

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Aurignacian grinding stone from Surein I (Crimea): “trace-ing” the roots of starch-based diet

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1827719> since 2021-12-22T20:12:05Z

Published version:

DOI:10.1016/j.jasrep.2021.102999

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

1 Aurignacian Grinding Stone from Surein I (Crimea): "trace-ing" the 2 roots of starch-based diet

3 ^{a,b,c,*}Laura Longo, ^dNatalia N. Skakun, ^eIrina E. Pantyukhina, ^fVera V. Terekhina, ^{g,h,*}Giusi Sorrentino

4 ^a DAIS, Ca' Foscari University, Venice, Italy, Campus Scientifico, Via Torino 155, 30170, Venezia-
5 Mestre, e-mail: laura.longo@unive.it; <https://orcid.org/0000-0001-6562-3047>

6 ^b DiSTABIF, Università degli Studi della Campania "Luigi Vanvitelli", Caserta, Italy, iCONA Lab, Via
7 Vivaldi, 43 - 81100 Caserta, e-mail: gstlongo@gmail.com.

8 ^c Nanyang Technological University, NTU, Singapore; ADM School, 81 Nanyang Drive, 637458,
9 Singapore ^d Institute for the History of Material Culture of the Russian Academy of Sciences (IHMC
10 RAS), 191086, Russia, St. Petersburg, Palace Embankment, 18, e-mail: skakunnatalia@yandex.ru;
11 <https://orcid.org/0000-0003-0579-3022>

12 ^e Institute of History, Archaeology and Ethnology of the Peoples of the Far-East, Far-Eastern Branch of
13 the Russian Academy of Sciences (IHAE FEBRAS), 690089, Russia, Vladivostok, 89 Pushkinskaya
14 street, e-mail: pantukhina2000@mail.ru; <https://orcid.org/0000-0001-6206-5799>

15 ^f Peter the Great Museum of Anthropology and Ethnography (Kunstkamera) of the Russian Academy
16 of Sciences (MAE RAS), 199034, Russia, St. Petersburg, University Embankment, 3, e-mail:
17 terehinavera@mail.ru; <https://orcid.org/0000-0002-7065-8284>

18 ^g Dipartimento di Fisica, Università di Torino, Via Pietro Giuria 1, 10125, Torino, Italy;
19 giusi.sorrentino@unito.it <https://orcid.org/0000-0001-6500-7439>

20 ^h Science and Technology in Archaeology and Culture Research Center - The Cyprus Institute, 20
21 Konstantinou Kavafi Street, 2121 Aglantzia, Nicosia, Cyprus

22 *Corresponding Authors:

23 Laura Longo, laura.longo@unive.it

24 Giusi Sorrentino, giusi.sorrentino@unito.it

25 Abstract

26 This study is applied to the unique grinding stone from Surein I retrieved in the Aurignacian
27 layers of the rockshelter located in the south of the Crimea Peninsula. Our research enables
28 us (i) to make reliable inference on the agency establishing the functional modification on the
29 surface of the Surein I grinding stone, (ii) to demonstrate this grinding stone served as steady
30 surface (Face A) to mechanically process plant material including roots and tubers (under
31 surface storage organs, USOs) and (iii) to set a chrono-cultural framework for starchy plant
32 tenderization, also responding to key issues relating to the dietary breadth of early waves of
33 *Homo sapiens* at the northern latitudes. We present a pilot research design which integrates
34 data derived from macro and micro-scales techniques, by coupling use-wear traces analysis
35 and use-related starch granules observation. The multi-scale approach allows distinctive
36 resolutions for surface texture analysis thanks to the combined use of stereo, metallographic
37 and digital microscopes; whereas transmitted and polarized light microscopes were used to
38 observe use-related biogenic residues (U-RBR), namely starch granules, and SEM provided
39 resolution down to the nano-scale. Our data suggest that *Homo sapiens* was exploiting the
40 rich environment of the Pontic steppe-grassland since its earliest presence in south-eastern
41 Europe by processing starchy plants to obtain calorific food. Moreover, this study brings fresh
42 lines of evidence to the broadening of dietary strategies during late MIS 3 (40-25 ka calBP) by

43 analysing ground stones from the poorly investigated non-flaked industry, and opens new
44 scenarios for the reasoning on *Homo sapiens* successful colonization of Eurasia.

45 **Keywords:** Wear-traces, Microscopy, Resolution, Methodological refinement, Use-Related
46 Biogenic Residues (U-RBR), Starch

47 **Highlights**

- 48 ● Methodological refinement for functional analysis of Palaeolithic ground stones
- 49 ● Optical light and scanning electron microscopy applied for surface texture and starch
50 analysis
- 51 ● Mapping of the functional related features
- 52 ● Surein I (Crimea) is the oldest direct evidence of grinding stone used to process USOs
- 53 ● *Homo sapiens* dietary flexibility and adaptation to Pontic steppe plant resources

54 **1. Introduction**

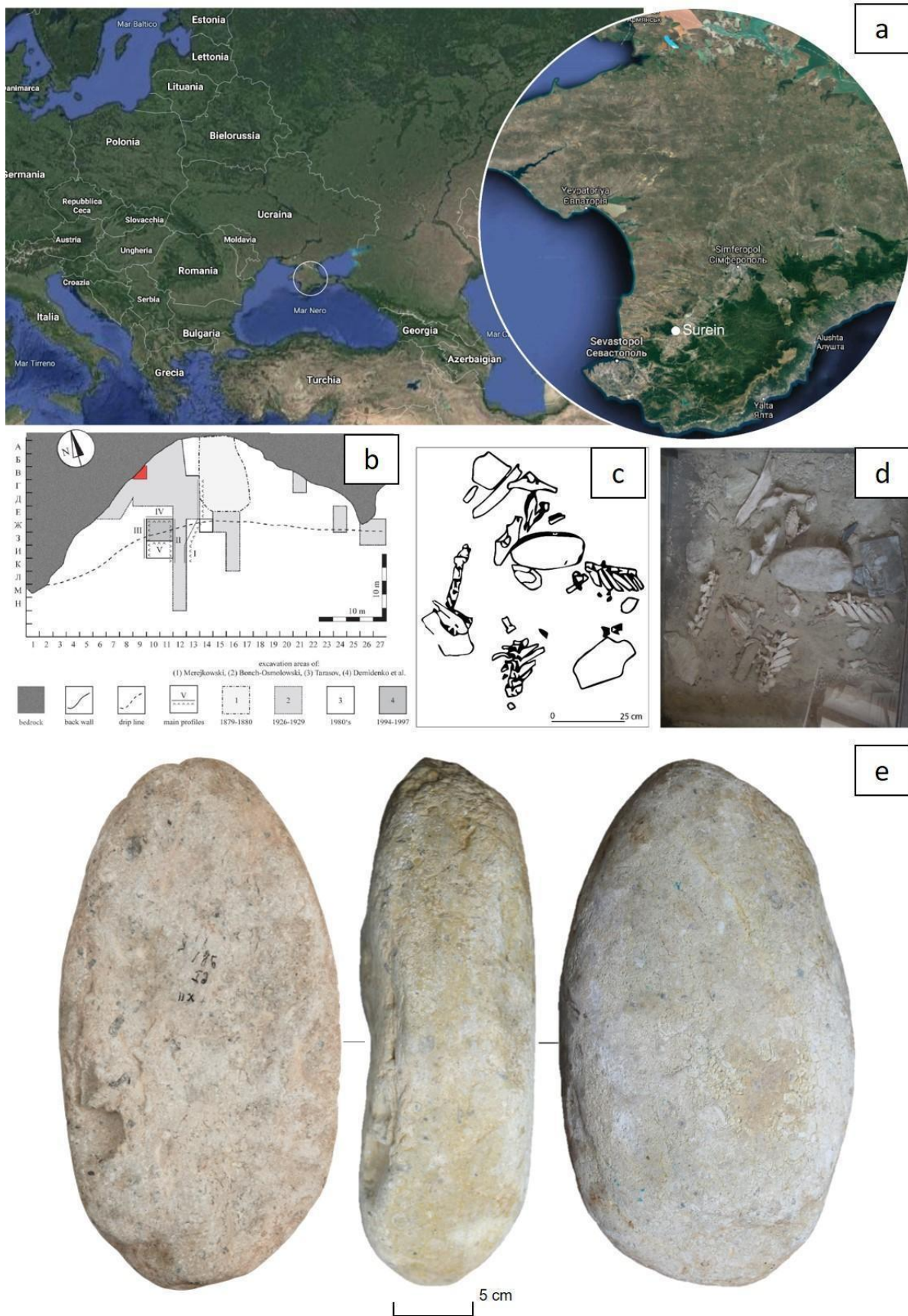
55 Within the broad assemblage of non-flaked industry, Palaeolithic ground stones
56 represent an under investigated source of data on different materials' transformation among
57 which plants, listed in the perishable edibles, are highly informative to reconstruct dietary
58 strategies. The term ground stones (macrolithic tools) is comprehensive of a multitude of stone
59 objects '*which were manufactured and/or used according to motions*' (Dubreuil et al. 2015 p.
60 106). In the case of Early Upper Palaeolithic items, we are referring to those '*not altered from*
61 *their natural rock shape*' (Adams, 2014 p. 15) used in both passive and active motions (Ebeling
62 and Rowan 2004, p. 108), such as lower steady grinding stone (i.e. Surein I presented here)
63 and movable items as pestles as we already applied in our previous work on Gravettian: the
64 terms grinding stone and pestles were used with reference to grinding and pounding activities
65 before crop domestication (Longo et al., 2018; Revedin et al., 2010; 2015). The present
66 research focuses on a task-specific tool used to mechanically transform plant starch-rich
67 storage organs (PSRSO) during early Upper Palaeolithic, when seedy cereals - to which
68 processing is referred most of the literature - were unlikely to be available. We evaluated that
69 wear-traces and starch granules extracted from ground stones may provide reliable
70 information about plant foraging and the mechanical processing aimed specifically at starch
71 extraction from the under and above surface storage organs (USOs and ASOs, Longo, 2016;
72 Longo et al., 2018; Revedin et al., 2010; 2015). We are fully aware that PSRSO processing
73 cannot be considered only as a technological/cultural phenomenon as it is intimately
74 connected with other biological and behavioural adaptations (Butterworth et al., 2016; Perry
75 et al., 2015; Longo, 2016), determining interactions that require complex yet careful analysis:
76 a challenge that goes beyond the scope of this work (Longo, 2016; Longo et al., 2020a). Here,
77 our main objective is to present the methodological refinements implemented in order to

78 investigate a large slab from Surein I (Crimea), aiming to locate and directly relate the active
79 surface of the ground stone with the adhering starch granules, by ensuring the provenience of
80 the U-RBR from the intentionally used areas across the large steady stone. This was obtained
81 by sampling the residues directly from the stone and also from the mold that revealed the deep
82 peel-off effect (see 3.5, 3.6 Fig. 9), a procedure that, to the authors knowledge, represent an
83 original contribution to both functional and residues analysis. An attempt to identify the
84 functionally active areas was already performed by roughness analysis on the 3D model (Next
85 Engine, Longo et al. 2018). Moreover, the mapping of the wear-traces provided insights for
86 the spatial distribution of the utilized areas and the main direction of use.

87 The project "*Unfolding the complexity of nutrition at the dawn of modern humans in*
88 *Eurasia*" started in 2016 (L.L. SUG, Singapore), already surveyed and sampled twenty sites
89 dating back to Late Pleistocene - Initial/Early Upper Palaeolithic (EUP) and Upper Palaeolithic
90 (UP), spanning western Eurasia to Central Asia (from Moldova to Crimea, to the Don river
91 reaching the Altai Mountains, in Siberia). Our data disclosed the processing of PSRSO by
92 means of ground stones since around 40 ka, possibly starting with the very early waves of
93 *Homo sapiens* venturing out of Africa towards boreal western Eurasia.

94 The experience acquired during our previous studies on palaeolithic ground stones supports
95 the development of a multistep analysis at macro and micro scale for the surface texture
96 modifications of the limestone slab, and down to the nanoscale for the starch granules (1-100
97 μm). Although surface texture is difficult to define, among tribological studies there is a general
98 agreement in considering it as the "*the features of surface relief*" (Myshkin and Grigoriev,
99 2013). Texture analysis of the grinding stone from Surein I displayed evidence of man-induced
100 surface modification, allowing to interpret its possible uses, amongst which the very likely
101 processing of PSRSO.

102 Our new procedures have proved to be useful to acquire relevant data supporting strong
103 evidence of plant processing in the Pontic steppe since the Aurignacian. Here, we present the
104 pilot study on the grinding stone from the Aurignacian layer 3, the lowermost according to
105 1926-29 excavation carried out by G. A. Bonch-Osmolovsky at Surein I rockshelter (Crimea)
106 (Fig. 1a-b). The Crimea peninsula is recognized for the richness of its Late Middle/and Early
107 Upper Palaeolithic record represented by both behavioural and biological remains referable to
108 Neandertal man (Kiik Koba, Ak-Kaya, Zaskalnaya VI, Stepanchuk et al., 2017) and to *Homo*
109 *sapiens* (Buran Kaya III burials, Pratt et al., 2011, and a molar tooth from Surein I unfortunately
110 lost as reported in Chabai et al., 2004, p. 56). The two species lived in the same environment,
111 therefore were exposed to the same range of available food sources, although isotopic data
112 support a diversified access to food sources by the two species (Drucker et al., 2017).



113
114
115
116

Fig. 1. a) The Surein I rockshelter is located on the southern rim of the Crimea Peninsula (Pontic Steppe); b) Map of Surein I rockshelter (modified from Bataille, 2016, Fig. 3: 53). In red, square 9B where the grinding stone was found; c) Drawing of the “structure” retrieved in square 9B, where the grinding stone is reported according to E.A.

117 *Vekilova (1957) in Fig. 34: 307; d) the restaging at MAE RAS, St. Petersburg (photo L. Longo, June 1991). The*
118 *exhibit is based on the information published by Vekilova. Surein I grinding stone is clearly visible with the water-*
119 *weathered dorsal face exposed, surrounded by fauna remains still in anatomic connection. In plain black, flint*
120 *artefacts; e) Surein I grinding stone: left, the unused surface (Face B); middle, the side; right, the coarse used*
121 *surface (Face A).*

122 Until recently, the study of the lithic assemblages mainly revolved around very detailed
123 analysis of the flaked industry. Despite the numerous efforts based on this approach, the study
124 of the material culture failed to clarify the conundrum of the so-called “transitional industry”
125 and to pinpoint the actual dwellers of the EUP layers that have not, as yet, been identified
126 unequivocally (Bataille et al., 2016, p. 53; Demidenko, 2014a).

127 The study of the Palaeolithic non-flaked industry might bring new and unexplored
128 information regarding the dietary habits of the hominins roaming in the refugia of Crimean
129 Peninsula around 40,000 years ago. The analysis of the grinding stone involved a
130 methodological refinement which includes the use of different resolution microscopes such as
131 stereomicroscope, reflected and transmitted light (IHMC, RAS), digital microscopy (hereon
132 DM) and electron scanning microscope, SEM, covering wear-traces and U-RBR, namely
133 starch grains. Bulky macro tools are difficult to examine under the standard structural designs
134 of most conventional light microscopes. We decided to use digital microscopes (Hirox and
135 Keyence) to scan large experimental stones, molds and araldite positives. Starch analysis was
136 then carried out according to established procedures at IHAЕ FEBRAS (Vladivostok) using
137 transmitted and polarized light and under SEM. We are confident that the methodological and
138 technological refinements applied to the study of Surein I grinding stone have enabled optimal
139 conditions for functional interpretation, which involves contextual different scales of resolution,
140 impacting on our research outcomes. The investigation, aiming at identifying functional
141 features supported by fine-grained data on the non-flaked stone tool from Surein I finally
142 demonstrates this is a grinding stone that serves as a steady surface to mechanically process
143 storage organs for modern human consumption.

144 **2. The archaeological material**

145 The large rockshelter of Surein I in the Crimea Peninsula (alias Siuren or Suiuren or
146 Surein, according to different transliterations, Demidenko et al., 2012; Demidenko, 2014a;
147 Bataille et al., 2018; Vekilova, 1957) is situated in the eastern slope of Bel’bek gorge, not far
148 from Sebastopol, on the second ridge of the Crimean Mountains (Fig 1a). The rockshelter is
149 43 m long, 15 m deep and 9-10 m high (Fig 1b), and is located 110 m above the sea level and
150 15-17 m above a small creek flowing nearby. K.S. Merezhkovski (alias Merejkowski and Ruev,
151 2018) in 1879-1880 excavated a first trench in the central part of the rockshelter and retrieved
152 1150 flint artefacts, not thoroughly published, conserved in part at the Historical Geology Chair
153 in St. Petersburg University, and in part at the Department of Archaeology of the Peter the

154 Great Museum of Anthropology and Ethnography (Kunstkamera) of the Russian Academy of
155 Sciences, St. Petersburg, Russia (hereinafter MAE RAS).

