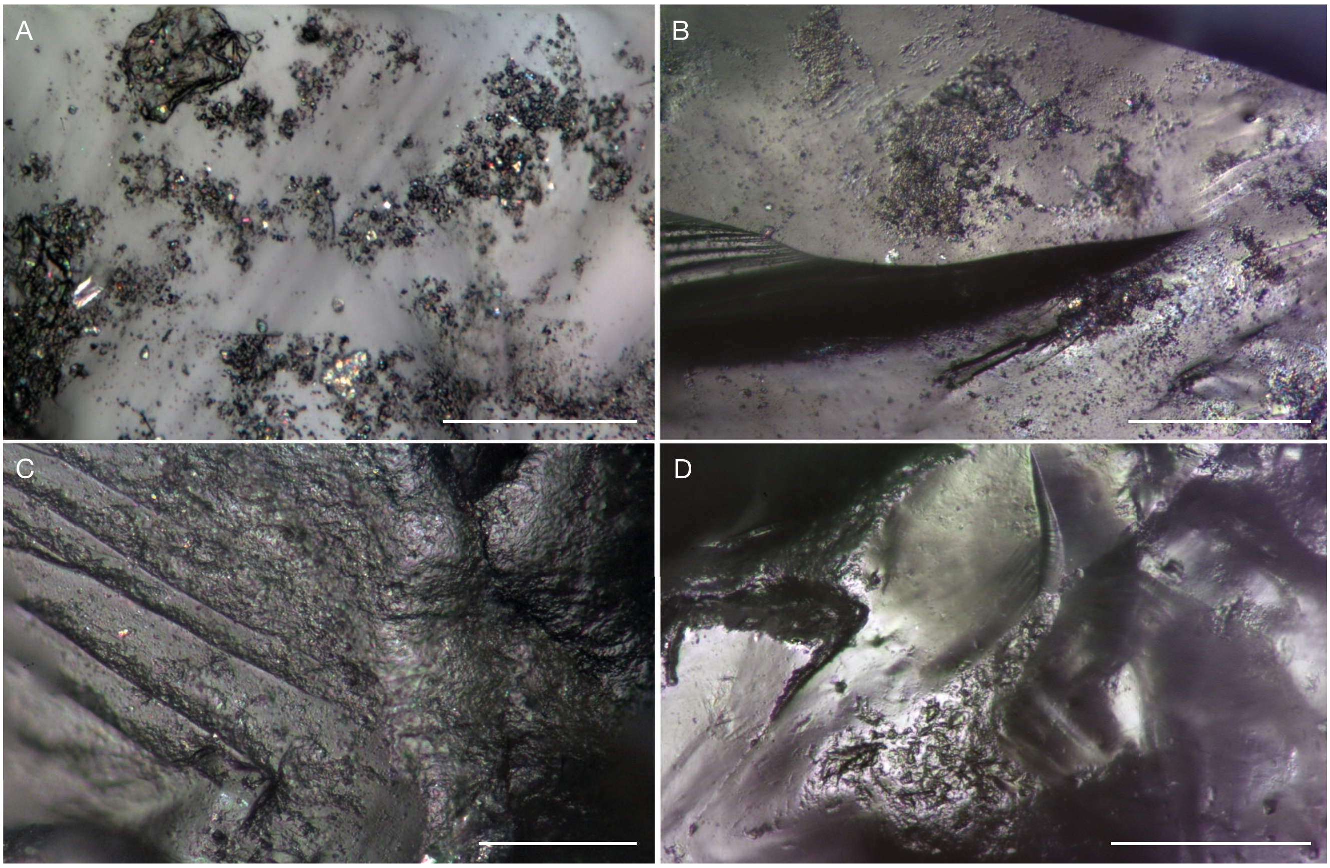


Fig. 12. — Comparison of wear produced by the fluvial transport experiment (**A** and **C**) and the wear present in the archaeological record from artifacts in channel lag deposits (**B** and **D**). Scale bars: 100 µm. Credits: Aline Galland.

Table 2. — Synthesis of taphonomic microwear types and their relative abundance, comparing experiments and the depositional environments in the archaeological record. The scale indicates the degree of development of each microwear category: (**-**) not observed or only present as highly localized traces, and relative abundance (**+**, present; **++**, abundant; **+++**, very abundant).

	Microwear				
Context	**Striation**	**Scarring**	**Rounding**	**Microfracturing**	**Polish**
Fluvial transport_Sand	-	+	+++	+++	-
Fluvial transport_Silt	-	-	+++	+++	-
Fluvial transport_Clay	-	-	+++	+	+++
Aeolian abrasion (1min)	-	+	-	-	-
Aeolian abrasion (5min)	-	++	-	+++	-
Channel lags	-	++	++	+++	-
Point bar	-	+	+	++	-
Floodplain	-	++	++	+++	++

the archaeological material is distributed on the whole piece with a light rounding of the ridges associated with a coarse and irregular pitting, sometimes in a circular shape (Fig. 11). The assemblages located in the silty sediments of point bar deposits are better preserved, as evidenced by low alteration at both macro- and microscopic scales (Fig. 19). The fracturing and rounding are present mostly on the micro-ridges and do not reach the internal surface of the quartz crystals. Finally, the lithic assemblages recovered from floodplain deposits, characterized by clayey sediments, have a heterogeneous preservation with a high degree of microfracturing and rounding of ridges (Figs 14; 19). This heterogeneity is not found at a macroscopic scale, as the artifacts mostly show little to no abrasion. One of the occurrences from the clayey deposit in a floodplain environment, OMO A82 stands out from the others because of its high level of taphonomic alteration (Fig. 19). Aeolian abrasion was not detected in the archaeological record. The taphonomic microwear related to these specific depositional environments show a tendency towards better preservation of archaeological material in point bar (i.e., silty sediments) deposits, compared to the preservation of material in floodplain and channel lag deposits.

