

1 A biodiverse package of southwest Asian grain crops facilitated high-elevation agriculture in
2 the central Tien Shan during the mid-third millennium BCE

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10

11 **Abstract**

12 We report the earliest and the most abundant archaeobotanical assemblage of southwest Asian
13 grain crops from Early Bronze Age Central Asia, recovered from the Chap II site in
14 Kyrgyzstan. The archaeobotanical remains consist of thousands of cultivated grains dating to
15 the mid-late 3rd millennium BCE. The recovery of cereal chaff, which is rare in
16 archaeobotanical samples from Central Asia, allows for the identification of some crops to
17 species and indicates local cultivation at 2000 m.a.s.l., as crop first spread to the mountains of
18 Central Asia. The site's inhabitants cultivated two types of free-threshing wheats, glume
19 wheats, and hulled and naked barleys. Highly compact morphotypes of wheat and barley grains
20 represent a special variety of cereals adopted to highland environments. Moreover, glume
21 wheats recovered at Chap II represent their most eastern distribution in Central Asia so far
22 identified. Based on the presence of weed species, we argue that the past environment of Chap
23 II was characterized by an open mountain landscape, where animal grazing likely took place,
24 which may have been further modified by people irrigating agricultural fields. This research
25 suggests that early farmers in the mountains of Central Asia cultivated a high diversity of
26 southwest Asian crops during the initial eastward dispersal of agricultural technologies, which
27 likely played a critical role in shaping montane adaptations and dynamic interaction networks
28 between farming societies across highland and lowland cultivation zones.

29

30 **Introduction**

31 Crops domesticated in various locations of Eurasia spread widely to new environments unlike
32 those where they were initially cultivated. A number of crops originating in diverse landscapes
33 of what is now present-day China, such as millets, hemp and buckwheat, spread to Europe,
34 while a variety of southwestern Asian crops, such as wheat and barley, became important food

35 sources across monsoonal Asia [1–4]. In the past decade, sampling for botanical remains during
36 archaeological excavation has become routine, and subsequent analysis has transformed our
37 understanding of the timing and routes of plant dispersals through Central Asia [5,6]. Along
38 these lines, one of the most important discoveries at the forefront of this fluorescence in
39 archaeobotanical research in Central Asia was the earliest millet and wheat found together at
40 the site of Begash in the Dzhungar Mountains of Kazakhstan dated to the end of the 3rd
41 millennium BCE [5,6]. Further work across China showed that during the first half of the
42 second millennium BCE, wheat and barley became fully integrated into millet cultivation
43 systems, thus transforming agricultural strategies and culinary traditions of communities in
44 ancient China [4,5,8–10].

45

46 Many questions still remain, however, in understanding the status of domesticated crops in
47 diverse societies across Eurasia during the earliest stages of multidirectional agricultural
48 dispersals [1,11–13]. We especially have a poor understanding of what species and their
49 morphotypes were moved and why [14,15], and whether different crop species took the same
50 pathways across wide swaths of Asia [4]. An additional enigma is represented by the earliest
51 broomcorn millet and bread wheat from Begash that were found exclusively in a human
52 cremation cist without crop processing chaff [7]. As this mortuary context does not inform
53 whether these grains were consumed by people or locally cultivated, Frachetti [12] applied the
54 term “seeds for the soul” to describe a cultural context of the seeds that was focused on ritual
55 use. Recently, isotopic analysis employing incremental sampling of ovicaprid tooth enamel
56 bioapatite for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values has shown that domesticated animals at Begash and the
57 adjacent Dali site, the latter dating approximately 400 years earlier than the former, were
58 foddered with millet during winter, suggesting that the spread of pastoralist subsistence
59 eastward was intricately tied to the subsequent westward dispersal of millet [16]. While this

60 research sheds light on the intersection of the ritual use and economic value of millets, the
61 cultural status of southwest Asian crops for local Central Asian societies during this period of
62 early crop dispersals remains unclear.