156 In 1926-1929 G.A. Bonch-Osmolovsky, continued excavations at Surein I and
157 identified three cultural layers by pioneering cutting-edge methodologies as he carefully
158 collected all the materials related to human activities and applied complex statistical analysis
159 for the interpretation of the finds (Vasil'ev, 2008, pp. 25-27), not yet in use by contemporary
160 western archaeologists. The excavated surface was divided into a grid (2 x 2 m) and Surein I
161 stratigraphy was presented during the Second (proto-INQUA) Congress held in 1932
162 (Leningrad, Soviet Union). Describing the flint inventory from Surein I rockshelter, the Russian
163 scholar attributed the findings to the western European Aurignacian complexes - the only
164 comparisons available at the time - and dated Surein I horizons to the second half of the last
165 Würm glaciation (Bonch-Osmolovsky, 1926; 1932). During 1926-29 excavation about 1000
166 tools were discovered in the bottom level together with a single molar tooth attributed to *Homo*
167 *sapiens* (Chabai et al., 2004, p. 56; unfortunately, the molar is lost, at present). The blade
168 industry includes scrapers, Busquet burins, small size hand axes, retouched blades,
169 Mousterian scrapers. 30 years later, E.A. Vekilova (Vekilova, 1957) re-addressed the study of
170 Surein I, comparing the materials with Trans-Caucasian assemblages (the Upper Palaeolithic
171 of Georgia) at that time finally available for comparisons to the Russian scholars. More recently
172 (1994-1997), a Ukrainian-Belgian team excavated the rockshelter intercepting the 1926-1929
173 trench and layers (F-G-H) obtaining the oldest absolute radiocarbon dating around 30 ka BP
174 which are considered "*too young* [... and] *not represent the true age*" Demidenko, 2014a;
175 2014b, p. 6720; Demidenko et al., 2012). The directly dated human bones at Buran Kaya III
176 recently retrieved in layer C demonstrate the presence of *Homo sapiens* in Crimea as early
177 as 31,900±240/-222 BP (Pratt et al., 2011) and further consolidate evidence for modern
178 humans as the actual users of the Surein I grinding stone.

179 Whatever demic or emic model can be called into the play, the attribution of the lower
180 layers of Surein I to the Aurignacian is still undisputed as demonstrated by the new excavation
181 and the radiocarbon dating obtained in 1994-1997, endorsing the previous stratigraphy,
182 although detailing 8 successive dwelling episodes (Bataille, 2016, Fig 2, p. 52). The oldest
183 phases are confirmed as the Krems/Dufour type and attributed to (proto) Aurignacian, and the
184 faunal composition is also similar to that retrieved in Bonch-Osmolovsky trench (Demidenko,
185 2014b).

186 The present paper focused on the large, oval-shaped, biogenic limestone grinding
187 stone from Surein I (236x122x68 mm; 3477 g; Fig. 1e) unearthed during the 1926–29
188 excavations in the lowermost layer 3 of the rockshelter (corresponding to layer G of 1994-97
189 excavation, Bataille, 2016, Fig. 2, p. 52), and dated back to >31 ka uncal BP. The large

190 grinding stone was retrieved in an intriguing close relationship with horse remains, still in
 191 anatomical connection (Fig. 1c-d) and was immediately noticed during the excavation,
 192 photographed, mapped and drawn (Fig. 1b-c, adapted from Vekilova, 1957; Bataille, 2016,
 193 Fig. 3). It is worth mentioning the cutting-edge methodology applied by Bonch-Osmolovsky,
 194 who paid careful attention to the documentation with notes, photographs and drawings
 195 devoted to this exceptional context, unusual at the time the excavation was carried out. On
 196 the basis of the forerunning scientific approach applied by Bonch-Osmolovsky, a real innovator
 197 in those times, the whole area (about 1 m²) was philologically reconstructed in the museum
 198 (MAE RAS, St. Petersburg), where the structure is restaged under a glass cage (Fig. 1d),
 199 which avoid dust and other putative contaminations, and it is available for study. Such detailed
 200 documentation of the artefact biography represents a strong case to clearly assess the
 201 contextual association of the grinding stone with the flaked industry and the horse remains still
 202 in anatomical connection, all referred to the layer 3 (the layer G of 1994-1997 excavation) and
 203 attributed to the Aurignacian. In 1957 E.A. Vekilova duly published such well documented
 204 material and also reported functional remarks derived from S.A. Semenov observations on the
 205 flint assemblages.

206 The stone shows two very different faces (Fig 1e): one strongly weathered by water
 207 when immersed in the river water (Face B, which faced upwards when retrieved during the
 208 excavation), whereas the opposite (Face A, leaning on the soil) is still rough and it is the one
 209 that was certainly used, after its collection from the river. The research design applied a fresh
 210 multi-scale approach to investigate both wear-traces and starch granules extracted from the
 211 functionally active areas of the large grinding stone. Shape, size and general morphology were
 212 acquired by means of 3D scanning and photogrammetry, while the comparative surface
 213 texture analysis of the used and unused areas of both faces, was integrated with the
 214 morphological characterization of ancient “starch granules candidate” still adhering to the
 215 active areas, and carried out by means of microscopes with different resolutions (Birarda et
 216 al., 2020; Longo et al., 2020a).

217 3. The multi-scale contextual approach

219 For this study several microscopes with different resolution and magnification were
 220 involved (Tab. 1): Optical microscope (OM), Digital microscope (DM), Scanning Electron
 221 Microscope (SEM).

Model	Microscope	Magnification	Location
MBC-10	OM, Stereomicroscope	8.4-98 x	IHMC, St. Petersburg (Russia)

OLYMPUS BHMJ	OM Metallographic (DIC lenses) Canon EOS 400D camera Helicon Focus software	50-500 x	IHMC, St. Petersburg (Russia)
AXIO Scope A1	OM Transmitted/Polarized light	200-800 x	IHAE FEBRAS, Vladivostok (Russia)
Hirox KH-8700	3D Digital Microscope (DM)	35-2500 x (2D and 3D modality)	STARC, The Cyprus Institute, Nicosia, Cyprus
Keyence VHX 7000	3D Digital Microscope (DM)	35-2000 x (2D and 3D modality)	VCH Lab, ADM School, NTU, Singapore
Jeol JSM-6700F	Field Emission Gun (FEG) SEM	200-2000 x acceleration voltage (5 kV)	NTU, Singapore
Zeiss EVO 40	SEM with EDS OXFORD INCA energy	200-2000 x acceleration voltage (5 kV)	UniFi, Florence, Italy
Zeiss Supra 40	Field Emission Gun (FEG) SEM with Gemini column	800-25000 x low acceleration voltage (2 kV)	IOM-CNR, Elettra Sincrotrone, Basovizza, Italy

222 *Tab. 1: microscopes involved in the study. Surein I grinding stone was directly investigated in St. Petersburg by*
223 *means of optical microscopes (OM), and sonicated to extract the starch. The molds (imprints) and the araldite*
224 *positives were analysed by means of DM in Cyprus and Singapore. Both molds and starch grains were analysed*
225 *with SEM.*

226 The study for attributing the function of Surein I grinding stone was carried out at
227 different scales of resolution and magnification and with various methodologies based on
228 tribological principles (Longo et al., 2018; 2020a; Birarda et al., 2020). Among them, surface
229 texture can be considered as “*the features of surface relief*” (Myshkin and Grigoriev, 2013),
230 and texture analysis is intended as the study of the deviation of the surface from a plane. This
231 can be applied to both macro and microscale as texture reflects the appearance of distinctive
232 surface patterns that can be analysed according to two main approaches: comparative and
233 parametric. Comparative wear-traces detection is based on qualitative analysis which reflects
234 analyst's experience and it is buffered by the resolution power and magnification of the
235 inspection technology. The comparative approach is applied in this analysis based on “*the*
236 *expert visual evaluation of the similarities*” between the observed tool and the experimental
237 reference (Myshkin and Grigoriev, 2013) by applying conventional Optical Microscopy (stereo
238 and reflected/metallographic microscopes), enhanced by the increasing resolution and
239 magnification lended by Digital Microscope and SEM. The resolution power based on visual
240 light, led and electron sources is influenced by the wavelength of the source beams and it
241 affects the discrimination between two adjacent points, hence the detailing capacity of the
242 obtained image. Our strategy is to analyse the functionality of grinding stone involving different
243 resolutions with the aim to increase the reliability of the comparative observation and to

244 understand the possible functions of the lower steady tool under scrutiny. The direct
245 observation of the archaeological grinding stone was carried out at MAE RAS, St. Petersburg,
246 by N.S. and V.T. using both low power and high-power approaches (optical microscopy).
247 Replicative experiments were carried out by N.S. to detail the reproduction of wear-traces and
248 worked materials transformation, and by L.L. and I.P. to build a suitable reference collection
249 for plants residues calibrated on the Pontic steppe coenosis (Longo et al., 2020a; Skakun et
250 al., 2019). In order to investigate the tool function, all “classical” approaches to wear-traces
251 analysis were applied (stereomicroscope and metallographic microscope, pioneered by S.A.
252 Semenov (1964) and L.H. Keeley (1980) and the following development, and the microscopes
253 involved are reported in Tab. 1.

254 During the survey (2015) the stone was 3D scanned to obtain a digital model by means
255 of Next Engine (Longo and Skakun, 2017; Longo et al., 2018). The putative used areas were
256 molded (impressions taken) using high-definition polyvinyl siloxane (PVS, Provil® novo light,
257 Heraeus Kulzer GmbH), selected after preliminary direct inspection by means of stereo and
258 metallographic scopes. The surface texture nanoscale replication was ensured by polyvinyl
259 siloxane impressions, a long-tested procedure for the authors (Longo, 2003) and the molds
260 were mapped on the actual surface of the stones. Repeated molding proved to be a very
261 useful practice during the experimental reproduction of the gestures and the kinematics of the
262 pounding activities. Also, molding disclosed an unexpected positive outcome due to its peel-
263 off effect, since the sequential peeling (up to three per used-area) was at first cleaning the
264 surface (from dust and putative contaminants adhering the surface) and, in second instance,
265 it dislodged unpredictable micro to nanoscale residues (i.e. starch, raphides and fibers
266 adhering to the molds) out of the inner pits, the crevices and the unevenness of the surface.
267 The following sonication (standard ultrasonic tank) of peeled/molded areas were still testifying
268 the presence of starch grains and other microremains (see paragraph 3.5)

269 In laboratory conditions, the molds were thus photographed by G.S. Digital microscopy
270 and SEM investigation was carried out on those obtained during 2015 and 2016 sampling
271 campaigns by L.L. and G.S. who worked independently by using digital microscopes: Keyence
272 VHX 7000 at VCH Lab at NTU (Singapore) and Hirox KH-8700 at Cyl-STARC (Cyprus). Starch
273 granules were observed at both light microscope and SEM (I.P. and L.L.). Finally, the
274 observations were cross-checked and the results discussed within the three groups of wear-
275 traces analysts working in St. Petersburg, Cyprus and Singapore.

276 Use-Related biogenic residue analysis (i.e. starch granules) was carried out by I.P.,
277 using a Zeiss AXIO Scope A1 and L.L. using several SEM, at low vacuum and with no coating,
278 to be furtherly chemoprofiled by means of FTIR spectrometry and ToF-Sims (Birarda et al.,
279 2020; Longo et al., 2020a). By using low and high-powered microscopes we feel confident
280 that our functional interpretation is supported by a solid methodological and technological

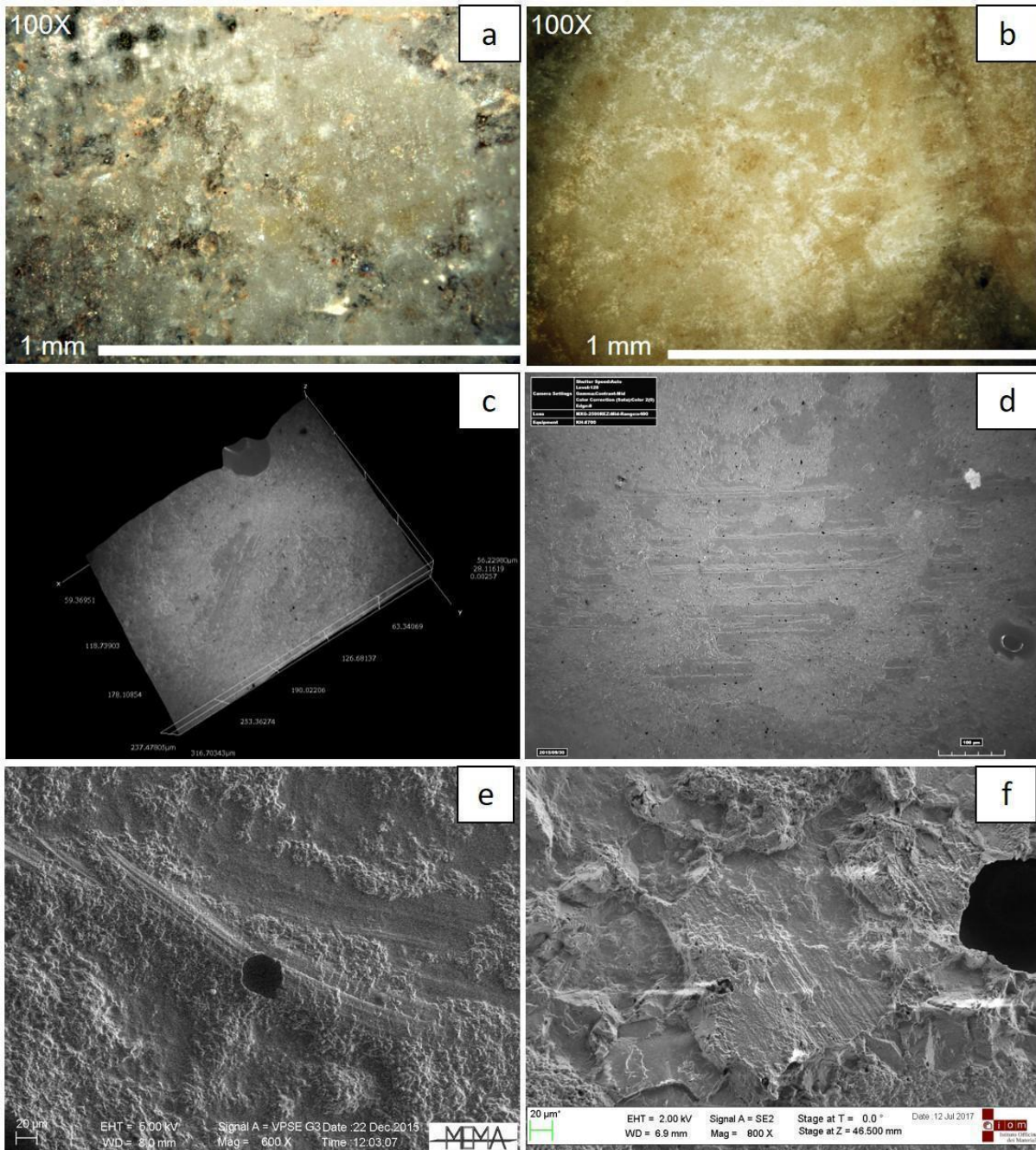
281 refinement which involves contextual different scales of resolution impacting on our research
282 outcomes.

283 **3.1 Traceology with direct optical observation**

284 The traceological analysis of the stone was carried out at low and medium
285 magnification (8.4–98x) with MBC-10 binocular microscope and oblique illumination. When
286 studying at micro level (50–500x), an Olympus BHMJ metallographic microscope was used,
287 equipped with a reflected light illuminator and differential-interference contrast (DIC) lenses.
288 The DIC produces a bias retardation which enhances the perception of the micro
289 topographical variations of the surface, and of the overall contrast, an effect that is obvious in
290 direct observation (Plisson, 2015, p. 221) and reduces chromatic aberration, a phenomenon
291 to which digital sensors are particularly sensitive. In fact, even when the sample texture or
292 micro-relief does not require this kind of vertical resolution enhancement, the DIC still improves
293 the quality of the photography (Plisson, 2015, p. 221). Micro-level shooting was carried out
294 using a Canon EOS 400D camera mounted on the metallographic microscope. To obtain high-
295 quality photographs of the stone surface by focusing over the entire area in one frame, the
296 Helicon Focus software was used. The surface of the tool is usually embossed, but with the
297 help of this focus stacking software, we are able to quickly and correctly combine several (5
298 to 20 or more) source images, at different focusing distances, into a fully sharp image (Fig.
299 2a-b). During this study, special attention was paid to the following diagnostic features: macro
300 changes of the relief, linear traces, gloss and polishing.