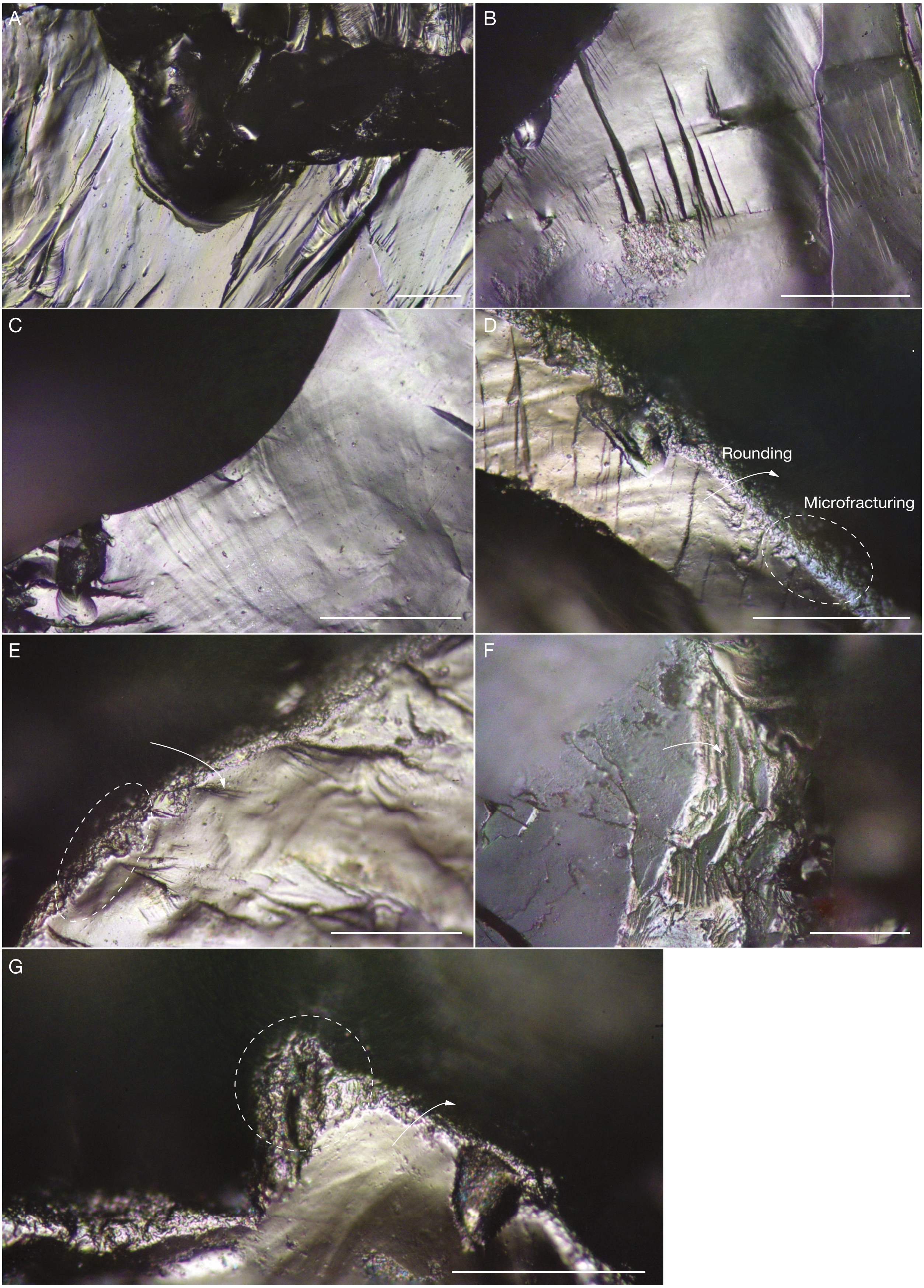


Fig. 13. — Taphonomic wear of archaeological artifacts in point bar deposits: **A**-**C**, sharp edges with unaltered crystals (**A**, OMO A43; **B**, **C**, OMO A167); **D**-**G**, microfracturing and rounding limited to the edges and the top of the topography (**D**, **E**, **G**, OMO A43; **F**, OMO A167). Scale bars: 100 µm. Credits: Aline Galland.