63

64 Whether wheat and barley constituted a singular crop package during their dispersal remains
65 an important line of inquiry. Current evidence suggests that barley took a different pathway
66 than wheat to reach the present territory of China, as the radiocarbon dates measured on wheat
67 and barley are substantially different across China, revealing that barley had spread later by
68 people along the highland route of the Inner Asian Mountain Corridor and the southern regions
69 of the Himalayan Mountains [4]. It has also been noted that small morphotypes of wheat were
70 selected for cultivation as wheat moved eastward to China, since diminutive and rounder
71 wheats may have been better suited to the culinary traditions dominated by small-grained
72 Chinese millets [14]. On the contrary, additional research has argued that compact
73 morphotypes of both wheat and barley recovered archaeologically in environmental margins,
74 such as the highlands of Central Asia is strongly influenced by environmental adaptation rather
75 than culinary preferences [15,17–19].

76

77 It is important to emphasize that our current understanding about the initial stages of the
78 Eurasian crop interchange across Central Asia is based on an extremely small quantity of plant
79 remains recovered from only a few archaeological sites dated to the 3rd millennium BCE, such
80 as Begash and Tasbas in Kazakhstan, Sarazm in Tajikistan, and South Anau in Turkmenistan
81 [20–23]. For example, at Begash (2450–2100 cal BCE), cultivated crops are represented only
82 by 13 compact free-threshing wheat grains, one barley grain, and 61 grains of broomcorn
83 millet, while at Tasbas (2840–2496 cal BCE) just five compact free-threshing wheat grains
84 were found, in addition to 11 ambiguously identified “Cerealia” grains [18,23]. Such a small

85 quantity of domesticated plant grains per site does not allow us to understand cultivation
86 strategies, the relative importance of consumption versus ritual use, or the coherence of early
87 agricultural packages.

88

89 Here, we present an early archaeobotanical assemblage consisting of five cultivated crops of
90 southwest Asian origin recovered from the high-elevation Chap II site located in the central
91 Tien Shan Mountains of Kyrgyzstan. The archaeobotanical samples represent the largest crop
92 assemblage so far found at 3rd millennium BCE sites between the Pamir, Tien Shan, and Altai
93 Mountains, representing thousands of carbonized cereal remains. The assemblage reflects a
94 strikingly high degree of biodiversity in wheat and barley grain morphotypes. Analysis of the
95 accompanying weed taxa recovered from Chap II hints on the past ecology of cereal cultivation,
96 suggesting that crops may have been grown with the aid of irrigation, while recovered chaff
97 fragments indicate local cultivation and processing. Notably, we present chaff and grain
98 remains of glume wheat that, for the first time, were recovered from the eastern regions of
99 Central Asia.

100

101 **The Chap II site**

102 The Chap II site is located in the Kochkor valley of central Kyrgyzstan at 2000 m.a.s.l.
103 (42°10'51.7" N, 75°51'3.64" E). The site is situated inside the inundation of a small loess hill
104 that protrudes from the foothills into the southeastern part of the 80-km long Kochkor valley
105 (Fig 1). The archaeological remains of Chap II were recovered through excavation of the Chap
106 I farmstead (1065-825 cal BCE), which was occupied during the transitional period from the
107 Late Bronze Age to the Early Iron Age [24]. In previous years, a small 6.5x6.5 m trench was
108 excavated that yielded a diverse assemblage of ceramic sherds, crop processing tools, domestic

109 animal skeletal remains, carbonized remains of domesticated grains and chaff, which together
110 reflect extensive agricultural and pastoralist activities by the inhabitants of the Chap I site [24].

111

112 **Fig 1.** The bird's eye view (a) and the perspective view (b) (courtesy of Google Earth) (b) of
113 the Kochkor valley facing west, with location of the Chap site shown situated near the village
114 of Karasu and Kochkor city. (c) The Chap site in relation to other archaeobotanically
115 analyzed sites in Kyrgyzstan.

116

117 The Chap II site is located stratigraphically below the occupational layers of Chap I and was
118 excavated in the summer of 2019. Chap II is separated from the final occupational strata of
119 Chap I by a *ca* 1-m thick loess deposit. The archaeological horizon of Chap II consists of two
120 ash pits (referred as pit 1 and pit 2), containing burned animal bones, one small fragment of
121 pottery, and abundant carbonized plant remains. The pits are separated from one another by a
122 sterile, 10-cm thick horizon; pit 1 is stratigraphically above pit 2, likely reflecting different
123 formation events. The bottom portion of pit 2 reaches a depth of 260 cm above the modern
124 surface and cradles a large, in-situ boulder. The deposition of pit 1 and 2 most likely were the
125 result of discarded domestic waste, since the pits were not associated with discernable features
126 that could be interpreted as being used for mortuary purposes or other commemorative
127 practices.