301 When describing flint and bone inventory from the Surein I rockshelter, G.A. Bonch-
302 Osmolovsky made remarks about the characteristics of putative working traces. However, this
303 is the first time that the functional study of the grinding stone is reported. The large pebble
304 belongs to the structure in the area 9B from the lowermost layer G as reported in E.A. Vekilova
305 (1957). The grinding stone shows an irregular-oval shape with a flat-convex cross section (Fig.
306 1e: center). The large oval stone shows two very different surfaces: Face A (Fig. 1e: right) is
307 quite coarse and still showing evidence of microfossils composing the biogenic original rock
308 (Fig. 9a), while Face B (Fig. 1e: left) is highly smoothed by water weathering (typical of stone
309 surface long exposed to water running in a river, which actually flows not far from the shelter).
310 Face A was downwards and embedded in the sediment, as carefully reported during the
311 excavation and in the philological restaging in the museum (Fig. 1c-d), and it is that on which
312 we concentrate our analysis: use-wear traces and adhering starch granules. Macro and micro
313 traces of utilization were concentrated in the central part of Face A, which is fairly flat with
314 negligible relief elevations. Significant macroscopic features are recorded only in certain areas
315 of the surface like polishing and flattening of the central area of the stone; no modern damage
316 was observed. Microscopic examination reveals spotty micropolishing with blurred edges,

317 situated on the highest points of the relief; it looks as dense, smooth, with varying degrees of
318 brightness, fading towards the periphery. In some areas we observed craters formed as a
319 result of light blows. The boundaries of the smoothed areas, when compared with the natural
320 surface of the stone, are slightly worn out and even, the protruding tops are polished. Linear
321 traces in polished areas look like short and long shallow lines with blurred, softly outlined
322 edges, less often as parallel scratches directed along the long axis of the object (Fig. 2 a-b).
323 However, the kinematic shows a general trend of the motion along the main axis of the
324 implement (Fig. 6). Well-defined wear traces are concentrated in the central part of the stone,
325 where molds 3 and 5 were taken, and to a lesser extent on peripheral areas. The features of
326 wear (striations, spotted polishes and the clear general abrasion of the central area which is
327 slightly lowered) drove us to identify this tool as a lower steady grinding stone. The direction
328 of linear traces, sub parallel to the long axis of the tool indicates that when working, the upper
329 mobile stone moved back and forth along one main direction.



330

331 *Fig. 2. Use-wear traces observed with different microscopy; a-b) optical microscope (OM) images of use-wear*
 332 *traces, flattened areas, groups of striations and rubbed areas are visible (b); c-d) DM images of the use-wear traces*
 333 *on the molds 3 and 5; c, 3D elaboration of the wear features at 1000x; d, bunches of striations visible at 400x) as*
 334 *observed with HIrox KH-8700. The length of parallel striae ranges from 70 to 200 µm and are visible on flattened*
 335 *areas; e-f) SEM images of striation and rubbed areas as observed on the mold (mold 3; e, 600x; f, 800x).*

336

3.2 Replicative experiment to reproduce the use of the grinding stone

337

338

339

340

341

To verify the results of use-wear analysis and to obtain a sufficient number of standards, we undertook a series of experiments that further the work begun by S.A. Semenov (1974), G.F. Korobkova (1972, 1987, 1999) and other researchers (Hamon and Plisson 2008; Revedin et al. 2010; Skakun and Plisson 2014; Skakun et al. 2020). This was necessary since the Palaeolithic ground stones are unmodified pebbles and slabs contrary to those used for

342 processing plant materials from later periods (Neolithic) which are shaped to fit their utilization,
 343 hence their morphology became highly diagnostic. Firstly, they were used to process wild
 344 plants, and not cultivated cereals, which are qualitatively different in structure. Secondly, their
 345 working parts, as a rule, preserve the stone's natural surface and are not processed, like the
 346 Neolithic ones, with special picketage for better adhesion of the processed material (mostly
 347 hard seeds) to the working surface of the tool, and therefore show evident shaping and other
 348 signs of wear. Our experiments were carried out according to a specifically developed
 349 protocol, which included the selection of blanks for tools similar to archaeological samples in
 350 shape and raw materials, selection of plant materials, identification of macro and micro use-
 351 wear traces at different stages of work, detailed recording of the experiment. Large
 352 pebbles/slabs with a flat surface were selected for the lower, steady grinding stones, and small
 353 flat-convex in profile pebbles as the upper active tools (Fig. 3a). A total of six experiments
 354 were carried out. For the main experiment on grinding vegetation, *Typha* sp. (USO) roots were
 355 used as modified material (Fig 3b-c). This plant was chosen because recent studies of the
 356 lower cultural layer (Layer G) of Surein I (AMS OxA-5154 28450 ± 600), from where the studied
 357 stone originates, show that the Crimean foothills of this time were characterized by a forest-
 358 steppe landscape (Demidenko et al., 2012; Chabai, 2000). The proximity to the water of the
 359 settlement is also confirmed by the remains of water vole and beaver (Vekilova 1971, p. 124,
 360 Table 3 and p. 126, Table 4), indirectly suggesting the likely presence of *Typha* sp. (USO)
 361 along the reservoir. When preparing the experiments, the roots of *Typha* sp. (USO) were
 362 preliminarily dried by a fire and peeled manually. Light crushing of the roots, kneading and
 363 grinding were carried out in two ways: in a circular and reciprocating motion, with increased
 364 pressure of the upper active tools on the processed material (Fig. 3b).

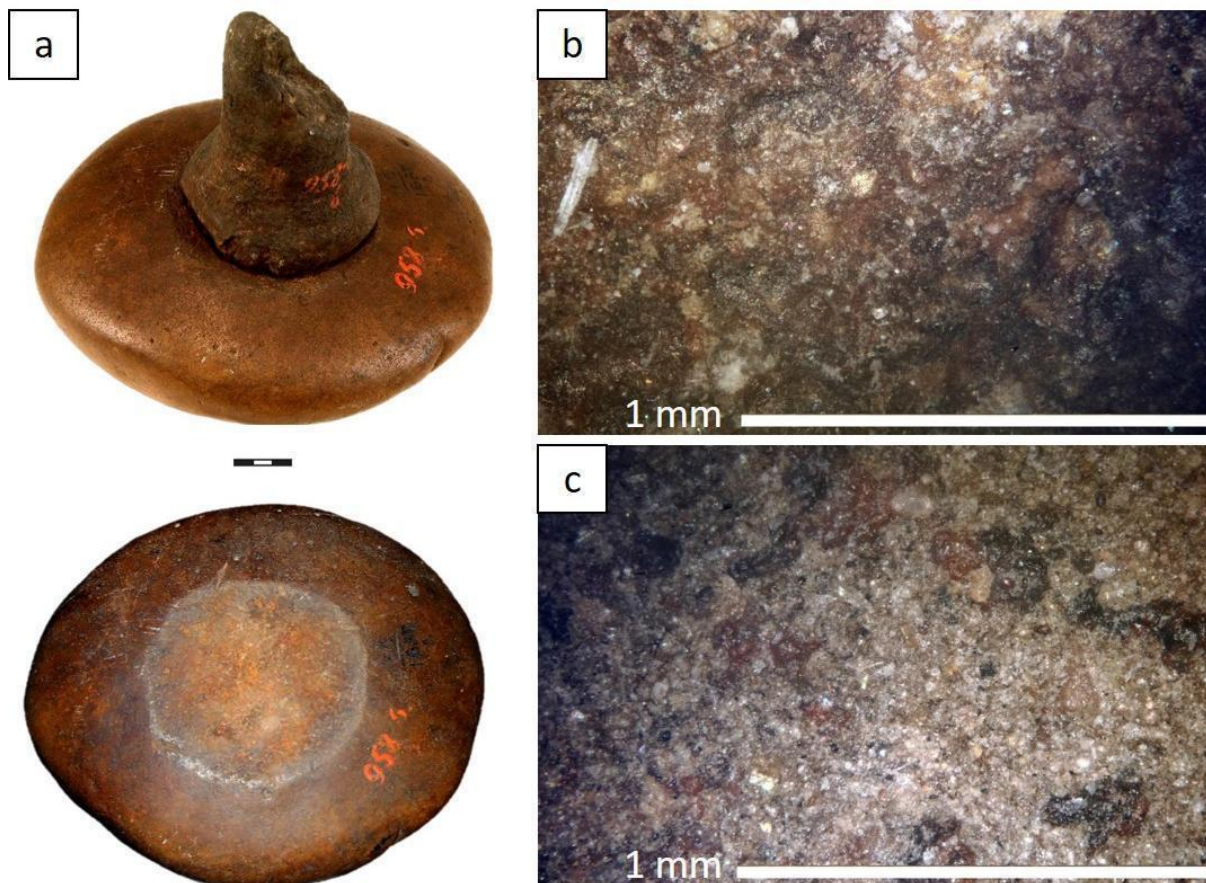


365
 366 *Fig. 3. The replicative experiment enacted to reproduce plant processing a) The raw material is consistent with the*
 367 *archaeological ones (limestone); b) N.N.S. during the replicative experiment; c) the stones are used for mechanical*

368 processing of the cattail dried rhizomes (*USO*, *Typha* sp.) to produce a fine flour; d-e) optical microscopy images
369 of wear traces created during the experimental work of the pebbles used as grinding stones and upper active
370 stones.

371 The first macro-traces of use in the form of a slight sheen on the protruding parts of the surface,
372 a slight deformation in the form of flattened asperities of the rock original surface arising from
373 light impacts, were recorded after two hours of operation (Fig. 3d). Clearer wear-traces, similar
374 to those found on archaeological objects: slight grinding of the protruding sections of the relief
375 of the working part, spots of a rather bright shine with uneven boundaries, fading towards the
376 periphery of the working part, weakly expressed micro-traces in the form of thin shallow lines
377 on the lower stone and upper stone were produced after 5 hours of intensive work (Fig. 3e).
378 As a result of rubbing the roots of *Typha* sp. (*USO*), a thin, light substance (Fig. 3d) was
379 obtained, similar in appearance to the product acquired during the experimental work with
380 replicas of instruments from the Palaeolithic site of Bilancino (Italy) and Pavlov VI (Revedin et
381 al., 2010).

382 It should be noted that there were no traces of friction between the upper and lower grinding
383 stones on both experimental and original tools. Apparently, this was hindered by the fibrous
384 layer of the processed plant material.



385 Fig. 4. a) Ethnographic tool (lower stone and mano) for grinding berries and grains (MAE RAS No. 958-6 / b-c)
386

387 *Cheyenne, Wyoming, USA, Late 19th century; b-c) microphoto of the working surfaces of the lower grinding stone*
388 *(b, 100x, scale bar = 1 mm) and mano (c, 100x, scale bar = 1 mm).*

389 According to the palynological data obtained from the study of the cultural layer G of Surein I,
390 it is possible to reconstruct that near the rockshelter grew mountain ash - *Sorbus aucuparia*
391 L., buckthorn - *Rhamnus cathartica* L., and juniper - *Juniperus* sp. (Vekilova, 1957, p. 251).
392 However, we could not report on starches referable to these plants. Nonetheless, we tested
393 wear traces on a mortar used for grinding berries and grains belonging to the ethnographic
394 collection of the MAE RAS (No. 958-6, Cheyenne, Wyoming, USA, Late 19th century). The
395 microscopic features of utilization on the ethnographic mortar are close to the traces we
396 described on the original grinding stone from Surein I and its experimental replica. The most
397 significant differences are expressed by the absence of macro deformation of the working
398 surface of the bottom of the mortar, that shows, instead, more even polishing covering the
399 bottom and partly the walls of the mortar, together with randomly located linear microscopic
400 features were found on its bottom (Fig. 4, modified after Skakun et al., 2020).

401 Further experimental work will be devoted to the study of use-wear features occurring on
402 different types of rocks (sandstone, diabase, quartzite, granite) used for processing plant
403 materials, aiming at identifying the dependence of the degree of wear development according
404 to the duration of use of the tools, the type of processed plant materials and the tribological
405 performance of the different rocks.

406 **3.3 Digital microscopy and SEM**

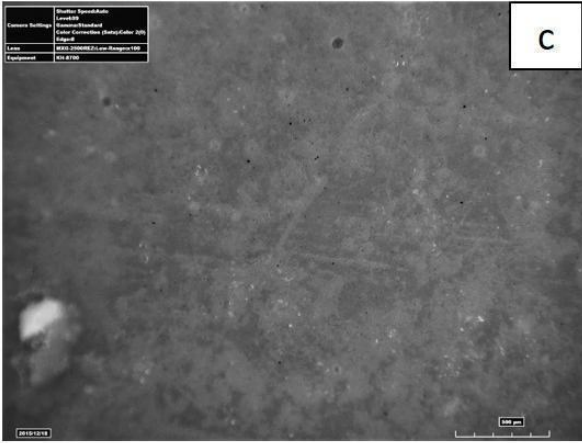
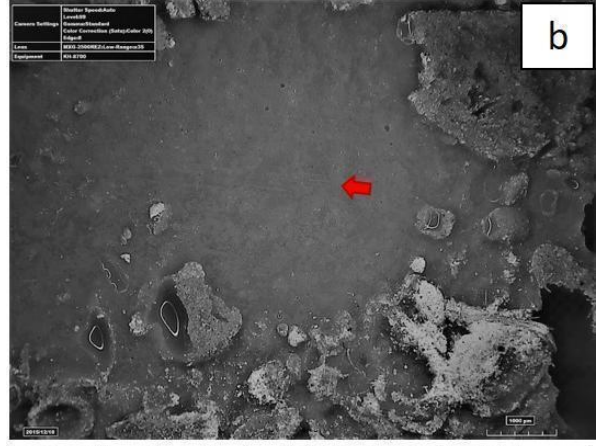
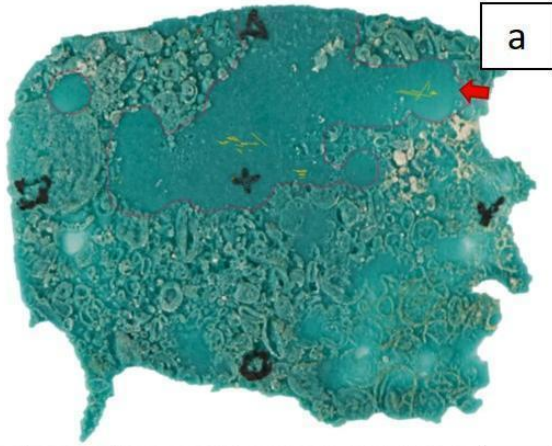
407 Direct investigation of large and bulky tools like ground stones by means of
408 conventional OMs is constrained by their structural design, as the stand and head are
409 designed for thin samples (e.g. slides), making it difficult to accommodate bulky shaped tools.
410 Similarly, the design of the SEM chamber is not suitable for oversized specimens. Therefore,
411 the design of DM is a relevant aspect in the selection of the most suitable microscope for
412 grinding stone wear-traces analysis. The DM stand is tall and adjustable, making it possible
413 to orient the optical head with respect to the surface of the stone, hence facilitating the
414 observation of large implements from multi-angle observation, as demonstrated during the
415 study of experimental grinding stone (VCH lab, Singapore). Moreover, the manual mode
416 allows for the tilting of the lens up to 90° and rotating the stage of 180°, facilitating observation
417 of the stone from various angles without handling. During inspection, all adjustments were
418 made without stone manipulation, using a small motorized console that greatly facilitates the
419 stitching operation (mosaicking pictures), enhancing precision and saving time for precisely
420 locating/mapping of the relevant spots on the tool surface.

421 Besides the issue raised by the dimension of the macrolithic tools, DM and SEM can
422 also overcome the depth-of-field and the focal distance constraints when inspecting highly

423 uneven surface texture and facilitate the scanning at different resolutions and higher
424 magnifications. Visual light microscopy is limited in the resolution by the classical Abbe
425 diffraction limit ($d = \lambda/2.8$) and the magnification of metallographic microscopy is generally
426 capped at a spatial resolution of hundreds of nanometers due to the wavelength range of
427 visual light. In the case of the ground stone's uneven surface, the overall capacity of DM
428 revealed to be highly informative when observing raw materials with marked roughness,
429 crevices, holes, contours and, in this case, microfossils. The DM technology can greatly
430 influence image quality because of its combined lenses, video-camera and graphic software
431 which are developed to optimize the relationship between depth-of-field, resolution and
432 brightness, providing images that appear to have higher resolution than allowed by the
433 diffraction-limited optics. The combination of the images - taken by the digital video camera at
434 several focal planes (up to 120) - allows to visualize the fine topography of a very large area
435 (highly improving the image processing obtained with Helicon Focus, already mentioned in
436 3.1) and to build a 3D imaging. The field emission gun characterizing FESEM allows for direct
437 investigation at very low potentials (we used maximum 5 kV) without coating, nevertheless
438 providing extremely focused high and low-energy electron beams with a spatial resolution $<$
439 2nm (that means 3 or 6 times better than conventional SEM) (Borrel et al., 2014). However,
440 during scanning some samples may overcharge, ending with white striations on the images
441 as happened with our starch granules (e.g. Fig. 8a' and Fig. 9d). The option "no coating"
442 revealed crucial when carrying out further chemoprofiling of the U-RBR by applying FTIR
443 spectroscopy and ToF-SIMS (Longo et al., 2020a). In the case of rough surfaces (like those
444 of the ground stones, very different from the fine and smooth surface texture of rocks used in
445 flaked industries) the wide depth of field available in DM and SEM reveals itself as crucial.