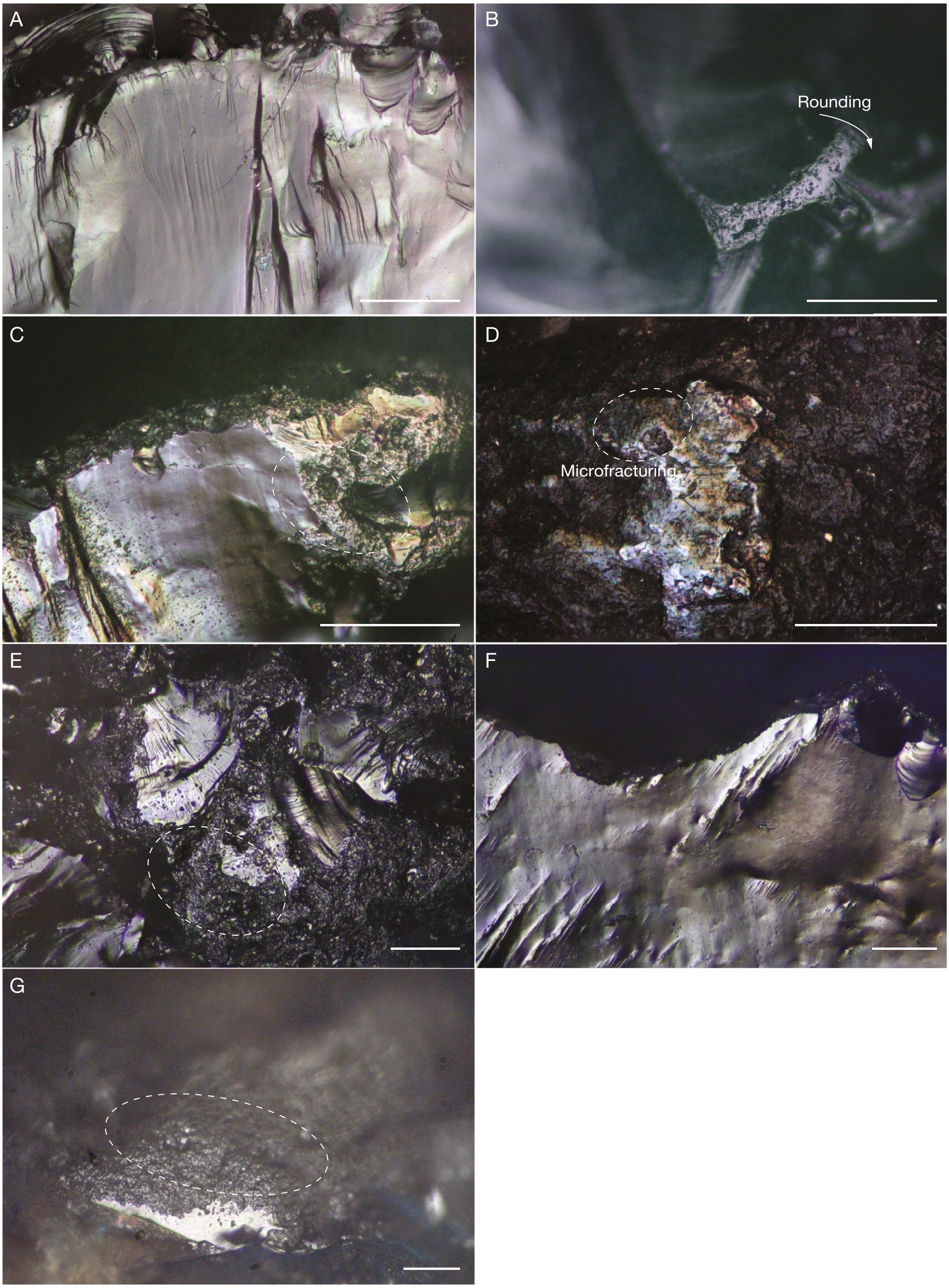


Fig. 14. — Taphonomic wear of archaeological artifacts in proximal floodplain deposits: **A**, OMO A2, unaltered crystal; **B**, OMO A13, heavy rounding, the center of the flake surface is almost polished, it is similar to the alteration resulting from the experiments using clay (see Figure 11); **C**, OMO A82; **F**, OMO A13, abrupt microfracturing of the edge, without reaching the internal surface of the crystal; **D**, **E** OMO A2; **G** OMO A13, heavy microfracturing, reaching the internal part of the crystals. Scale bars: 100 µm. Credits: Aline Galland.