128

129 **Methods**

130 **Archaeobotanical analysis**

131 We followed the British Heritage strategy of macrobotanical sampling by collecting at least 40
132 L of sediment from two different areas of each archaeological context. This sediment volume

133 produces a more comprehensive diversity of plant taxa in archaeological deposits than that
134 yielded from sample volumes of 10 L, which in turn, better reflects human subsistence
135 activities [25]. Bucket flotation using a 0.3 mm screen was used to float sediment samples. In
136 total, 136 L of sediment from the two discernible ash pits were floated: 40 L from pit 1 and 96
137 L from pit 2. The flotation samples were analyzed archaeobotanically at the Bioarchaeology
138 Research Centre of Vilnius University, where they are currently archived. The
139 stereomicroscope and the reference collection of Bioarchaeology Research Centre, including
140 botanical seed atlases, were used to identify and quantify plant remains [26,27]. No permits
141 were required for the described study, which complied with all relevant regulations.

142

143 **Radiocarbon dating**

144 Radiocarbon dating of carbonized grains by accelerator mass spectrometer (AMS) ^{14}C dating
145 was performed at the 14CHRONO Centre for Climate, the Environment, and Chronology,
146 Queen's University Belfast. Three cereal caryopses collected from flotation samples were
147 selected for direct dating: two wheat grains from pit 1 and one barley grain from pit 2.
148 Radiocarbon determinations were calibrated using IntCal13 calibration curve [28], which were
149 modelled in OxCal v. 4.3 [29] according to their stratigraphic positions relative to previously
150 identified occupational layers yielding ^{14}C dates of domesticated grains recovered from Chap
151 I previously reported by Motuzaitė Matuzevičiūtė et al. [24].

152

153 **Results**

154 **Cultivated plants**

155 The archaeobotanical assemblages of pits 1 and 2 are dominated by grains and chaff of free-
156 threshing and glume wheats and also barleys of naked and hulled varieties. In total, 661 free-

157 threshing wheat caryopses (*Triticum aestivum/durum*), including whole and slightly
158 fragmented grains, were recovered. The free-threshing wheat grains have highly compact
159 morphotypes with strikingly large variation in grain size, ranging from 6 to 2.4 mm in length,
160 4.2 to 1.8 mm in breadth, and 3.4 to 1.2 mm in depth. The majority of wheat grains probably
161 belong to two free-threshing species of *T. durum* and *T. aestivum* (Fig 2). The grains of those
162 species were counted together, yet the presence of rachis internodes belonging to bread wheat
163 and durum wheat shows that the assemblage contains both species (Table 1) (Fig 3a, b).

164

165 **Fig 2.** The compact wheat varieties from the Chap II site. The images of wheat show large size
166 variation.

167

168 Sixteen grains of glume wheat, probably representing emmer wheat (*T. dicoccum*), were
169 distinct from the free-threshing wheat grains, based on the grains having narrower widths as
170 compared to free-threshing wheat and also exhibiting shallow, elongated and blunted apexes
171 and embryo notches, higher dorsal ridges (keel) and slight deflections on the ventral side (Fig
172 3d). The recovery of one fragment of a glume base clearly shows the presence of glume wheat
173 in the archaeobotanical assemblage of Chap II (Fig 3c).

174

175 **Fig 3.** Rachis internodes of free-threshing hexaploid wheat (*Triticum cf. durum*) (a), *Triticum*
176 *cf. aestivum* (b); Glume base and grains of glume wheat (*Triticum cf. dicoccum*) (c, d).

177

178 The majority of recovered barleys belong to highly compacted varieties of *Hordeum vulgare*
179 var. *nudum*., totaling 257 grains. As observed in wheat, the naked barley grains also vary
180 widely in size and shape, ranging from 6.4 to 2.7 mm in length, 4.3 to 1.8 mm in breadth, and
181 3.5 to 1.2 mm in depth (Fig 4). Surprisingly, the measurements of barley are similar to the

182 measurements of wheat. In fact, some of the barley grains were so strongly compacted, that
183 differentiating them from wheat was only possible from the lateral view (Fig 4). Three barley
184 grains were identified to hulled barley varieties. At Chap II, most barley remains are
185 represented by symmetrical grains, probably belonging to two- or four-row varieties. Counting
186 partial and whole grains together, both pits yielded 482 grains of barley. Due to fragmentation,
187 2040 grain remains were identified as “Cerealia” type.