446 In order to overcome both structural and optical constraints, replicas of the surface (i.e.
447 molding compound polyvinyl siloxane) were taken to allow the higher scale observation, being
448 a familiar and long-tested procedure for the authors (Longo, 2003; Longo et al., 2020a; 2020b;
449 Macdonald et al., 2018; Pedergrana et al., 2016). In the case of macrolithic tools the position
450 of the impressions on the grinding stone was documented to map the observed traces (Fig.
451 6). Molds are suitable for direct investigation under any optical microscope and prove to be
452 highly reliable even when scanned with DM (Fig. 2c-d) and SEM (Fig. 2e-f). The molds of the
453 putative used areas were analysed with two different 3D digital microscopes: Hirox KH-8700
454 (at Cyl-STARC in Cyprus, by G.S. and L.L.) and Keyence VHX-7000 (at VCH Lab, NTU,
455 Singapore, by L.L.) which cover a magnification range from 35 to 2500x (times). The DM
456 higher resolution details the features already observed under lower resolution microscopy (Fig.
457 2 c-d: striations polish) and adds evidence of lesser-developed traces, decidedly increasing
458 the ultimate functional attribution. In Fig. 5 we exemplify the key features observed with DM
459 on the 4 molds (out of 5) taken out of Face A. Fig. 5a shows the mapping, on mold 3, of the

460 bunches of striae on the flattened area - surrounded by the unmodified original surface -
461 outlined in red (5b and 5c). The following microphotos are imaging polished areas and
462 striations on molds 2, 4 and 5. It is noticeable that molds 3 and 5 are covering the central area
463 of the grinding stone, where the most intense and lasting pressure was exercised, therefore
464 flattening and lowering the area causing a slight shadowing of the surface that can recall the
465 look of tribochemical wear, observed as spotted polish with different degrees of brightness.
466 Moreover, bunches of shorter and lighter striae testify a coupled motion such as pounding and
467 dragging as the alignment of the striae is suggesting (Fig. 5a-c), and accordingly their
468 orientation is both parallel and perpendicular to the main axis of the grinding stone. On the
469 molds we observed U-RBR such as starch granules and fibres (Fig. 5e and h), that were then
470 observed under the SEM (Fig. 10). Molds 2 and 4, taken in peripheral areas affected by a
471 lesser prolonged activity, show more defined and sharp striae and polished areas (Fig. 5e and
472 5f). The unprecedented results of our study demonstrate DMs as the most feasible equipment
473 for the study of large implements with rough surfaces as ground stones enabling easy
474 inspection at both high resolution and magnification.

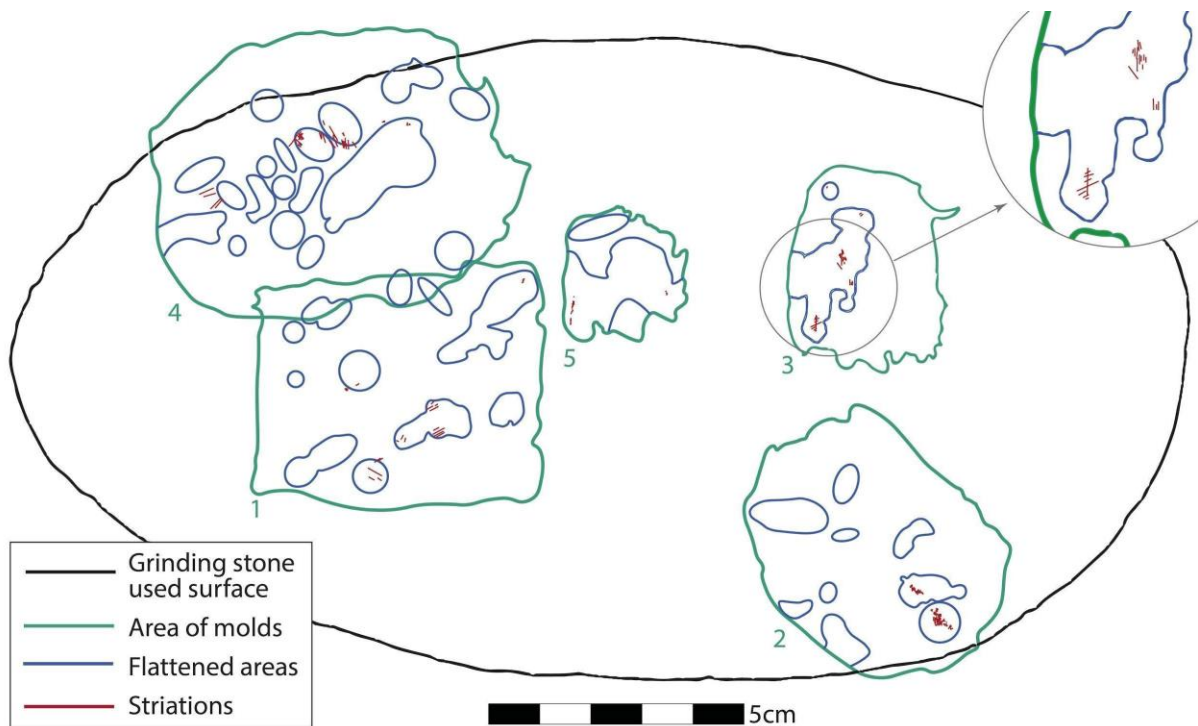


476 *Fig. 5. a) Mold 3 with flattened areas highlighted in red and striation in yellow; b) smashed biogenic formations*
477 *visible around a flattened area where bunches of parallel striations (indicated by the red arrow) are visible and they*
478 *are crossed by a couple of longer striae parallel to the main axis of the stone (35x and c at 100x); d) striations on*
479 *a rubbed area on mold 5 (200x); e) series of sharp striae visible already at low magnification (35x) on mold 4; f)*
480 *bunches of parallel micro-striations on a polished area on mold 2 (600x); g) plant fiber on a rubbed area, next to a*
481 *striation and to parallel striations on mold 5 (100x); h) the same residue at higher magnification (2500x), part of the*
482 *striation is still clearly visible next to it.*

483 **3.4 Mapping of the wear-traces**

484 The identified use-wear traces on the stone (shapeless rubbed-down traces, weak and
485 light linear traces, spotted polished areas, other wear features), detailed by scanning the
486 molds with the DMs, were photographed at increasing magnification (within a consistent
487 standard: 200X, 500X, 1000X, 1500X, 2000X), and one or more details were identified as
488 reference to map the same trait/s when imaged at higher magnification (Fig. 5a-c). Moreover,
489 the contact side of the molds (impressions) were photographed and orthorectified.

490 In addition to molding, Surein I stone tool was 3D scanned (Next Engine, at maximum
491 intensity) for digital reproduction and for off-site inspection (Longo et al., 2018; McCartney and
492 Sorrentino, 2019, pp. 69-73). In order to elaborate the 3D model and the digital elevation model
493 (DEM) (McCarty, 2014), the stone tool was also photographed and referred to a coordinate
494 system. The orthophotos of the used surface (Face A), were matched into a final orthomosaic.
495 This procedure allowed us to import in AutoCAD the orthorectified images of the molds of Face
496 A, together with the images acquired with the different microscopes. The wear-traces
497 microphotos were scaled (according to the magnification) and co-registered through the
498 recognition of three common points. When entered in AutoCAD each magnification was
499 treated as a different layer. The final goal was to relocate the microscopic features in each
500 relative position on the molds, and the impressions were finally mirrored and aligned to the
501 stone surface. This procedure aims to create a schematic map of the featured traces of use
502 on the grinding stone's original surface, assigning the utilized areas and the main direction of
503 use (e.g. see the direction of the striations and the areas of their higher concentration, Fig. 6).



504

505 *Fig.6. Schematic map of the molded areas: flattened areas (outlined in blue) and striations alignment (in red) are*
 506 *highlighted, revealing their actual location on the central part of Face A and the striations can be even oblique to*
 507 *the main axes of the stone (evidence for a widened motion).*

508

3.5 The use-related starch granules

509

510

511

512

513

514

515

516

517

518

519

520

521

522

523

524

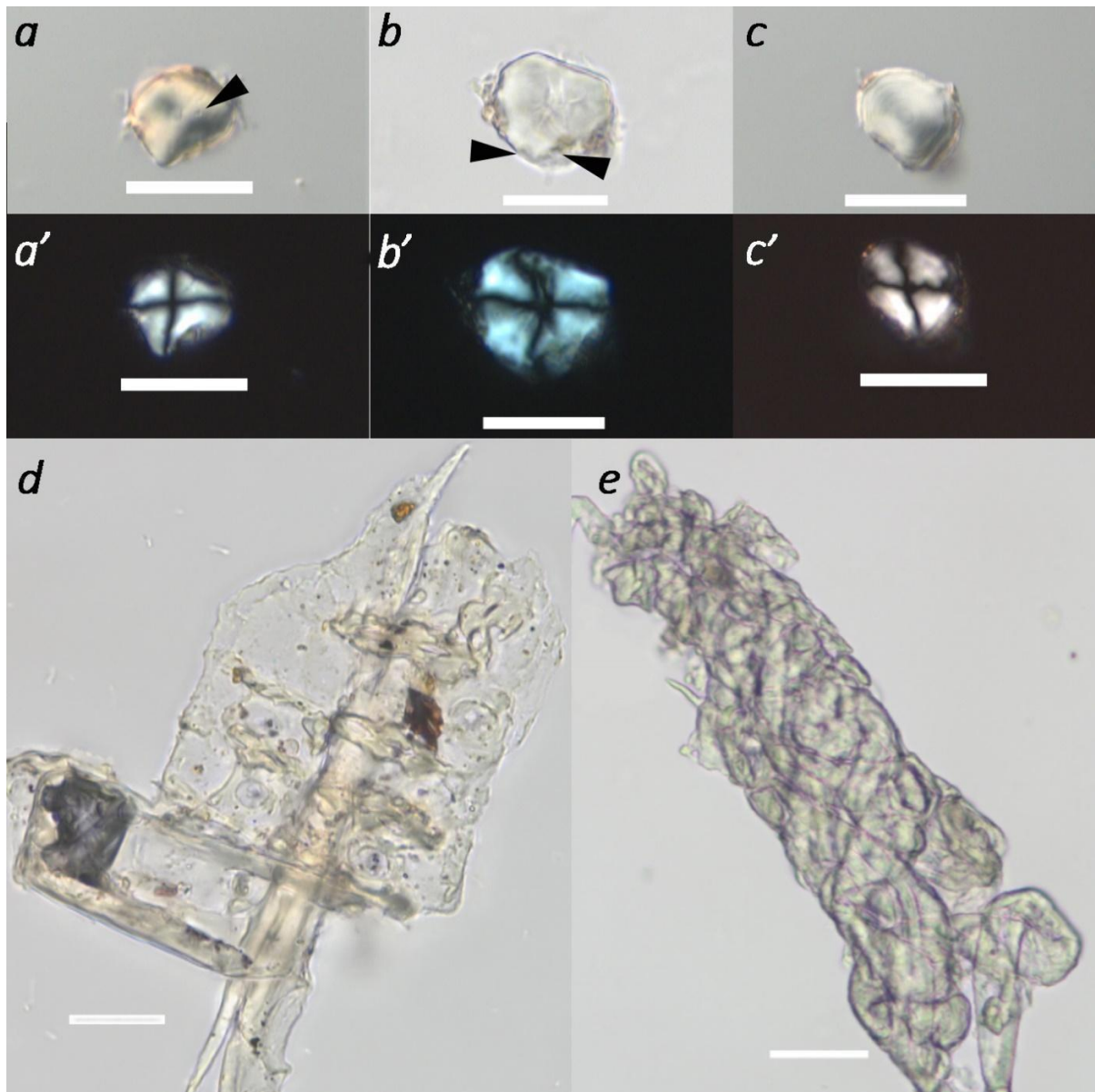
525

526

Use-related starch granules were extracted through standard ultrasonic tank cleaner at room temperature (double-frequency ultrasonic power 180 W, 28 kHz is used for overall clean, 40 kHz for precise clean) by soaking part of the tool. The operation occurred at the MAE RAS in St. Petersburg (2017), after both the preliminary inspection through stereomicroscope and metallographic microscope and the molding carried out as described in 3.1. Surein I liquid sample was then processed by I.P. at the Institute of History, Archaeology and Ethnology, Far East Branch, RAS, (IHAE FEB, Vladivostok, Russia). The preparation followed the methods in use by scholars (Torrence and Barton, 2006; Therin and Lentifer, 2006; Yang et al., 2012). Bleaching and careful cleaning of the lab surfaces and consumables is routine prior to starch granule extraction. Cesium chloride (CsCl) was the salt added to prepare the heavy liquid to segregate the starch granules from the accompanying sediment. The addition of this salt calls for multiple rinsing episodes in order to be carefully washed-off the final solution and to ensure the effectiveness of the further nanoscale analysis (Birarda et al., 2020; Longo et al. 2020a).

A Zeiss AXIO Scope A1 was used to scan the isolated residues. The solution (10% glycerol and 90% distilled water) with the isolated starch granules was mounted on a slide and observed at 200-800x under unpolarized (Fig. 7 a-e) and polarized transmitted light using DIC-contrast modalities (Fig. 7 a'-c'). Micrographs and measurements were taken using the microscope software. All starch granules showed the typical Maltese cross (extinction cross

527 under polarized light) and other diagnostic features (Gott et al., 2006) (Fig. 7 a'-c'). The starch
 528 granules are classified according to criteria proposed in previous studies (Piperno et al., 2004;
 529 Torrence and Barton, 2006): the shape of the granules in various projections, surface features,
 530 position and shape of the hilum, the presence and features of facets, the type of polarization-
 531 cross and characteristics of rays, the presence of lamellae and damage allowing for a
 532 confident identification of genuine starch granules.



533
 534 *Fig. 7. Surein I: Starch granules and U-RBR isolated from the utilized areas on face A, bar 20 μm, e) – 50 μm; a-
 535 b) Polyhedral granules, black arrows – surface craters after enzymatic attack; c) Ellipsoidal granule; a'-c') the same
 536 starches granules under polarised light. The extinction crosses are visible; d) Plant vascular tissue; e) Plant tissue
 537 or fiber.*

538 Seven granules of starch and fragments of plant tissues were obtained out of the
 539 sonicated sample of Surein I. None of them has a complex of attributes reliably comparable
 540 with any sample of the reference collection in Vladivostok lab, which includes 120 species

541 from 24 families encompassing wild and cultivated cereals, pulses, plants with USO and ferns.
542 This collection is mainly composed and constantly replenished with plants present in the
543 Russian Far East that do not correspond to the studied region, either geographically and
544 paleoecologically. At DAIS (Ca' Foscari, Venice, Italy) we are building a reference collection
545 with plants consistent with the western and south-eastern coenosis of boreal Eurasia, selected
546 among the list reported in recent reviews (Hardy, 2010; Kovárník and Beneš, 2018; Shipley
547 and Kindscher, 2016). As well, SEM imaging and FTIR spectrometry are applied to
548 characterize the starch granules in order to build a physical-chemical reference of starches
549 from the PSRSO record coherent with the Pontic steppe coenosis during Late MIS 3.

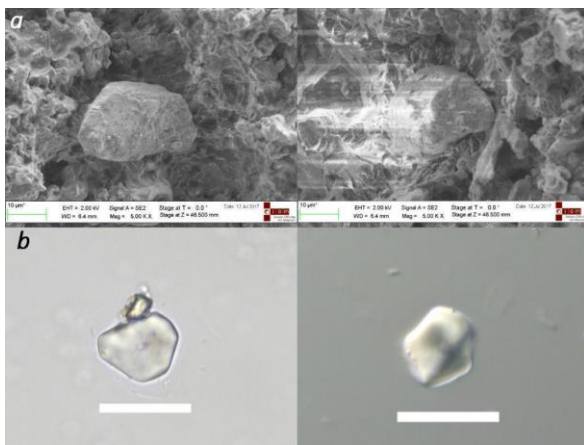
550 The seven starch granules can be divided into two groups. The first includes 4 granules
551 of a polyhedral shape. Size range is 15-23 μm . The extinction cross varies from (X) to (+) type
552 and the rays are straight or curved. Hilum is located in the center, rounded. Some granules
553 exhibit radial cracks. Two starch granules have surface damage in the form of craters, similar
554 to the result of an enzymatic attack (Fig. 7 a-b).

555 The other 3 grains have oval-like forms. Another section-view was not available. Size
556 range is 18-19 μm . The polarization cross varies from (X) to (+) type and the rays are straight
557 and curved. Hilum is located in the center, with a rounded outline. Two of them have lamellae
558 and one show transverse crack.