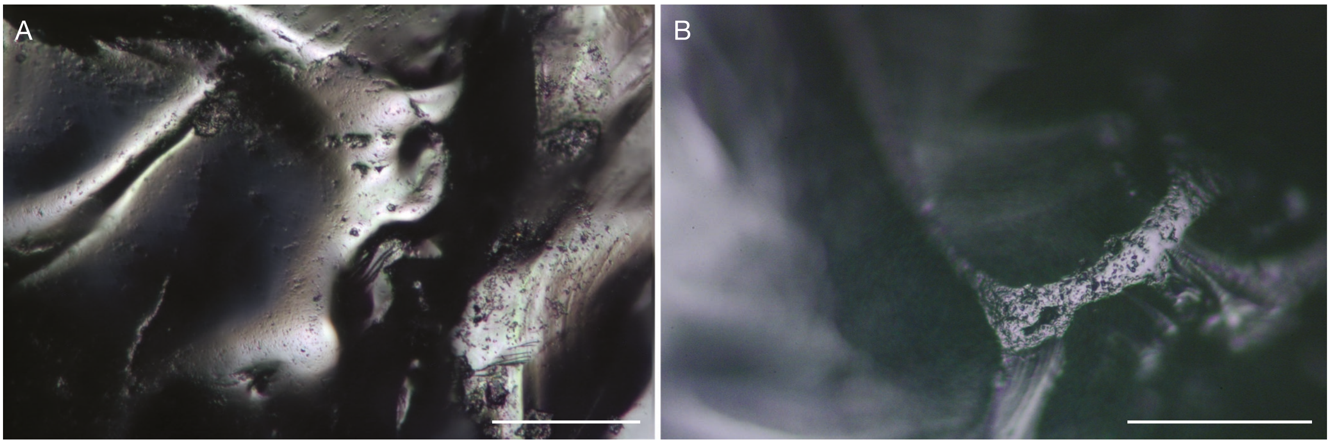


Fig. 15. — Comparison of wear produced by the fluvial transport experiment (**A**) and the wear in the archaeological record from artifacts in proximal flood-plain deposits (**B**): **A**, polish produced by fluvial transport in clay; **B**, taphonomic polish away from the cutting edge (OMO A13). Scale bars: 100 µm. Credits: Aline Galland.

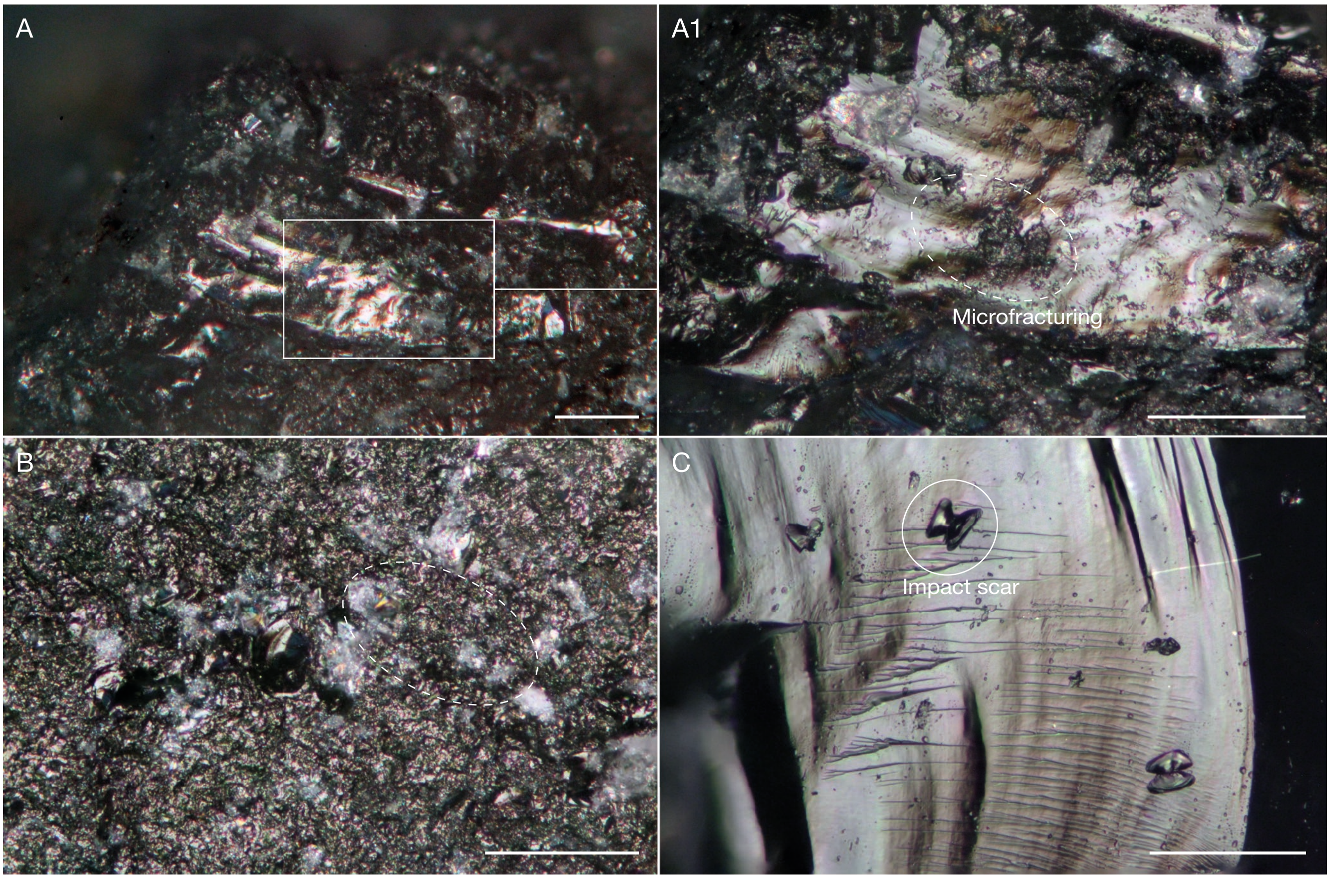


Fig. 16. — Experimental taphonomic wear from aeolian abrasion on three artifacts: **A** (A1 being a close-up of A), **B**, wear resulting from 5 minutes of aeolian abrasion. The surface is highly damaged by impacts, the original crystals are not preserved; **C**, wear resulting from 1 minute of aeolian abrasion. The surface is almost intact with minor traces of impact on the surface of crystals. Scale bars: 100 µm. Credits: Aline Galland.