188

189 **Fig 4.** Highly compact morphotypes of naked barley from Chap II.

190

191 It was surprising that no remains of East Asian crops were recovered from the flotation
192 samples, such as broomcorn or foxtails millet, which were present at Chap I [24]. Interestingly,
193 34 carbonized food fragments, up to 9.5 mm in size, were also identified. These remains were
194 characterized by porous or amorphous-like matrices and a burned, lumpy conglomerate, some
195 containing cereal bran fragments. These charred food pieces probably represent the remains of
196 bread or porridge. The food fragments were not analyzed in this study but will be the subject
197 of future research.

198

199 **Wild plants**

200 The most common seed remains in the wild plant assemblage were from *Chenopodium* sp.
201 (goosefoot), represented by 760 carbonized grains (Table 1). *Chenopodium* plants normally
202 represent ruder weeds that grow in nitrogen-rich, former domestic spaces [30,31]. The second
203 most abundant wild seeds were from *Carex* sp. (sedges), totaling 658 carbonized grains (Table
204 1). Five morphotypes of *Carex* caryopses were identified, which likely all belong to different
205 species (Fig 5). Most *Carex* plants grow in wetland ecosystems and tolerate saline waters [32].
206 The presence of sedge seeds among the domesticated grains at Chap II could mean that crops

207 were grown in close proximity to sedges, possibly along irrigated channels or mountain
208 streams. The other wild species are represented by smaller seed counts. The majority of them
209 reflect open meadow, arable and possibly irrigated landscapes, such as *Salsola kali*, *Polygonum*
210 sp. or *Galium* sp. (Table 1). Moreover, the majority of taxa are not found in the undergrowth
211 of forests [33,34], which helps illustrate a local environment surrounding Chap II that was
212 devoid of trees.

213

214 **Fig 5.** The five types of *Carex* sp. (sedges) found at Chap II.

215

216 **Table 1.** Archaeobotanical identifications from Chap II.

217

		Context	Pit 1	Pit 2	Total
	Family	Taxa			
Domesticated	Poaceae	<i>Triticum aestivum/durum</i>	118	204	322
		<i>Triticum aestivum/durum</i> (fragments)	81	258	339
		<i>Triticum aestivum</i> and <i>T. durum</i> (rachis internode)		2	2
		<i>Triticum</i> cf. <i>dicoccum</i>	5	11	16
		<i>Triticum</i> cf. <i>dicoccum</i> (rachis internodes)		1	1
		<i>Hordeum vulgare</i> (naked)	125	132	257
		<i>Hordeum vulgare</i> (hulled)	2	1	3
		<i>Hordeum</i> sp. (fragments)	106	116	222
		<i>Cerealia</i> (fragments)	688	1361	2049
Wild	Amaranthaceae	<i>Chenopodium</i> sp.	280	480	760
		<i>Amaranthus</i> sp.	4	2	6
		<i>Salsola kali</i>	12	18	29
	Caryophyllaceae	<i>Cerastium</i> sp.		2	2
		<i>Vaccaria</i> sp.		2	1
	Cyperaceae	<i>Carex</i> sp. (five types)	209	449	658
	Fabaceae	<i>Pisum/Vicia</i> sp.		1	1
		<i>Trifolium/Melilotus</i> sp.	2	5	7
		<i>Medicago/Trifolium</i> sp.		6	6
		<i>Hippocrepis comosa</i>		1	1
	Poaceae	<i>Agrostis</i> sp.	1		1
		<i>Stipa</i> type		2	2
		<i>Bromus</i> sp.	5	1	6
		Poaceae		1	1
	Polygonaceae	<i>Polygonum</i> sp.		5	5

	Ranunculaceae	<i>Ranunculus</i> sp.		2	1
	Rosaceae	<i>Potentilla</i> sp.		1	1
	Rubiaceae	<i>Galium</i> sp.	14	24	38
	Lamiaceae	<i>Thymus</i> sp.		1	1
		Bread/food remains	9	25	34