559 In addition to starch granules, the sample contained other residues. There are
560 fragments of plant tissues such as vascular and epithelial tissues and plant fibers (Fig. 7 d-e).
561 Therefore, the contextual presence of different plants-related remains and other use-related
562 biogenic residues (as already observed by Hardy et al., 2001; Pearsall, 2015) are supportive
563 of the genuine origin of the starch granules observed on Surein I grinding stone.

564 The limited amount of starch granules in the liquid sample can be explained by the
565 history of the artifact (surely washed and most probably brushed since the discovery), its
566 curation and in the last instance by the starch sampling strategy. It is relevant to recall that
567 polyvinyl siloxane imprints removed the main residues from the working surface and, due to
568 the geometry and dimensions of the ground stone, only a small part of the tool original area
569 was fitting in the ultrasonic tank, hence the sonication interested just a small peripheral area
570 of the tool (Skakun et al., 2019). Because of this constraint, the sonicated area is not one
571 referable to the most active areas. Such a small amount of starch granules extracted from the
572 sonication, in comparison with the more consistent number extracted from the molds, is
573 considered a good evidence of the absence of modern contamination and the localization of
574 residues in areas with use-wear traces is conducive to their authenticity. Therefore, we can
575 confidently say that the detected residues are mainly associated with the ground stone
576 utilization, and not due to soil deposits or other biasing conditions.

577 When comparing images of the starch granules we evaluate that the set of starch types
578 observed under OM and SEM did not differ significantly. There are distinguishable types and
579 shapes in the SEM samples: flattened round-oval granules corresponding to the Triticeae tribe
580 (Fig. 8), which is the most common group composing the Pontic steppe grassland. The first
581 group of OM starch granules finds analogies with another type of starch granules in SEM.
582 They have a multifaceted elongated shape. The presence, in the OM samples, of such
583 characteristics as the shape of the hilum, lamellae, and cracks are the projection of the internal
584 structure of the grain which can be detailed with the resolution of the SEM (Fig. 11). This is
585 the very first report on the coupled observation (OM and SEM) of ancient starch granules (Fig.
586 8).

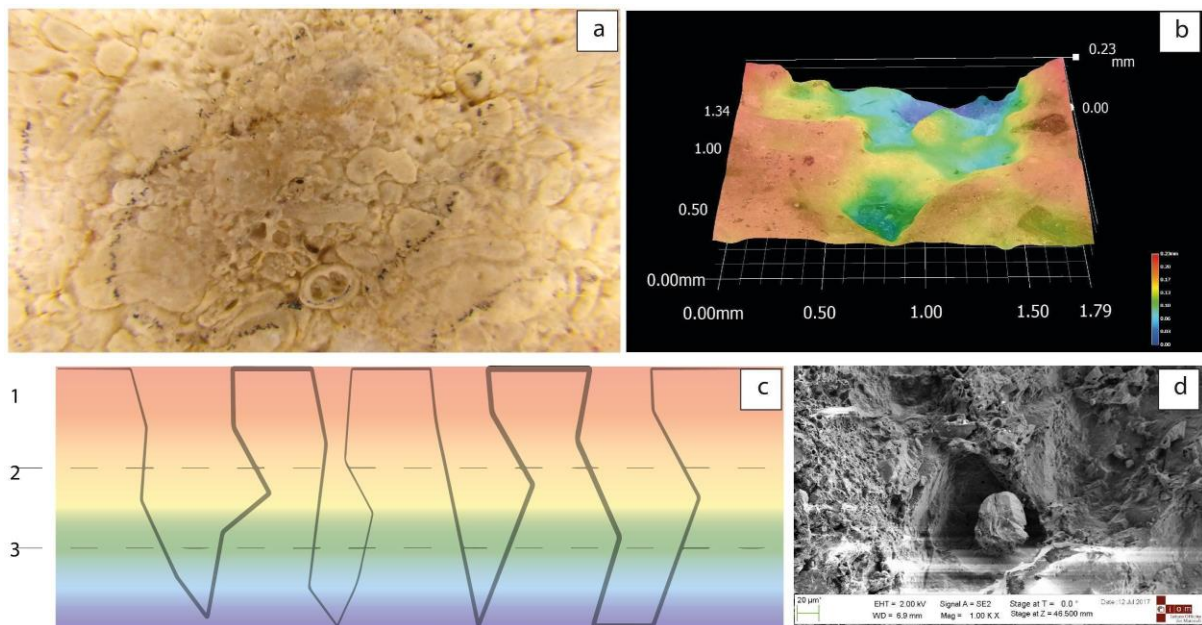


587
588 *Fig. 8. Surein I grinding stone. Correlated starch granules form as observed with SEM and OM microscopy; a)*
589 *Polyhedral shaped grains on the mold, bar 10 µm; b) Polyhedral shaped grains from the sonicated sample, bar 20*
590 *µm.*

591 **3.6 Starch granules under SEM**

592 During the sampling, we developed a standardized procedure for the analysis of both
593 wear-traces and U-RBR (i.e. starch). It included wearing powder-free gloves, careful dusting
594 of the stone surface with a clean soft brush and running a first macroscopic inspection of the
595 putative used areas, taking close-up macro photos (Longo et al., 2020b). Once the suitable
596 areas are identified (see above 3.1), the further steps include deep cleaning of the areas by
597 means of the molding peel-off effect exerted by the thixotropic property of the polyvinyl
598 siloxane that enters in the unevenness, holes and crevices of the stone surface and extract
599 actual ancient starch granules (Fig. 9). The sonication was performed at MAE RAS, St.
600 Petersburg, to extract putative “genuine” use-related biogenic residues (Collins and Copeland,
601 2011; Copeland and Hardy, 2018). Molding obtained prior to sonication can peel-off putative
602 contaminants (a case still under analysis, since contamination cannot be ruled out in any
603 archaeological condition). However, the starch granules extracted do not look modern and
604 both DM and SEM inspections proved that starch granules and other U-RBR, adhering to the

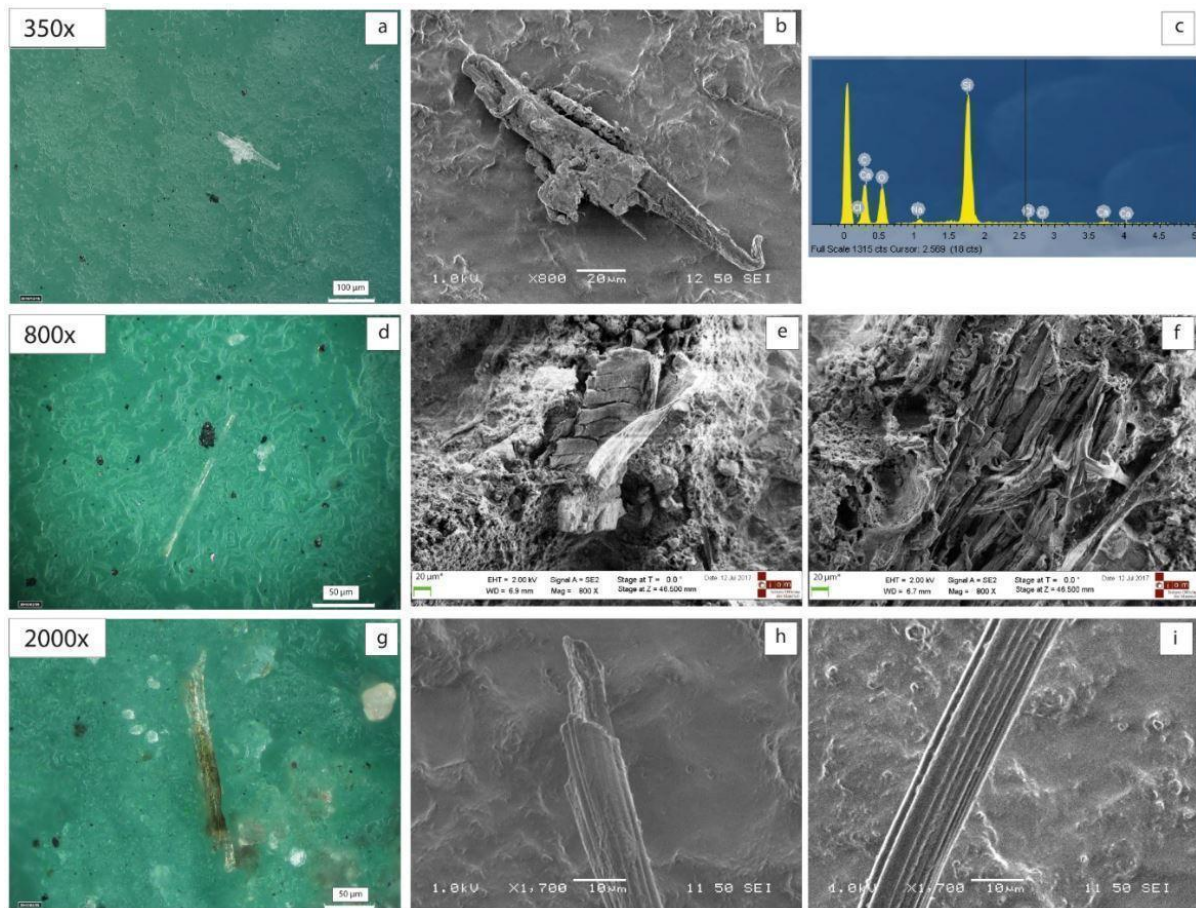
605 molds, are associated with wear-traces (Fig. 9d and Fig. 8a: SEM images of starch adhering
 606 to mold 3; Fig. 5g-h and Fig. 10: DM and SEM images of other U-RBR adhering to molds 1, 3
 607 and 5). Molding generates peels from plant remains still entrapped into the crevices of the
 608 archaeological grinding stone: this demonstrates the direct relationship of the starch granules
 609 with the functionally active areas (as exemplified by the wear-traces on molds 5, pictured in
 610 Fig. 5g-h), a case never reported before, to our knowledge. This unexpected discovery proved
 611 to be fruitful for extracting starch granules out of the molds during the chemo-profiling of the
 612 granules by means of SR-FTIR spectroscopy. A selection of starch granules isolated in
 613 Vladivostok underwent the nanoscale analysis with FEG-SEM (Fig. 11; Longo et al., 2020a).
 614 To perform the very first systematic observation of Palaeolithic starch granules under scanning
 615 electron microscopy a Zeiss SUPRA 40 high resolution FEG-SEM, based on the 3rd
 616 generation GEMINI column (available at ION CNR-Elettra Sincrotrone, Basovizza, Italy) was
 617 used. The optimal structural characteristic of this FEG-SEM enables for direct observation of
 618 the starches (and other residues) with no coating, thus enabling further analysis (e.g. SR-FTIR
 619 and TOF-SIMS, Longo et al., 2020a; Birarda et al., 2020).



620
 621 *Fig. 9. a) The uneven surface of the active side (Face A) of Surein I grinding stone. Limestone microfossils are*
 622 *detailed with the function “digital microscope mode” provided by the Ricoh WG-30 camera (7,5x); b) DM false*
 623 *colour 3D model of the mold microtopography: the deeper areas are in green and blue, while the higher are in*
 624 *yellow and red (Keyence VCH 7000); c) we propose an ideal model of the crevices according to b). This*
 625 *unevenness can serve to entrap both the contaminants and the U-RBR. In our hypothesis 1: the first mold extracts*
 626 *putative contaminants, together with sediment, dust, and other biases and can be used as cross-check reference;*
 627 *2-3, second and third mold progressively clear the microtopography and increase the extraction of genuine ancient*
 628 *starches as demonstrated in d) where a starch granule is entrapped in the crevices of the 3rd mold (view under*
 629 *SEM).*

630 As mentioned above, the limits imposed by the resolution of conventional light
 631 microscopy to detect starch granules, mostly when dealing with those falling in the lowest size
 632 range (<50 μm) can be overcome by SEM: this allows a further level of analysis of the U-RBR

633 morphological features, and has proved useful in examining the small starches extracted from
 634 Surein I grinding stone. Hence, SEM did help to identify new features appreciable at higher
 635 magnification, and, compared to visible light microscopy, has enabled us to count more starch
 636 granules (ten in a single 0,5 μ L droplet) and to observe other plant remains (i.e. fibres and
 637 raphides, Fig. 10 and Fig. 11 d, f). SEM inspection renders the surface sculpturing and the
 638 morphological features highly evident, highlighting attributes never featured before for such
 639 ancient remains (Fig. 11).

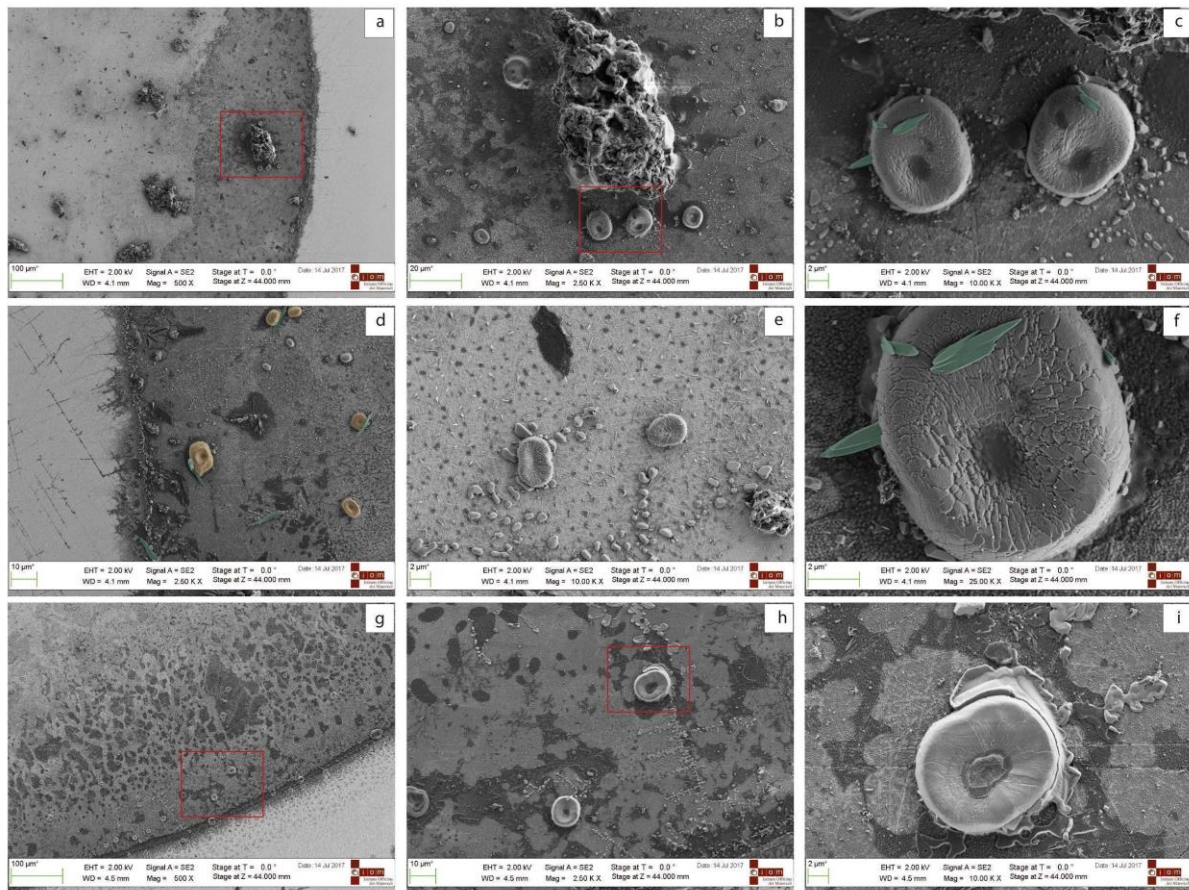


640
 641 *Fig. 10. Surein I, molds 1, 3 and 5: adhering plant remains. a, d, g) DM direct observation of the molds at different*
 642 *magnifications showing adhering plants remains; a, b, c) putative plant remains under DM and SEM with EDAX*
 643 *analysis evidencing Cl, C, Ca, O, Na, Si; d, e, f) plant tissues at DM and SEM; g, h, i) DM and SEM images of*
 644 *candidate phytolith.*

645 In the case of Surein I, starch granules are clustering in two types with evident hilum,
 646 distal or central, and the shape looks as “roundish with a stretch” in the central portion of the
 647 grain and also lamellae were clearly visible (Fig. 11). During the scanning, several granules
 648 evidently crushed or broken were observed. Accompanying plants remains were also
 649 evidenced such as raphides, parenchyma, and phytoliths (Fig. 11 c-d and f: raphides, in light
 650 blue), that are thoroughly discussed elsewhere (Birarda et al., 2020; Longo et al., 2020a;
 651 2020b). As mentioned above, the lack of tailored reference collection for plants used for
 652 economic purposes during the Late MIS 3, when *Homo sapiens* was living in the Pontic steppe,

653 makes it challenging to speculate on the taxonomic attribution of the identified starch granules
654 (Hardy et al., 2001). Therefore, we are implementing the reference collection with plants
655 available in the Pontic steppe today. The list includes those present during late MIS 3, i.e.
656 *Betula* sp., *Rhamnus cathartica* L., *Sorbus aucuparia* L., *Juniperus* sp., willow *Salix* sp, *Populus*
657 *tremula* as already reported by Vekilova (1957; 1971) and shrubs and grasses with storage
658 organs (Hardy, 2010) suitable to be collected and processed for the extraction of dietary
659 carbohydrates like *Stipa* sp. (among ASO) and *Typha* sp., *Arundo donax*, and *Phragmites* sp.
660 (among USO), already reported in pollen lists of the area available in the literature
661 (Hammerman, 1929; 1934; Gerasimenko, 2004; Demidenko et al., 2012). Modern plants are
662 collected with the dual purpose (i) to extract starch, under lab-controlled conditions, for
663 physical-chemical and morpho-structural characterization (including ageing under controlled
664 parameters) and (ii) to be used in experiments of mechanical tenderization and traces
665 development (G.S. PhD project, ongoing).