However, this is context specific and should not be accepted as a diagnostic and universal feature for all archaeological sites that have this depositional history. In fact, channel lags and floodplain deposits can still be considered for use-wear analyses when the taphonomic microwear is well characterized. In this case, the microwear observed in the experiments can be considered as diagnostic for the archaeological material; for example, the presence of homogenous circular pitting, and rounding scattered on the whole surface of the artifact indicates fluvial transport in sandy sediments.

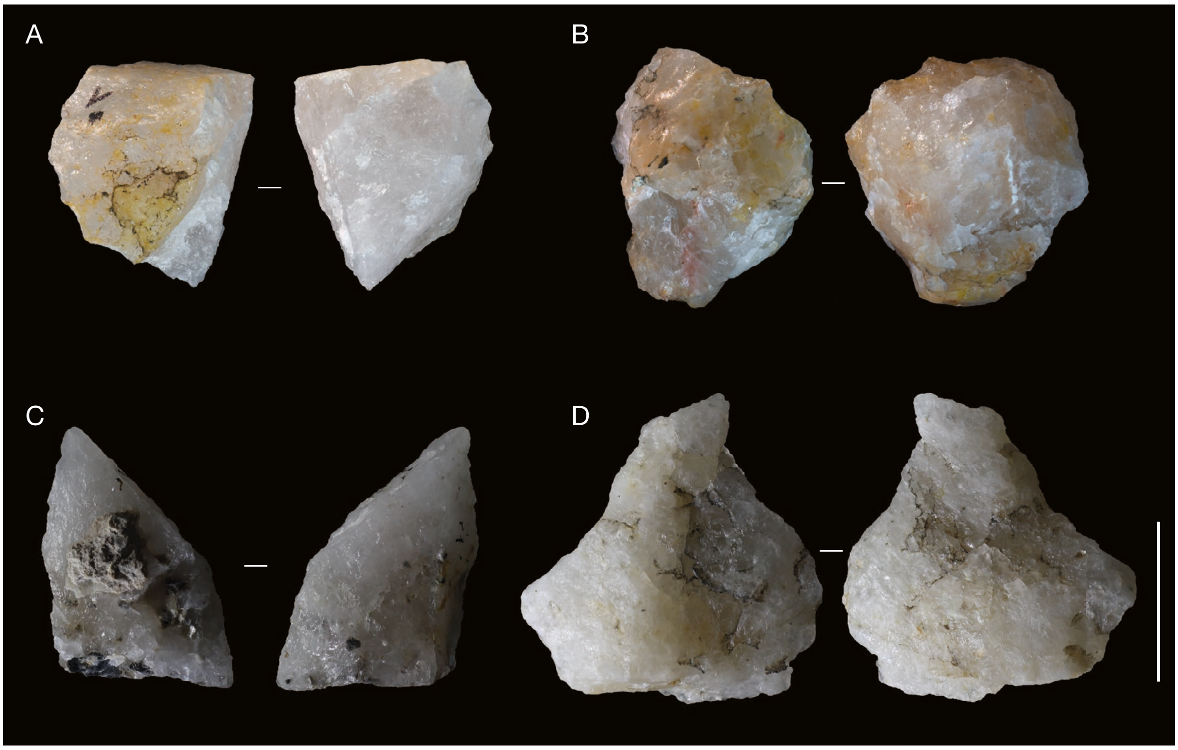


FIG. 17. — Photographs of artifacts used in the aeolian experiment (**A**, **B**) compared to altered archaeological artifacts from floodplain deposits (**C**, **D**). Experimental artifacts: **A**, aeolian alteration for 1 min, see Figure 16C; **B**, aeolian alteration for 5 min, see Figure 16A; **C**, archeological artifacts: OMO A2, see Figure 18B; **D**, OMO A13, see Figure 18D. Scale bar: 2 cm. Credits: Aline Galland.