218

219 Radiocarbon dating

220 Three radiocarbon determinations were measured on two individual wheat grains from pit 1
 221 and one individual barley grain from pit 2. Showing consistency with the relative stratigraphic
 222 position of pit 2 below pit 1, the modelled date of the barley grain from pit 2 is 2467-2292 cal
 223 BCE, while the wheat grains from pit 1 together provide a modelled date of 2402-2047 cal
 224 BCE (Table 2; Fig 6). Overall, the two pits date to nearly 1500 years before the occupation of
 225 Chap I, raising the possibility that the site was abandoned for a considerable amount of time
 226 during the second millennium BCE (Fig 6).

227

228 **Fig 6.** The images of directly radiocarbon dated naked barley from pit 2 (top) and free-threshing
 229 wheat grains (middle and bottom) from pit 1 with listed calibrated dates from Chap II site.

230

231 **Table 2.** AMS radiocarbon dates measured on macrobotanical remains recovered from Chap
 232 II. Previously published radiocarbon dates taken on domesticated grains from Begash [7] and
 233 Tasbas [23] are also shown to help contextualize the chronology of Chap II.

Site	Dated material	Context	Lab number	¹⁴ C age BP	±	Calibrated age (cal. BCE 95.4% range)	Modelled age (cal BCE 95.4% range)	Modelled mean age (cal BCE)
Chap II	Wheat	Pit 1	UBA-41509	3754	33	2284-2038	2294-2047	2195
Chap II	Wheat	Pit 1	UBA-41508	3857	31	2462-2284	2402-2204	2299
Chap II	Barley	Pit 2	UBA-41507	3899	30	2469-2297	2467-2292	2371
Begash ¹	Wheat & broomcorn millet	Burial cist	Beta-266458	3840	40	2460-2150	-	-
Tasbas ²	Wheat	Burial cist	Beta-391200	4010	30	2617-2468	-	-

234

235 **Fig 7.** Modelled radiocarbon dates measured on wheat barley grains from Chap II in relation
236 to the occupational period of Chap I previously reported by Motuzaitė Matuzevičiūtė et al.
237 [24].

238

239 **Discussion**

240 Dated to the middle to second half of the 3rd millennium cal BCE, the archaeobotanical
241 assemblage of Chap II represents the earliest and the most abundant assemblage of cereal and
242 wild plant macrobotanical remains in eastern Central Asia and is further notable for its recovery
243 at 2000 m.a.s.l. Contrary to previous suggestions that an initial eastward dispersals of wheat
244 and barley may have diverged from one another upon reaching the Inner Asian Mountain
245 Corridor [4], the early co-occurrence of both wheat and barley in similar proportions at Chap
246 II suggests that these crops spread into the highlands of Central Asia as a package. This scenario
247 indicates that people engaging in plant cultivation in the Tien Shan were equally invested in
248 varieties of wheat and barley that already had been adapted to high elevations, where short
249 growing seasons and low temperatures impose considerable difficulties for farmers. The
250 biodiversity of crops, reflected in both the compact grain morphotypes, large variation in cereal
251 grain sizes, and relative abundance of taxa, present at Chap II illustrates subsistence strategies
252 that likely favored agricultural resilience by safeguarding crop production from extreme and
253 uncertain weather conditions characteristic of montane environments. However, it is notable
254 that the archaeobotanical assemblage of Chap II lacks Chinese domesticates of millet, which
255 provide agriculturalists with additional flexibility in production on account of millets having
256 short growing seasons and drought tolerance. The fact that broomcorn millet was recovered at
257 Begash located at 900 m.a.s.l. [7] and likely cultivated there and at Dali located at 1500 m.a.s.l.
258 [16], both in the neighboring region of Semirech'ye (southeastern Kazakhstan), had previously

259 implied that millet may have also reached the central Tien Shan by the end of the third
260 millennium BCE. The definitive absence of millet at Chap II may indicate that 1) interaction
261 networks reaching into the northern stretches of the Inner Asian Mountain Corridor did not
262 connect people living in the central Tien Shan or 2) an elevational ceiling for successful
263 cultivation below 2000 m.a.s.l. existed for millet cultigens in the third millennium BCE. During
264 the occupation of Chap I 1500 years later, millets formed an important component of the local
265 crop repertoire, potentially overcoming prior environmental constraints [35].