666 Another positive mark of SEM observation is the “3D like” effect which makes the
667 observation of the U-RBR much detailed and allows for the identification of features at the
668 nanoscale like lamellae and exfoliation, interpreted as due to mechanical processing as well
669 as to other physical or chemical events occurring during the tenderization, hence man-made
670 (Birarda et al., 2020, Fig. 4). However, the phenomenon might have occurred during
671 diagenesis, and the on-going ageing experiments in a climatic chamber (at DAIS, Venice) will
672 possibly shed light on the mechanism of the exfoliation and other features observed.



673
 674 Fig. 11. SEM: Starch granules extracted from the sonication of molds 3 and 5, usually they are distributed along
 675 the outline of the droplet. Starch granules in a-d and g-i are imaged at different magnifications with the lower range
 676 resembling those obtained under OM. Starches (on purpose coloured in light orange in 11d) and raphides (calcium
 677 oxalate crystals) on purpose coloured in light blue 11c-f) are still adhering to different granules, testifying their
 678 consistency with USO attribution of the granules; e-f; h-i) Starch different morphology, surface structure and central
 679 hilum.

680 4. Discussion

681 Our research aimed at: (i) collecting evidence supporting Surein I grinding stone was
 682 used to mechanically transform PSRSO into food, (ii) implementing the investigative
 683 procedures with *ad hoc* methodological refinements for both wear-traces and U-RBR analysis.
 684 Finally, the results obtained with this innovative research design are supporting fine-grained
 685 data to unfold the complexity of nutrition at the dawn of modern human colonization of the
 686 south-eastern Eurasian steppe during late MIS 3 (40-25 ka calBP). By that time, the boreal
 687 continent was already inhabited by Eurasian archaic humans, namely Neandertals and
 688 Denisovans further to the east, well adapted to their ancestral boreal environments, who were
 689 thriving on a highly carnivorous diet (Jaouen et al., 2019). Even for the ancient settlers of
 690 Crimea, prompted to be one of the south-eastern refugia for late Neandertals, the bulk
 691 collagen $\delta^{15}\text{N}$ high values are suggesting they fed on a typical terrestrial-based diet (Drucker
 692 et al., 2017). The early occurrence of *Homo sapiens* in the peninsula is represented by the
 693 remains of Buran Kaya III, layer C, which direct dating supports for modern humans presence

694 before the harsh HS 4 conditions (Heinrich Stadial) (Pean et al., 2013). Together with the
695 recent radiocarbon dating of Bacho Kiro cave (Bulgaria) it is possible to set back the early
696 presence of anatomically modern humans in the Pontic Steppe around 40 ka calBP (Fewlass
697 et al., 2020), extending the length for the overlapping of the newcomers with the late
698 Neandertals in the area. Vekilova (1957) anticipated that Surein I oldest assemblages recall
699 features comparable with the Transcaucasian Upper Palaeolithic (Zamiatnin, 1957, and lately
700 Korkia, 1998), among which some instruments show similarities with the Levantine industries,
701 and with the EUP assemblage of Mezmaiskaya cave (Golovanova et al., 2006). However, in
702 this mixed peopling scenario, with late Neandertals' resilient presence and early *Homo*
703 *sapiens* appearance, there is much debate over who actually may have developed the so
704 called "transitional industries" reported for the Pontic Steppe sites. These industries include
705 innovative elements - and are listed with different names i.e. Late Micoquian, Streletskayan,
706 or eastern Szeletian, Proto-Aurignacian, Aurignacian, etc. (Demidenko, 2014b; Bataille et al.,
707 2016, just to name a few within a vast literature). Therefore, it is crucial to explore other lines
708 of evidence to disentangle the long chain of circumstances that allow us to identify who actually
709 developed the transitional/Initial/EUP cultures: the resilient Neandertals or modern humans
710 newcomers. Although flaked industries represent – along with bones - the most frequent
711 physical remains left by hunter-gatherer activities, they cannot be considered as the only
712 source of behavioural information and to reconstruct nutritional strategies.

713 Off the beaten track, we addressed the broad assemblage of non-flaked industry
714 specifically focusing on ground stones retrieved in boreal latitude EUP sites associated with
715 *Homo sapiens*, in order to elucidate their high potential as reliable source of information for
716 dietary strategies (Birarda et al., 2020; Longo, 2016; Longo et al., 2020a). The investigation
717 of Surein I task-specific tool - the large biogenic limestone slab retrieved in the lowermost
718 Layer 3 of G.A. Bonch-Osmolovsky 1926-29 excavation (layer G, Bataille, 2016) referred to
719 Aurignacian – provided data to demonstrate its use to transform PSRSO by mechanical
720 tenderization such as grinding, pounding and threshing.

721 The methodological refinement applied to the study of Surein I grinding stone
722 consistently integrates the research design with different stages: from the sampling strategy -
723 to avoid further potential contamination - to the concerns arisen during the complex integration
724 of the probes in use, and analysis from the macroscale down to the nanoscale. We developed
725 a coupled macro to nanoscale investigation of the Surein I grinding stone, considering the
726 contextual occurrence of wear-traces and U-RBR, namely starch granules. The application of
727 different microscopes with increasing resolution and magnifying capability (Optical, Digital and
728 Scanning Electron Microscopy) made it possible to couple the different methodologies and to
729 overcome the limits due to the resolution power of the applied technologies. Our procedures

730 combine the acquisition of 3D geometry, the direct observation of wear-traces (in the
731 museums) and the further detailing of the features on the stone tool molds (imprints). Mapping
732 and relocating the functional features (the wear-traces, the flattened areas, and the orientation
733 of the striations) from the molds to the original stone is a step forward in functional analysis of
734 ground stones when investigated at high resolution. We are aware that due to methodological
735 constraints, e.g. heuristic requirements, equipment availability, and time restraints, these
736 techniques are applied at present to a limited number of samples and to address specific
737 questions (i.e. wear-traces on different raw materials pebbles and starch granules, Longo et
738 al., 2020a; Birarda et al., 2020).

739 Furthermore, we identify a best practice to extract U-RBR correctly from the used areas
740 of the stones with reference to the internal and external constraints of the available facilities.
741 The starch granules adhering to the grinding stone are tiny (in the case of Surein I < 50 µm
742 average size, within a range of 1-100µm), thus, requires micro and nanoscale analysis to be
743 appreciated. One of the main constraints of use-related residues analysis is that it can be
744 affected by the unpredictable effects of contamination (Crowther et al., 2014; Dozier, 2016;
745 Mercader et al., 2018 for review), which is an even greater concern when sampling from
746 museum collections and old excavations. The topic is widely treated by several scholars
747 (Pearsall, 2015; Ma et al., 2017) who also report on experiments carried out to verify the
748 feasibility of starch migrating from the soil or from the surrounding weeds, to the surface of the
749 stone tools. Hart (2011) has demonstrated that is not the case, and if contamination occurred
750 it is limited to the very external surface of the tool, since he did not find any contaminants
751 starch granules in the sonication of the control experiments. Hart's results can be taken as
752 reference for the reliability of U-RBR entrapped at the bottom of crevices, holes, etc. of the
753 coarse ground stone surface. We actually paid great attention, through all the analytical steps
754 to control putative pollution and other biases that may hinder actual U-RBR and specifically
755 those related to starchy plants intentional processing. The practice of taking three successive
756 molds, progressively clearing possible biases, made the ultrasonic extraction suitable for the
757 identification of ancient use-related biogenic residues, although it can limit the number of
758 remains extracted as experienced in our study (only seven starch grains were extracted from
759 the sonication). The contextual extraction of U-RBR signifies the presence of different plant-
760 related remains (starch, raphides, parenchyma, phytoliths) on the areas bearing clear wear-
761 traces and proved to be supportive of the genuine origin of the starches observed on Surein I
762 grinding stone (Hardy et al., 2001; Pearsall, 2015). The standardized procedure we developed
763 to extract starch granules has enabled us to correlate residues and wear-traces – intended as
764 an evidence of PSRSO intentional processing - as well as to confirm the presence of genuine
765 ancient starches. Considering the long history of the grinding stone examined, any trace of

766 modern starch on it would not display the dilapidated appearance that all our starch granules
767 displayed.

768 Plant remains are perishable and difficult to track. For the southern hemisphere, J.
769 Mercader was the first reporting on sorghum seeds from Ngalaue cave (Mozambique), a site
770 dated to 105-55 ka (Mercader, 2009). Further to the south, parenchyma remains, retrieved in
771 hearths and ash-rich layers, were attributed to charred roots and rhizomes at Border cave
772 (177 ka), and at Klasies River cave since 65 ka (Larbey et al., 2019; Wadley et al., 2020).
773 Although no ground stones have been retrieved in the mentioned sites, therefore no direct
774 evidence for intentional processing is documented, the findings are consistent with the
775 presence of *Homo sapiens*. Phytoliths and starch granules were recovered from two slabs
776 retrieved in the Middle Sangoan occupations of Sai Island (Sudan) and interpreted as
777 evidence of plants processing dating back to 200 ka ago (Van Peer et al., 2003). One can
778 speculate that *Homo sapiens* in Africa was already including in his dietary breadth starch-rich
779 foods, mostly rhizomes, the veritable plant storage organs. Therefore, it is possible that plant
780 processing was a technological practice that *Homo sapiens* exported with its northward
781 explorations.

782 At boreal latitudes, putative plant foods have been reported throughout the late
783 Pleistocene (Hardy, 2010; Kovárník and Beneš, 2018; Shipley, 2016); however, the intentional
784 plant processing by means of ground stones is not very frequent until the Holocene. Hence,
785 ours is a challenging hypothesis for the considered time period (late MIS 3). In the Levant
786 phytolith from grass husks were associated with Neandertal (70-55 ka) at Amud cave (Madella
787 et al., 2002), whereas charred legumes and nuts (i.e. acorns and pistachio) were recognized
788 at Kebara (48–59 ka; Lev et al., 2005). Pulses (i.e. lentil, chickpea, pea, vetchling), fruit and
789 nuts are reported at Theopetra Cave in Greece (Mangafa, 2000). Starch granules are reported
790 on 3 artefacts from the Swabia Aurignacian sites by Hardy B.L. et al. 2008, although they
791 caution that it is unlikely that flaked tools were used in the starchy plants processing. Plant
792 remains correlated with prevailing shrub tundra have been reported from the Aurignacian site
793 of Hohle Fels (Swabia, Germany), where few seeds attributed to Asteraceae and to the broad
794 group of Poaceae are referred to be used by humans around 44,2 ka calBP, together with
795 bark fragments interpreted as bearberry (Riehl et al., 2015). In Crimea, the very first
796 publication reporting intentional plant processing dates back to 2001, thanks to the pivotal and
797 inspiring study on 50 flaked flint tools from the Late Middle Palaeolithic layers of Starosele and
798 from Buran Kaya III layer C, attributed to the Early Upper Palaeolithic (Streletskaya) (Hardy et
799 al., 2001). The coupled investigation of wear-traces and residues analysis highlighted the
800 retrieval of soft plant parenchyma and wood tissues, the latter interpreted as hafting traces for
801 spear heads and, more in general, woodwork undertaken in both the sites. What is particularly

802 relevant for the present study is the data derived from the analysis of the trapezoidal microlith
803 from Buran Kaya III. The OM compelling analysis of the residues revealed the presence of
804 starch granules and raphides (calcium oxalate crystals) and the wear-traces suggest the tool
805 “was hafted and used to plane or to scrape a starchy substance” (Hardy et al., 2001, p. 10976).
806 As said, for late Pleistocene starches, it is very difficult to “identify the plant material to taxon”
807 (ibid.), however, the presence of raphides suggests they originated from starch-rich storage
808 organs like rhizomes (USOs, Hardy et al., 2001). Intriguingly enough, our analysis of Surein I
809 grinding stone revealed not only wear-traces compatible with plant processing, but OM and
810 SEM inspection clarify the presence of both starches and raphides, that are conducive to
811 interpret starch granules as pertaining to three to four different geophytes (Fig. 11). Our
812 previous work on ground stones from Gravettian hunter-gatherer settlements clearly
813 demonstrated the intentional tenderization of geophytes (USOs) such as *Typha* rhizomes,
814 *Botrychium ternatum*, *Lactuca tuberosa* and *Arctium lappa* which were processed in the Italian
815 peninsula and in Central Europe, therefore throughout the cold boreal territories (Longo et al.,
816 2020a; Longo et al., 2018; Revedin et al., 2010; Skakun et al., 2019).

817 Ethnographic sources report starch-rich water-lilies rhizomes are foraged from spring
818 to autumn across Eurasia northern latitudes (Gubanov et al., 2002). The use of baking or
819 boiling USOs is well reported in the Far East to prepare a sort of porridge or soup, and kasha
820 is still the traditional meal in Russia (Podmaskin, 2007). Also, it is acknowledged that
821 mechanical processing, leaching and even roasting are necessary steps that make plant food
822 bioavailable for the further metabolization occurring once plant foods are ingested. The
823 practice of mechanical processing into flour and then drying the crumble, which is therefore
824 losing most of the mass and the weight, reduces the bulkiness and concentrates the nutritional
825 power and can readily be consumed or stored for a delayed utilization, making the staple
826 starchy-food easy to store and to transport, i.e. a highly suitable reservoir for Palaeolithic
827 mobile hunter-gatherers.

828 Plants are predictable and their perennating undersurface storage organs - meaning
829 available all year round - are rich in highly nutritious carbohydrates and short-chain fatty acids,
830 which enable plants to survive ecological and climatic downturns. This turns out to be vital
831 even for *Homo sapiens* who was the hominin who could efficiently transform PSRSO into
832 calorific food due to the ptialin, the salivary enzyme regulated by the AMY 1 gene that is
833 duplicated in *Homo sapiens* but not in the archaic humans (Perry et al., 2015; Butterworth et
834 al. 2016; Longo, forthcoming). It is our opinion that the step-change capacity of efficiently
835 metabolizing highly calorific starch-rich food revealed a crucial adaptation to survive the
836 adverse climatic conditions *Homo sapiens* faced throughout late MIS 3 “volcanic winters”
837 (Golovanova et al., 2010), enabling *Homo sapiens* to access different nutrients in the course
838 of climatic downturns occurring at the northern latitudes. The Surein I grinding stone was

839 possibly used to process geophytes (USOs) surviving in cold and more arid steppe, where
840 mostly lean animals such as horses, deers and steppe bisons were supplying fats and meat.
841 Direct isotopic evidence from the *Homo sapiens* burial retrieved Buran Kaya III supports that
842 plant food consumption in EUP modern humans was significantly higher compared to the
843 Neandertals diet, and the two species most probably co-existed in Crimea (Drucker et al.,
844 2017), supporting they accessed different foods. Although still speculative, it is worth
845 considering that starches might have supplied *Homo sapiens* with those nutrients that spared
846 him from the constraints of a strictly carnivore diet (i.e. rabbit starvation; Speth and Spielmann,
847 1983; Speth, 2018).

848 **Final remarks**

849 Altogether, our study enabled us to identify Surein I macrolithic tool as a grinding stone,
850 used by *Homo sapiens* to mechanically process starch-rich storage organs into more easily
851 bioaccessible chunks and gross-grained flour. Our approach represents a due methodological
852 refinement, highly relevant towards establishing the ground stone's function within the elusive
853 processing strategies of plant originated food since the very beginning of Early Upper
854 Palaeolithic. We trust that our multi-scale contextual approach supports fine-grained data that
855 Surein I task-specific macrolithic tool was used to process under surface starch-rich organs
856 (USOs). Relying on the results of wear-traces and starch granules (including fibers and
857 raphides) directly associated to the used areas, we speculate that *Homo sapiens*, while
858 roaming across the Pontic Steppe, was foraging plants devoted to starch extraction from under
859 surface storage organs (USO, such as cattail, cane, reed) by mechanically processing them
860 into raw food. The chronology for modern humans' presence in south-eastern Europe, makes
861 Surein I grinding stone the oldest direct evidence of intentional geophyte processing during
862 Aurignacian settling, providing proof for a breakthrough in the dietary strategies of modern
863 humanity.