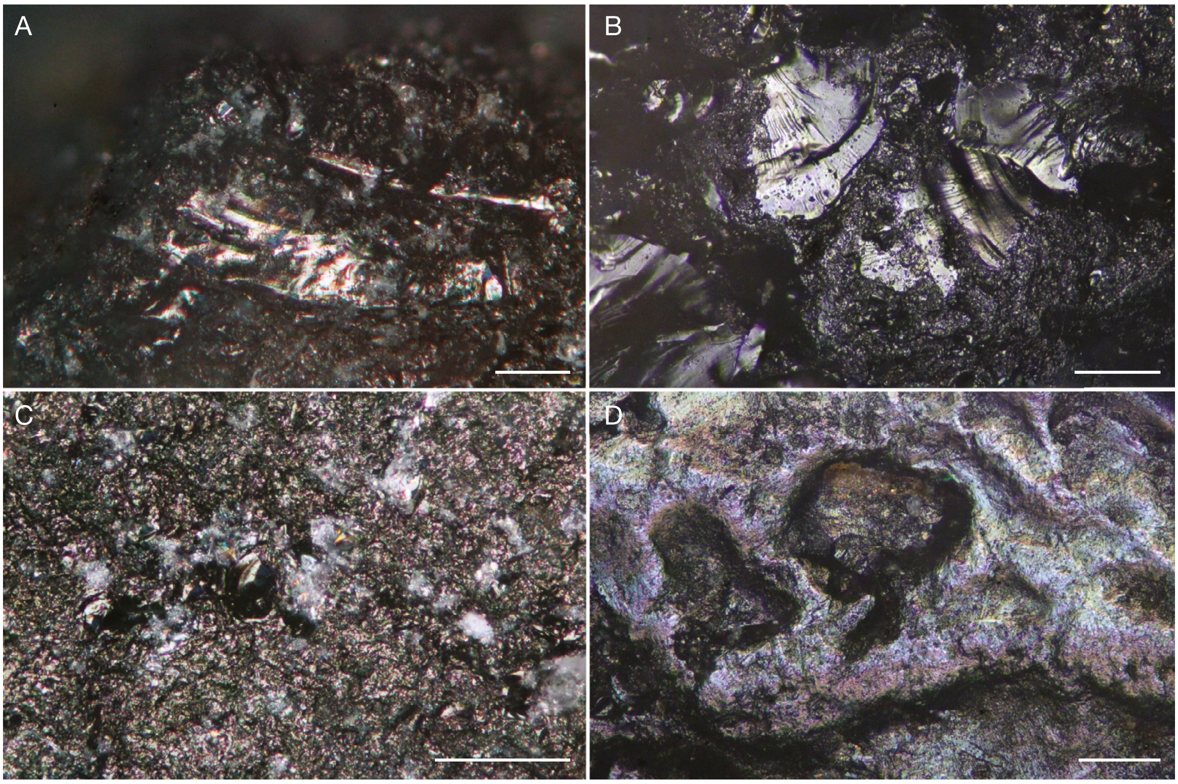


FIG. 18. — Comparison of wear produced by the aeolian abrasion experiment (**A** and **C**) and the wear seen in the archaeological record on heavily altered artifacts (**B** and **D**): **A**, **C**, quartz flake surfaces after 5 minutes of aeolian abrasion; **B**, heavy alteration in a floodplain deposit (OMO A2); **D**, heavy alteration with rounding in a floodplain deposit (OMO A13). Scale bars: 100 µm. Credits: Aline Galland.

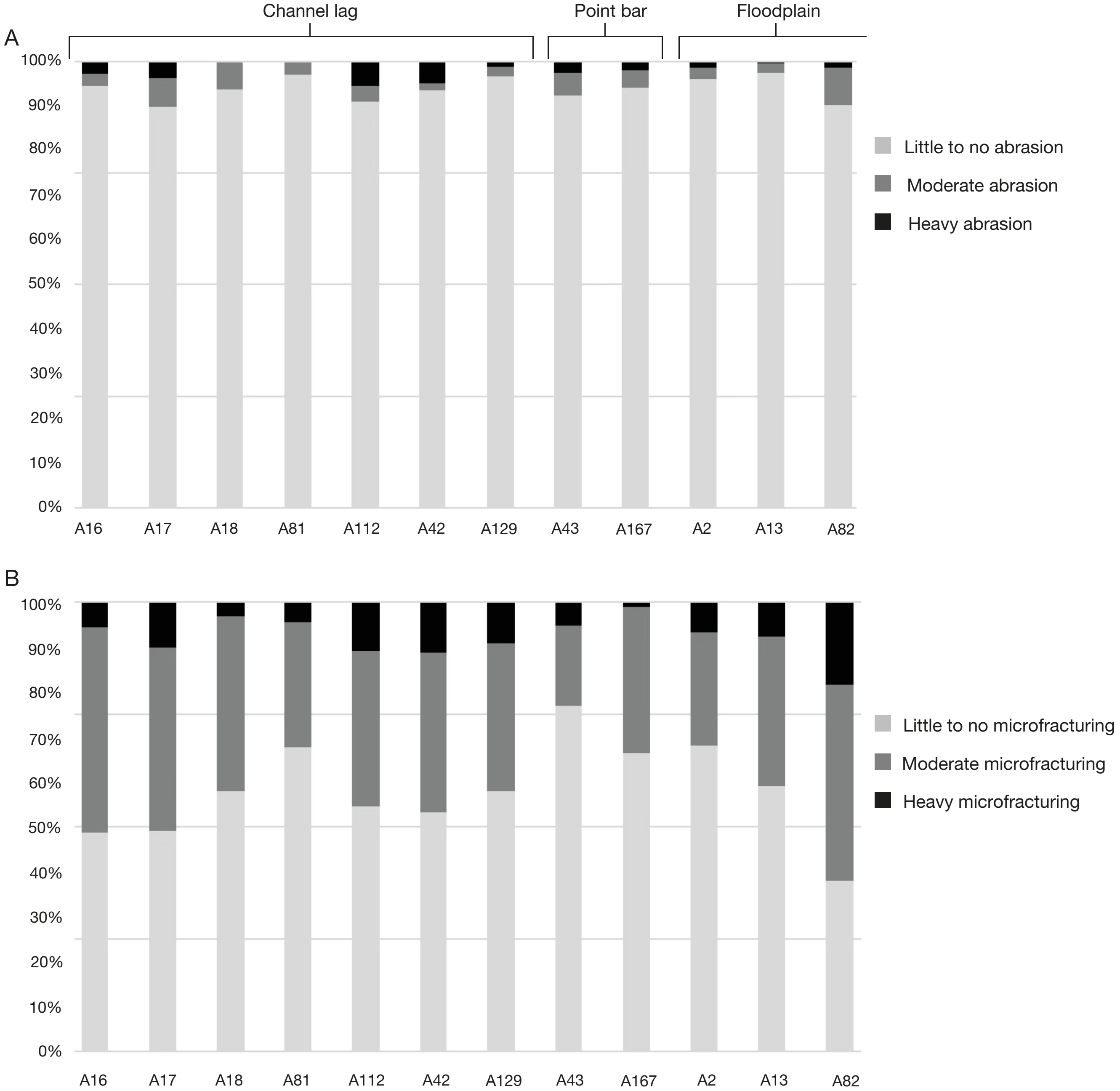


FIG. 19. — Cumulative histograms of alterations at macroscopic (**A**) and microscopic (**B**) scales for each of the selected occurrences according to their depositional environments. Detailed table of the artifacts in Supplementary information.

DISCUSSION

This work emphasizes the significance of taphonomic experiments in comprehending the preservation of lithic assemblages, at both macro- and microscopic scales, in relation to their depositional environments. Quartz is known for their resistance to physical and chemical alteration (Boudeulle *et al.* 1979; Baesemann 1986; Knutsson 1988a; Caruana *et al.* 2014), unlike volcanic rocks and cherts, which are often not well-preserved enough for functional analysis in Oldowan contexts (Beyries 1993). The material hardness, rated at 7 on the Mohs scale, is comparable to chert. However, unlike chert, quartz materials are not affected by the various patinas that often develop on it (Ollé *et al.* 2016). Although more resistant and chemically stable, quartz materials are subject to specific types of fracturing and abrasion (Knutsson 1988a; Tallavaara *et al.* 2010; Venditti *et al.* 2016). The identification of alteration traces on quartz is crucial in distinguishing between anthropic and taphonomic traces (Knutsson & Lindé 1990; Venditti *et al.* 2016). Therefore, conducting taphonomic experiments is essential to gain a better understanding of these traces and their characteristics.

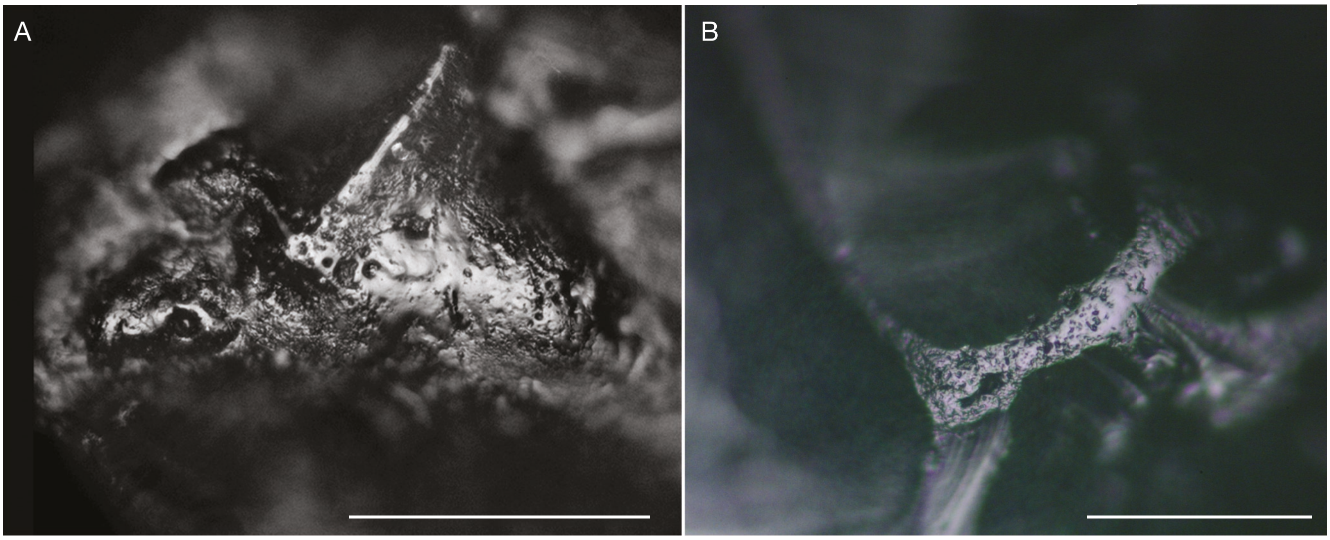


Fig. 20. — Microscopic illustrations of polish from experimental and taphonomic contexts: **A**, scraping *Daucus carota* L. during 60 min, intensive undulating and smooth polish (modified from Bello-Alonso *et al.* 2019); **B**, artifact from a floodplain deposit at OMO A13, taphonomic polish away from the cutting edge. Scale bars: A, 200 µm; B, 100 µm. Credits: A, Bello-Alonso *et al.* 2019; B, Aline Galland.