864 **Acknowledgments**

865 We are thankful to several scholars and institutions listed herein. Yu.K. Chistov, Vice director
866 of the Peter the Great Museum of Anthropology and Ethnography, G.A. Khlopachev, Head and Chief
867 Curator of the Department of Archaeology, V.G. Moiseyev - scientific Curator of Paleoanthropological
868 collections of the Department of Anthropology, Kunstkamera-MAE RAS, St. Petersburg; Scholars: M.V.
869 Sablin, Laboratory of Theriology, Zoological Institute RAS, St. Petersburg, Russia, and A. Tetrushvili,
870 PhD of the Institute Archaeology of Tbilisi State University, Georgia; they all support the sampling and
871 sustained our research, under formal MOU within RAS and NTU. For the access to SEM: Ciancio and
872 N. Cefarin (IOM-CNR, at Elettra Sincrotrone); and the Service MEMA-UniFi. S. Hermon, D. Abate and
873 R. Georgiou for the access to Hirox Digital Microscope and Next Engine 3D scan, within a Research
874 Agreement between PI (L.L.) and the Science and Technology in Archaeology and Culture Research
875 Center of The Cyprus Institute (Cyl-STARC, Cyprus, 2015-2017), and to Vera de Moitinho for the 3D
876 scans (2015).

877 We are grateful to C. Laurini for the technical support; M. Iovino and A. Belfer-Cohen for critical
878 enhancement of the earlier draft; and to K. Cozza for English revision of the manuscript.

879 This work was supported by NTU (Singapore) SUG grant M4081669.090 (PI, L.L.); Elettra
880 Sincrotrone, grant No. 20170057 (PI, L.L.). A special mention goes to L. Vaccari, G. Birarda and N.,
881 Cefarin of the SISSI-Chem beamline of ELETTRA Sincrotrone (Basovizza).

882 State task of scientific research No. 0184-2014-0008 to, Institute for the History of Material
883 Culture IHMC-RAS, St. Petersburg (Russia) N.N.S. N.N.S and V.V.T.'s study was funded by RFBR and
884 RPF according to the research project № 19-59-25002.

885 The PhD research project (Retrieve a novel: new multi-scale surface texture analysis of ground
886 stone tools - REVEAL awarded to G.S.) has received funding from the European Union's Horizon 2020
887 research and innovation program under the Marie Skłodowska-Curie grant agreement No 754511 (PhD
888 Technologies Driven Sciences: Technologies for Cultural Heritage - T4C).

889 **Authorship:** L.L. conceived the overall project and initiated the study design (NTU grants
890 holder) collaborating with N.N.S., L.L. and G.S. further developed research implementation and
891 methodological refinement on surface texture analysis. V.V.T. and N.N.S. conducted use-wear analysis
892 and V.V.T. took microphotos of use-wear traces with optical microscopes; prepared starch solution.
893 G.S. and L.L. carry out surface texture analysis and acquired use-wear traces with digital microscope
894 and SEM. I.P. made the starch analysis (OM) and L.L. scanned U-RBR under SEM. G.S. provided input
895 to support data management (2D and 3D geomatic approaches, wear-traces mapping). L.L. and G.S.
896 designed and L.L. wrote the article. G.S. and I.P. made the figures. All authors read and approved the
897 final manuscript.

- 899 Adams, J.L. 2014. *Ground Stones Analysis: A Technological Approach*, 2nd Edition. The University of
900 Utah Press and American Southwest, Salt Lake City, 336 p.
- 901 Bataille, G., 2016. Extracting the “Proto” from Aurignacian. Distinct Production sequences of Blades
902 and Bladelets in the Lower Aurignacian Phase of Siuren I, Units H and G (Crimea). *Mitteilungen der*
903 *Gesellschaft für Urgeschichte* 25, 49–86.
- 904 Bataille, G., Tafelmaier, Y., Weniger, G.-C., 2018. Living on the edge. A comparative approach for
905 studying the beginning of the Aurignacian. *Quat. Int.* 474, 3–29. DOI: 10.1016/j.quaint.2018.03.024.
- 906 Birarda G., Cagnato C., Cefarin N., Stani C., Pantyukhina I., Badetti E., Covalenco S., Marcomini A.,
907 Obada T., Sava E., Sorrentino G., Skakun N., Vaccari L., Longo L. (2020) Direct morpho-chemical
908 characterization of elusive plant residues from Aurignacian Pontic Steppe ground stones: supper's
909 ready for *Homo sapiens*. **bioRxiv** 455690 doi.org/10.1101/2020.07.23.212324.
- 910 Bonch-Osmolovsky, G.A., 1926. *Paleoliticheskaya stoyanka v Krymu. Predvaritel'noye soobshcheniye*
911 *[Paleolithic site in the Crimea. Preliminary Report]*. *Rossiyskiy antropologicheskiy zhurnal [Russian*
912 *Journal of Anthropology]* 14, 3/4, 81–87 (in Russian).
- 913 Bonch-Osmolovsky, G.A., 1932. The study of the Crimean caves in 1932. *PIMC* 9-10, 56-57 (in
914 Russian).
- 915 Borel, A., Ollé, A., Vergès, J.M., Sala, R., 2014. Scanning Electron and Optical Light Microscopy: two
916 complementary approaches for the understanding and interpretation of usewear and residues on stone
917 tools. *J. Archaeol. Sci.* 48, 46–59. doi.org/10.1016/j.jas.2013.06.031.
- 918 Butterworth, P.J., Ellis, P.R., Wollstonecroft, M., 2016. Why protein is not enough: the roles of plants
919 and plant processing in delivering the dietary requirements of modern and early Homo. In *Oxbow Books*
920 2016, 31-54. ISBN-13: 978-1785701238
- 921 Chabai, V.P., 2000. Osobennosti perekhoda ot srednego k verhnemu paleolitu v Krymu [Peculiarities
922 of the transition from the Middle to Upper Paleolithic in the Crimea]. *Stratum Plus*. No. 1, 54-83.
- 923 Chabai, V.P., Monigal, K., Marks, A.E. (Eds.), 2004. The Middle Paleolithic and Early Upper Paleolithic
924 of Eastern Crimea III. ERAUL 104, Université de Liège.
- 925 Collins, M.J., Copeland, L., 2011. Ancient starch: Cooked or just old? *PNAS* 108 (22), E145.
926 DOI: <https://doi.org/10.1073/pnas.1103241108>.
- 927 Copeland, L., Hardy, K., 2018. *Archaeological Starch. Agronomy* 8, 4, 1–12.
928 <https://www.mdpi.com/2073-4395/8/1/4>.
- 929 Crowther, A., Haslam, M., Oakden, M., Walde, D., Mercader, J. Documenting contamination in ancient
930 starch laboratories. *J. Arch. Sc.* 49, 90-104 (2014). <https://doi.org/10.1016/j.jas.2014.04.023>
- 931 Demidenko, Y.E., 2014a. The great North Black Sea Region Early Upper Palaeolithic and human
932 migrations into the region from different territories. In: Otte, M. and Le Brun-Ricalens, F. (Eds.), *Modes*
933 *de contacts and déplacements au Paléolithique eurasiatique. Actes XIV UISPP, Commission 8, ERAUL*
934 140, Université de Liège, 171–185.
- 935 Demidenko, Y.E., 2014b. Siuren I Rockshelter: From the Late Middle Paleolithic and Early Upper
936 Paleolithic to the Epipaleolithic in Crimea. In: Smith, C. (Ed.), *Encyclopedia of Global Archaeology*.
937 Springer, New York, 6711–6721.

- 938 Demidenko, Y.E., Otte, M. and Noiret, P. (Eds.), 2012. Siuren I rock-shelter. From late Middle Paleolithic
939 and early Upper Paleolithic till Epi-Paleolithic in Crimea, ERAUL 129, Université de Liège.
- 940 Dozier, C. A. 2016. Airborne starch dispersal from stone grinding: Experimental results and implications.
941 *Journal of Archaeological Science: Reports* 8, 112-115, <http://dx.doi.org/10.1016/j.jasrep.2016.05.057>.
- 942 Drucker, D.G., Yuichi, I., Naito, Y.I., Stéphane Péan, S., Prat, S., Crépin, L., Chikaraishi, Y., Ohkouchi,
943 N., Puaud, S., Lázničková-Galetová, M., Patou-Mathis, M., Yanevich, A., Bocheren, H., 2017. Isotopic
944 analyses suggest mammoths and plants in the diet of the oldest anatomically modern humans from far
945 southeast Europe. *Sci. Rep.* 7 (1), 1–10. DOI: <https://doi.org/10.1038/s41598-017-07065-3>
- 946 Dubreuil, L., Savage, D., Delgado-Raack, S., Plisson, H., Stephenson, B., de la Torre, I., 2014. Use-
947 wear analysis of ground stone tools: Discussing our current framework. In: Marreiros, J. M. et al. (eds.),
948 *Use-Wear and Residue Analysis in Archaeology, Manuals in Archaeological Method, Theory and*
949 *Technique*, DOI 10.1007/978-3-319-08257-8_7.
- 950 Ebeling, J., Rowan, Y.M. 2004. The Archaeology of the Daily Grind: Ground Stone Tools and Food
951 Production in the Southern Levant. *Near Eastern Archaeology* 67(2), 108-117. DOI: 10.2307/4132366
- 952 Fewlass, H., Talamo, Sahra, Wacker, L., Kromer, B., Tuna, T., Fagault, Y., Bard, E., Shannon P.
953 McPherron, S.P., Aldeias, V., Maria, R., Martisius, N.L., Paskulin, L., Rezek, Z., Sinet-Mathiot, V.,
954 Sirakova, S., Smith, G.M., Spasov, R., Welker, F., Sirakov, N., Tsanova, T., Hublin, J-J. 2020. A 14C
955 chronology for the Middle to Upper Palaeolithic transition at Bacho Kiro Cave, Bulgaria. *Nature*
956 *Ecology&Evolution* <https://doi.org/10.1038/s41559-020-1136-3>.
- 957 Gerasimenko, N., 2004. Vegetational History of Buran-Kaia III. In: Chabai, V.P., Monigal, K., Marks,
958 A.E. (Eds.), *The middle Paleolithic and Early Upper Paleolithic of Eastern Crimea. The Paleolithic of*
959 *Crimea, III*. ERAUL 104, Université de Liège, 19–34.
- 960 Golovanova, L.V., Doronichev, V.B., Cleghorn, N., Burr, G., Sulergizkiy, L., Hoffecker, J. 2006. The
961 early Upper Paleolithic in Northern Caucasus (new data from Mezmaiskaya cave, excavation 1997).
962 *Eurasian Prehistory* 4, 43-78.
- 963 Golovanova, L.V., Doronichev, B.V., Cleghorn, N.E., Koulkova, M.A., Sapelko, T.V., Shackley, S., 2010.
964 Significance of Ecological Factors in the Middle to Upper Palaeolithic Transition. *Curr. Anthr.* 51 (5),
965 655–691. DOI: <https://doi.org/10.1086/656185>.
- 966 Gott, B., Barton, H., Samule, D., Torrence, R., 2006. The Biology of Starch. In: Torrence, R., Barton, H.
967 (Eds.), *Ancient Starch Research*. Left Coast Press, Walnut Creek, 35–45. ISBN 1315434873, 978-1-
968 3154-3487-2.
- 969 Gubanov, I.A., Kiselieva, K.V., Novikov, V.S., Tikhomirov, V.N. 2002. Illyustrirovannyi opredelitel'
970 rastenii srednei Rossii [Illustrated determinants of plants in Central Russia]. Vol. 1: Ferns, hortails,
971 flocks, gymnosperms, angiosperms (monocots). *Tovarischestvo nauchnykh izdaniy [Fellowship of*
972 *Scientific Publications] KMK Press, Institut technologicheskikh issledovaniy [Institute of Technological*
973 *Research Press], Moscow (in Russian).*
- 974 Hammerman, A.F., 1929. Kohlereste aus dem Paläolithikum der Krim. Hohen Sjuren I und II. *Bulletin of*
975 *the Commission for the study of the Quaternary period* 1, 39–42.
- 976 Hammerman, A.F., 1934. Resultati izucheniya chetvertichnoi flori po ostatkam drevesnogo uglya
977 [Results of studying the Quaternary flora from the remains of charcoal]. In: *Trudi II Mezhdunarodnoi*
978 *konferenzii, Sovetskakya sekziya po isucheniu chetvertichnogo perioda v Evrope* 5 [Proceedings of the
979 international conference of the Association for the study of the Quaternary period in Europe. Soviet
980 section] 5, s. 66–74.

- 981 Hamon C., Plisson H. 2008. Functional analysis of grinding stones: the blind-test contribution. In
 982 «Prehistoric Technology» 40 Years Later: Functional Studies and the Russian Legacy / Edited by L.
 983 Longo and N. Skakun. BAR International Series 1783. Archaeopress, Oxford, 29-38.
- 984 Hardy, B.L., Kay, M., Marks, A.E., Monigal, K., 2001. Stone tool function at the Paleolithic sites of
 985 Starosele and Buran Kaya III, Crimea: Behavioral implications. PNAS 98 (19), 10972–10977.
- 986 Hardy, B. L., Bolus, M., Conard, N. J., 2008. Hammer or crescent wrench? Stone-tool form and function
 987 in the Aurignacian of southwest Germany. Journal of Human Evolution (54), 648-662.
- 988 Hardy, B.L., 2010. Climatic variability and plant food distribution in Pleistocene Europe: implications for
 989 Neanderthals diet and subsistence. Quant. Sci. Rev. 29, 662-679.
 990 DOI:10.1016/j.quascirev.2009.11.016.
- 991 Hart, T.C., 2011. Evaluating the usefulness of phytoliths and starch grains found on survey artifacts.
 992 JAS 38 (12), 3244–3253. DOI: <https://doi.org/10.1016/j.jas.2011.06.034>.
- 993 Jaouen, K., Richards, M.P., Le Cabec, A., Welker, F., Rendu, W., Hublin, J.-J., Sorressi, M., Talamo,
 994 S., 2019. Exceptionally high $\delta^{15}\text{N}$ values in collagen single amino acids confirm Neandertals as high-
 995 trophic level carnivores. PNAS 116 (11), 4928–4933. DOI: <https://doi.org/10.1073/pnas.1814087116>.
- 996 Keeley, L.H., 1980. Experimental Determination of Stone Tool Uses: A Microwear Analysis. University
 997 of Chicago Press, Chicago.
- 998 Korobkova, G.F., 1972. Eksperimental'noye izucheniye orudiy truda i drevnikh proizvodstv epokhi
 999 paleolita [An experimental study of tools and ancient industries of the Paleolithic era]. In B.A. Rybakov
 1000 (Ed.), Arkheologicheskiye otkrytiya [Archaeological discoveries] 1971. Nauka, Moscow, 171–173 (in
 1001 Russian).
- 1002 Korobkova, G.F., 1987. Khozyaystvennyye komplekсы rannikh zemledel'chesko-skotovodcheskikh
 1003 obshchestv yuga SSSR [Economic complexes of early agricultural and cattle-breeding societies of the
 1004 south of the USSR]. Nauka, Leningr. branch, Leningrad (in Russian).
- 1005 Korobkova, G.F., 1999. Cycles of Agriculture Economy as Seen from Experimental and Use-wear
 1006 Analysis of Tools. In: Anderson, P.C. (Ed.), Prehistory of Agriculture. New Experimental and
 1007 Ethnographic Approaches. Institute of Archaeology, University of California, Los-Angeles, 183–192
 1008 (Monograph 40). ISBN 1938770870, 978-1-9387-7087-6.
- 1009 Korkia, I.D. 1998. Zedapaleolituri kultura sakartvelos chrdiloaghmosavlet shavizghvistsirethshi [Upper
 1010 Paleolithic culture of the northeastern Black sea litoral of Georgia]. Tblisi: Metsniereba (in Georgian with
 1011 Russian summary).
- 1012 Kovárník, J., Beneš, J., 2018. Microscopic Analysis of Starch Grains and its Applications in the
 1013 Archaeology of the Stone Age. Interdisciplinaria Archaeologica 9 (1), 1–12. DOI:
 1014 10.24916/iansa.2018.1.6.
- 1015 Larbey, C., Mentzer, S.M., Bertrand Ligouis, B., Wurz, S., Jones, M.K., 2019. Cooked starchy food in
 1016 hearths ca. 120 kya and 65 kya (MIS 5e and MIS 4) from Klasies River Cave, South Africa. J Hum.
 1017 Evol. 131, 210–227. DOI: <https://doi.org/10.1016/j.jhevol.2019.03.015>.
- 1018 Lev, E, Kislev, M.E., Bar-Yosef, O. 2005. Mousterian vegetal food in Kebara Cave Mt. Carmel. Journal
 1019 of Archaeological Science (32): 475–484. DOI: 10.1016/j.jas.2004.11.006
- 1020 Longo, L., 2003. Lo studio delle tracce di usura sui reperti litici. In: Minelli, A., Peretto, C. (Eds.),
 1021 Metodologie per lo scavo archeologico, C.E.R.P Isernia, 155–182.