Our results echo pioneering taphonomic experiments such as those conducted by Schick (1986), who demonstrated that water flow can cause substantial physical modification to lithic surfaces, including edge rounding, surface smoothing, and abrasion wear that vary depending on sediment load and transport energy. Her work highlighted the complexity of interpreting lithic surface modifications in fluvial contexts and emphasized the importance of characterizing taphonomic modifications. This experimental work highlights new microscopic criteria for the discrimination between taphonomic and anthropogenic use-wear in quartz materials. Usually, the microscopic taphonomic alterations are characterized by the randomness of their location and orientation on the artifact surfaces and edges which has been mentioned before for other raw materials (Levi Sala 1986; Márquez *et al.* 2001; Burroni *et al.* 2002; Asryan *et al.* 2014; Berruti & Arzarello 2020). In the context of the paleo-Omo meandering river, our observations could serve as a baseline for other African contexts in similar environments. The lack of striations evidenced in fluvial transport and aeolian abrasion is a significant criterion to differentiate taphonomic wear from use. Striations are a key element to identify the direction of movements during anthropic activities and this observation opens promising perspectives for forthcoming functional analyses. The main wear produced by fluvial transport is rounding and pitting of the crystal ridges and surfaces induced by movement of water and impact of sediment grains. In addition, a word of caution is necessary when identifying polish, as fluvial transport in clay may produce polishes that are morphologically comparable to those described for the processing of fresh plants and tubers (Fig. 20) (Bello-Alonso *et al.* 2019). Our observation suggest that similar microscopic wear may arise through distinct processes. Making this distinction is facilitated by analysis of wear location and organization in relation to other alterations on the whole surface of quartz artifacts.

In the context of the aeolian experiment, the nature and granulometry of the abrasive material may influence the identification of surface alterations. Although aeolian wear may have been overprinted by subsequent water transport prior to the burial of the artifacts, the predefined characteristics of the abrasive used in our experiment may have influenced the observed results. Future research could explore the potential to distinguish between alterations caused by different types of wind-transported abrasives. This opens new experimental avenues for refining our understanding of aeolian modification processes.

Each depositional environment has a particular impact on artifact preservation. The channel lag deposits dominated by sand produced moderate alterations to artifact surfaces, which can be explained by a low energy and/or short fluvial transport duration. Point bar deposits, dominated by silt, best preserve the assemblages and artifact surfaces, whereas artifacts in floodplain deposits, composed mainly of clay, have the worst preservation at the microscopic scale. This high level of alteration can seem paradoxical when considering their primary context (the same for the three proximal floodplain occurrences); *in situ* and in a fine-grained clayey matrix. This unfavorable preservation is caused by argiliturbation (Duffield 1970; Eswaran & Cook 1988; Eswaran *et al.* 1999) where compression and the gravitational movements undergone by artifacts have played a major role in creating post-depositional alterations. The presupposition that artifacts would be better suited for use-wear analysis within fine sediments does not hold in this type of context, even if size sorting analysis shows that small debris were not washed away and that macroscopic edge damage is low (Maurin *et al.* 2017). In contrast, occurrences in a secondary context in coarse sediments may present good preservation conditions for functional analyses because this taphonomic microwear is clearly identifiable. The secondary context of these artifacts, while having a more complex taphonomic history, is not a hindrance to a good understanding of hominin tool-assisted activities (Chu 2013), and brings complementary data to the primary contexts of the Shungura Formation. This is particularly important to consider as most of the archaeological occurrences in Member F are located in secondary contexts. In addition, the fact that quartz represents more than 95% of the assemblages (Delagnes *et al.* 2011) is another favorable factor in the preservation of use-wear in coarse-grained sediments as this raw material is more resistant to alterations. These observations also open interesting new research possibilities as the eastern African Early-Middle Pleistocene is dominated by archeological settings in fluviatile deposits (e.g., Asfaw *et al.* 1992; Barsky *et al.* 2011; Gallotti & Mussi 2018; Semaw *et al.* 2018; Hovers *et al.* 2021).

CONCLUSION

The identification of traces of functional use-wear on the cutting edges of flakes relies on the necessary characterization of taphonomic wear prior to functional analysis. This work therefore focuses on setting up taphonomic experiments, enabling us to determine the preservation of lithic assemblages in relation to different depositional environments within alluvial plain settings, like those observed in the Shungura Formation (Member F). We were thus able to confirm that each sediment type produces characteristic wear that can be differentiated from one another and distinguished from anthropogenic use-wear, which will be the focus of a future publication. Point bar deposits best preserve artifact surfaces, as opposed to channel lags and floodplain deposits. The methodological added-value of characterizing taphonomic traces could be further enhanced by additional experiments coupled with in-depth characterization of the traces observed, in particular for the impact of movements undergone by artifacts in clay deposits, which have yet to be analyzed using a dedicated experimental protocol. This could be accompanied by quantified characterization using confocal microscopy, whose potential has already been demonstrated for flint (Evans & Donahue 2008; Ibáñez *et al.* 2016, 2014; Caux *et al.* 2018; Galland *et al.* 2019; Borel *et al.* 2021) and looks promising for quartz (Itamiya *et al.* 2021). The analysis of taphonomic signatures associated with various depositional environments shows that the age of Oldowan assemblages does not restrict the applicability of functional analyses to quartz materials.

Supplementary information

The Supplementary information detailing the attributes of artifacts for each occurrence is available online at: https://doi.org/10.5281/zenodo.11204868

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Authors contributions

A.G., A.D. and J.-R.B. led field research and new specimen acquisition, A.D. and I.C.-C. participated to the conceptualization and supervision of the study; A.D. and A.G. participated to data curation; A.G. performed the analysis, methodology and acquired all data presented in the manuscript; A.D. and J-R.B. participated to funding acquisition; A.G. wrote the original draft of the manuscript with comments and revisions from I.C.-C., A.D., and J.-R.B.

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