- 1022 Longo, L. 2016. Gestures from the Past: Grinding Stones and Starchy Food Processing at the Dawn of
 1023 Modern Humans. 22nd International Conference on Virtual Systems & Multimedia (VSMM) IEEE Xplore
 1024 Digital Library, ISBN: 978-1-4673-8993-8, 294-300.
- 1025 Longo, L., Skakun, N., 2017. Comprehensive study of the purpose of ancient stone tools using digital
 1026 technology. *Geoarchaeology and Archaeological Mineralogy -2017*, Proceedings of the IV Scientific
 1027 Youth School, Miass (Russia), 46-49 (in Russian).
- 1028 Longo, L., Skakun, N., Sorrentino, G., Vassallo, V., Abate, D., Terekhina, V., Sinitsyn, A., Khlopachev,
 1029 G., Hermon, S., 2018. Les gestes retrouvés: a 3D visualisation approach to the functional study of Early
 1030 Upper Palaeolithic grinding stones. In: Matsumoto, M. and Uleberg, E. (Eds.), *Exploring Oceans of
 1031 Data*, CAA 2016, Oslo. Archaeopress, Oxford, 447–455. ISBN-13: 978-1784917302.
- 1032 Longo, L., Altieri, S., Birarda, G., Cagnato, C., Cefarin, N., Graziani, V., Obada, T., Pantyukhina, I.,
 1033 Ricci, P., Skakun, N., Sorrentino, G., Terekhina, V., Tortora, L., Vaccari, L., Lubritto, C., 2020a. At the
 1034 origins of a starch-rich diet. A multidimensional approach to investigate use-related biogenic residues
 1035 on percussive stone tools. *Environmental Archaeology* (in press).
- 1036 Longo, L., Birarda, G., Cagnato, C., Covalenco, S., Pantyukhina, I., Skakun, N., Vaccari, L., Sorrentino,
 1037 G., 2020b. Coupling the beams: how controlled extraction methods and FTIR, OM and SEM reveal
 1038 starchy plants grinding in Pontic Steppe. *Journal of Archaeological Science: Reports*, Special Issue
 1039 ICAS-EMME Cyprus (in press).
- 1040 Ma, Z., Zhang, C., Li, Q., Perry, L., Yang, X. 2017. Understanding the Possible Contamination of Ancient
 1041 Starch Residues by Adjacent Sediments and Modern Plants in Northern China. *Sustainability*, 9, 752.
 1042 doi:10.3390/su9050752.
- 1043 Macdonald, D., Harman, R., Evans, A.A., 2018. Replicating surface texture: Preliminary testing of
 1044 molding compound accuracy for surface measurements. *J. Archaeol. Sci. Rep.* 18, 839–846.
 1045 DOI: <https://doi.org/10.1016/j.jasrep.2018.02.036>.
- 1046 McCarty, B.A., 2014. What is Orthorectification? [https://apollomapping.com/blog/g-faq-](https://apollomapping.com/blog/g-faq-orthorectification-part)
 1047 [orthorectification-part](https://apollomapping.com/blog/g-faq-orthorectification-part) (accessed the 4 April 2020)
- 1048 McCartney, C., Sorrentino, G., 2019. Ayaia Varvara a preliminary analysis of stone tools used in pigment
 1049 processing and tanning with ochre. In: Astruc, L., McCartney, C., Briois, F., Kassianidou, V. (Eds.). *Near
 1050 Eastern Lithic Technologies on the Move. Interactions and Contexts in Neolithic Traditions*, *Studies in
 1051 Mediterranean Archaeology*, 150, 63-78.
- 1052 Madella, M., Jones, M.K., Goldberg P., Goren Y., Hovers, E. 2002. The exploitation of plant resources
 1053 by Neanderthals in Amud Cave (Israel): the evidence from phytolith studies. *Journal of Archaeological
 1054 Science* (29), 703–719. DOI: 10.1006/jasc.2001.0743.
- 1055 Mangafa, M., 2000. Plant exploitation from the Middle Palaeolithic to the Neolithic: from food gathering
 1056 to farming. *Archaeobotanical study of Theopetra cave*. In: Kyparissi-Apostolika N (ed.) *Theopetra Cave:
 1057 Proceedings of the International Conference*, Trkala, 135–138.
- 1058 Mercader, J., 2009. Mozambican grass seed consumption during the Middle Stone Age. *Science* 326
 1059 (5960), 1680–1683. DOI: <https://doi.org/10.1126/science.1173966>.
- 1060 Mercader, J., Bundaia, M., Collins, J.M., Copeland, L., Crowther, A., Henry, A., Itambu, M., Larter, S.,
 1061 Longo, L., Patalano, R., Sammynaiken, R., Tyler, R., Xhaufflair, H. (2018) Exaggerated expectations in
 1062 ancient starch research and the need for best practices and authenticity criteria. *FACETS* (3), 777-798.
- 1063 Myshkin, N.K., Grigoriev, A.Y., 2013. Roughness and texture concept in Tribology. *Tribology in Industry*,
 1064 35 (2), 97-103.

- 1065 Pearsall, D.M., 2015. *Paleoethnobotany: a handbook of procedures*. Third edition. Routledge, Taylor &
1066 Francis, New York, 348–353. ISBN 1611322995, 978-1-6113-2299-6.
- 1067 Pean, S., Puaud, S., Crepin, L., Pratt, S., Quiles, A., van der Plicht, J., Valladas, H., Stuart, A.J.,
1068 Drucker, D.G., Patou-Mathys, M., Lanoe, F., Yanevich, A., 2013. Middle to Upper Palaeolithic sequence
1069 of Buran-Kaya III (Crimea, Ukraine): New stratigraphic, paleoenvironmental, and chronological results.
1070 *Radiocarbon* 55 (2-3), 1454-1459.
- 1071 Pedergrana, A., Asryan, L., Fernandez-Marchena, J.L., Olle, A. 2016. Modern contaminants affecting
1072 microscopic residue analysis on stone tools: A word of caution. *Micron* 86, 1–21.
1073 DOI: <http://dx.doi.org/10.1016/j.micron.2016.04.003>.
- 1074 Perry, G.H., Kistler, L., Kaleita, M.A., Sams, A.J., 2015. Insights into hominin phenotypic and dietary
1075 evolution from ancient DNA sequence data. *Journal of Human Evolution* 79, 55-63. DOI:
1076 [10.1016/j.jhevol.2014.10.018](https://doi.org/10.1016/j.jhevol.2014.10.018).
- 1077 Piperno, D., Weiss, E., Holst, I., Nadel, D., 2004. Processing of wild cereal granules in the Upper
1078 Palaeolithic revealed by starch grain analysis. *Nature* 430, 670–673.
1079 DOI: <https://doi.org/10.1038/nature02734>.
- 1080 Plisson, H., 2015. Digital photography and traceology: from 2D to 3D. In: Lozovskaya, O.V, Lozovski,
1081 V.M., Girya, E. Yu. (Eds.), *Sledy v istorii. K 75-letiyu Shchelinskogo V.E.* [Traces in History. To the 75th
1082 anniversary of V.E. Shchelinsky]. IHMC RAS, St. Petersburg, 216–231.
- 1083 Podmaskin, V.V., 2007. *Vvedeniye v etnografiyu Dal'nego Vostoka Rossii: narodnaya meditsina i*
1084 *kul'tura pitaniya* [Introduction to ethnography of the Far East of Russia: traditional medicine and food
1085 culture]. Dalnauka Press, Vladivostok (in Russian).
- 1086 Pratt, S., Pean, S., Crepin, L., Drucker, D. G., Puaud, S.J., Valladas, H., La'znic'kova'-Galetova', M.,
1087 van der Plicht, J., Yanevich, A.. 2011. The Oldest Anatomically Modern Humans from Far Southeast
1088 Europe: Direct Dating, Culture and Behavior. *PlosOne*, 6, 6, e20834.
- 1089 Revedin, A., Aranguren, B., Becattini, R., Longo, L., Mariotti Lippi, M., Skakun, N., Sinitsyn, A.,
1090 Spiridonova, E., Svoboda, J., 2010. Thirty thousand-year-old evidence of plant food processing. *PNAS*
1091 107 (44), 18815–18819. DOI: <https://doi.org/10.1073/pnas.1006993107>.
- 1092 Revedin, A., Longo, L., Anichini, E., Aranguren, B., Gennai, M., Marconi, E., Mariotti Lippi, M.,
1093 Ronchitelli, A., Svoboda, J., 2015. New findings about Gravettian technologies for plant processing:
1094 Paglicci and Dolni Vestonice. *Quat. Int.* 359, 77–88.
1095 DOI: <http://dx.doi.org/10.1016/j.quaint.2014.09.066>.
- 1096 Riehl, S., Marinova, E., Deckers, K., Malina, M., Conrad, N.J., 2015. Plant use and local vegetation
1097 patterns during the second half of the Late Pleistocene in southwestern Germany. *Archaeol. Anthropol.*
1098 *Sci.* 7, 151–167. <http://doi.org/10.1007/s12520-014-0182-7>
- 1099 Ruev, V.L., 2018. K.S. Merezhkovskiy — issledovatel' arkheologicheskikh pamyatnikov v Krymu (1879–
1100 1880) [Konstantin Merezhkovsky as an Investigator of the Archaeological Monuments of the Crimea
1101 (1879–1880)]. *Povolzhskaya arkheologiya* [The Volga River Region Archaeology] 4 (260), 248–263 (in
1102 Russian). DOI: <https://doi.org/10.24852/2018.4.26.248.263>.
- 1103 Semenov, S.A., 1964. *Prehistoric Technology: An Experimental Study of the Oldest Tools and Artefacts*
1104 *from Traces of Manufacture and Wear*. Cory, Adams and Mackay, London.
- 1105 Semenov, S.A., 1974. *Proiskhozhdenie zemledelia* [Origins of Agriculture]. Leningrad.

- 1106 Shipley, G.P., Kindscher, K., 2016. Evidence for the Paleoethnobotany of the Neanderthal: A Review
1107 of the Literature. *Scientifica*, 12. Article ID 8927654, DOI: <http://dx.doi.org/10.1155/2016/8927654>.
- 1108 Skakun, N., Plisson, H., 2014. Some Results of the Experimental-Archaeological Expedition at Bodaki.
1109 *Sprawozdania Archeologiczne* 66, 83–90. ISSN 0081-3834.
- 1110 Skakun, N., Longo, L., Leonova, N.B., Terekhina, V.V., Pantiukhina, I.E., Eltzov, M.V., Vinogradova,
1111 E.A., 2018. Predvaritel'nyye rezul'taty kompleksnogo analiza kamennoy plitki iz rkhneopaleoliticheskoy
1112 stoyanki Kamennaya Balka II [Preliminary results of a comprehensive analysis of rubbing tile from the
1113 Upper Paleolithic site of Kamennaya Balka II]. In: Lozovskaya, O.V. (Ed.), *Strategiya*
1114 *zhizneobespecheniya v kamennom veke, pryamyie i kosvennyie svidetel'stva rybolovstva i sobiratel's*
1115 *[Subsistence strategies in the stone age, direct and indirect evidence of fishing and gathering]: materialy*
1116 *mezhdunarodnoy nauchnoy konferentsii, posvyashchenoy 50-letiyu V.M. Lozovskogo [materials of the*
1117 *international scientific conference dedicated to the 50th anniversary of V.M. Lozovskiy]. IHMC RAS;*
1118 *GH, St.-Petersburg, 238–240 (in Russian). DOI: <http://doi.org/31.600/978-5-85803-525-1>.*
- 1119 Skakun, N., Terekhina V., Longo L., Pantiukhina I.E. (2019): Contemporary use-wear studies in
1120 archaeology. The Past of Humankind as seen by the Petersburg Archaeologists at the Dawn of the
1121 Millenium (Centennial of the Russian Academic Archaeology). St. Petersburg Centre for Oriental
1122 Studies Publishers, 2019, pp. 157-165. DOI: 31.600/978-5-85803-525-1 (in Russian).
- 1123 Skakun, N.N., Zhilin, M.G., Gutieres, K., Pawlik, A., Gorashchuk, I.V., Terekhina, V.V., Mateva, B.,
1124 Bostanova, T.M., Shulga, D.M., 2020. Nekotorye rezul'taty eksperimental'no-trasologicheskikh
1125 issledovaniy, provodivshihsy v letnej arheologicheskoy shkole v Bolgare [Some results of experimental-
1126 traceological research carried out at the summer archaeological school in Bolgar]. *Arheologiya*
1127 *evrazijskij stepej [Archeology of the Eurasian steppes]* 3, 323-329.
- 1128 Speth, J.D., Spielmann, K.A., 1983. Energy source, protein metabolism, and hunter-gatherer
1129 subsistence strategies. *J. Anthr. Arch.* 2 (1), 1–31. DOI: [http://dx.doi.org/10.1016/0278-4165\(83\)90006-](http://dx.doi.org/10.1016/0278-4165(83)90006-5)
1130 [5](http://dx.doi.org/10.1016/0278-4165(83)90006-5).
- 1131 Speth, J.D., 2018. Neanderthals, vitamin C, and scurvy. *Quat. Int.* 500, 172–184.
1132 DOI: <https://doi.org/10.1016/j.quaint.2018.11.042>.
- 1133 Stepanchuk, V.M., Vasilyev, S.V., Khaldeeva, N.I., Kharlamova, N.V., Boruttskaya, S.B., 2017. The last
1134 Neanderthals of Eastern Europe: Micoquian layers IIIa and III of the site of Zaskalnaya VI
1135 (Kolosovskaya), anthropological records and context. *Quat. Int.* 428 (Part A), 132–150.
1136 <https://doi.org/10.1016/j.quaint.2015.11.042>.
- 1137 Therin, M., Lentifer, C. 2006. A protocol for extraction of starch from sediments. In: Torrence, R., Barton,
1138 H. (Eds.), *Ancient Starch Research*. Left Coast Press, Walnut Creek, 159–161.
- 1139 Torrence, R., Barton, H. (Eds.), 2006. *Ancient Starch Research*. Left Coast Press, Walnut Creek.
1140 DOI: [http://doi.org/10.1663/0013-0001\(2007\)61\[302a](http://doi.org/10.1663/0013-0001(2007)61[302a).
- 1141 Van Peer, P., Fullagar, R., Stokes, S., Bailey, R. M., Moeyersons, J., Steenhoudt, F., Geerts, A., T.
1142 Vanderbeken, De Dapper, M., Geus, F., 2003. The Early to Middle Stone Age Transition and the
1143 Emergence of Modern Human Behaviour at site 8-B-11, Sai Island, Sudan. *Journal of Human Evolution*
1144 (45) 187–193.
- 1145 Vasil'ev, S.A., 2008. Drevneysheye proshloye chelovechestva: poisk rossiyskikh uchenykh [The oldest
1146 past of mankind: the search for Russian scientists]. IHMC RAS, St. Petersburg (in Russian).
- 1147 Vekilova, E.A., 1957. Stoyanka Suren' I i yeyo mesto sredi paleoliticheskikh mestonakhozhdeniy Kryma
1148 i blizhayshikh territoriy [Surein I and its place among the Paleolithic sites of Crimea and the next

- 1149 territories]. In: Materialy i Issledovaniya po Arkheologii SSSR [Materials and Research in the
1150 Archaeology of the USSR] 59, 235–323 (in Russian).
- 1151 Vekilova, E.A., 1971. Kamenniy vek Krimea. Nekotorie itogi i problemi [The stone age of the Crimea.
1152 Some results and problems]. In: Materialy i Issledovaniya po Arkheologii SSSR [Materials and Research
1153 in the Archaeology of the USSR] 173, 6,117–161 (in Russian).
- 1154 Wadley, L., Blackwell, L., d'Errico, F., Siever, C., 2020. Cooked starchy rhizomes in Africa 170 thousand
1155 years ago. *Science* 367 (6473), 87–91. DOI: <https://doi.org/10.1126/science.aaz5926>.
- 1156 Yang, X., Wan, Z., Perry, L., Lu, H., Wang, Q., Zhao, C., Li, J., Xie, F., Yu, J., Cul, T., Wang, T., Li, m.,
1157 Ge, Q. 2012. Early millet use in northern China. *Proceedings of the National Academy of Science*
1158 109/10, 3726–3730. DOI: <https://doi.org/10.1073/pnas.1115430109>.
- 1159 Zamiatnin, S.N. 1957. The Palaeolithic of western Transcaucasus I: the Palaeolithic caves of Imeretia.
1160 *Sbornik Muzeja antropologii i etnografii* 17, 432-499 (in Russian).