266

267 The archaeobotanical assemblage at Chap II site is dominated by domesticates of southwest
268 Asian origin: free-threshing wheats (possibly *T. durum* and *T. aestivum*) and both naked and
269 hulled barleys. The free-threshing wheat grains correspond to compact wheat forms noted in
270 the Dzhungar Mountains of Semirech'ye [6,18,19]. Furthermore, archaeobotanical research in
271 Kyrgyzstan identified compact wheat forms at the sites of Uch Kurbu, Aigyrzhal-2, and Mol
272 Bulak located in the highland regions (Fig 1c) [15,17], which suggests that compact wheat
273 morphotypes are adapted to high elevations. Other researchers have also noted the suitability
274 of compact wheats for agriculturalists in marginal environments of south and east Asia, such
275 as monsoonal areas of India and the highlands of the Tibetan plateau [14,36]. It has been argued
276 that, compared to non-compact forms, compact varieties of wheat exhibit greater standing
277 power against extreme weather conditions, such as strong winds and intense rains that can
278 cause lodging and stem breakage [15]. In addition to compact forms, large variation in wheat
279 grain size was also noted for the wheats at Chap II, ranging from 6.0 to 2.4 mm in length, 4.2
280 to 1.8 mm in breadth and 3.4 to 1.2 mm in depth. This wide variation in grain size may be the
281 result of environmental factors that crop plants were exposed to during grain development.
282 Previous experimental research has shown that plants experiencing physiological stress from
283 differences in water availability, ambient temperature, or amount of nutrients during grain

284 filling resulted in grain size diminution, due to interference in the deposition of carbohydrates
285 in the grains [37–42]. In addition, Reed [43] also showed that grains from a single ear of spelt
286 wheat exhibited a wide variety of sizes, indicating that variability in grain size can also be due
287 to heterogeneous ripening times of grains on the ear.

288

289 It is noteworthy to point out that the biometrical data for wheat grains recovered from Bronze
290 and Iron Age sites in Kyrgyzstan substantially overlap with that of wheat grains from second
291 millennium BCE sites in north western China [14,15]. In eastern regions of monsoonal China,
292 however, ancient wheat grains show dramatically smaller sizes and follow a more uniform size
293 distribution, which suggest that the eastward spread of wheat was associated with an overall
294 convergence to diminutive grains [14]. Further research is needed in order to understand
295 whether the reduction in wheat grain size in monsoonal China was influenced by climate,
296 human choice, or the geographical origins of particular wheat morphotypes.

297

298 The presence of two types of free-threshing wheat rachis internodes (Fig 3) and the large
299 diversity of wheat grain morphotypes found at Chap II and at other sites in Kyrgyzstan, such
300 as Argyrzhali-2 and Uch-Kurbu [17], suggest that probably both tetraploid and hexaploid free-
301 threshing wheat were cultivated. In China, archaeobotanical research mainly reports grain
302 morphology, thus offering opportunities for future analysis of rachis internodes to test whether
303 both tetraploid and hexaploid free-threshing wheats were cultivated there and, possibly, to
304 resolve the timing and dispersal routes of these species.

305

306 The discovery of glume wheat at Chap II site during early phases of southwest Asian crop
307 dispersals to the central Tien Shan is also important for understanding the limits of its eastward
308 spread. Current evidence suggests that the cultivation of glume wheat did not reach the present-

309 day territory of China at the initial stage of southwestern crop dispersal during the third-second
310 millennia BCE. The free-threshing wheats were selected instead of glume wheats as they
311 dispersed eastwards from centers of domestication in southwest Asia [44]. Most ancient
312 Chinese wheat remains are hexaploid free-threshing *Triticum aestivum* [45–47], in contrast to
313 the types of wheat recovered from Neolithic and Bronze Age sites in southwestern Asia, where
314 agriculture was mainly based on glume wheat [44].

315

316 A review by Stevens et al. [44] reported modern glume wheat varieties (*T. aestivum* var.
317 *tibeticum* JZ Shao) in western China with limited distribution in Yunnan, Tibet, and Xinjiang,
318 in addition to a glume wheat variety in Yunnan (*Triticum aestivum* subsp. *yunnanense* King ex
319 SL Chen). Notably, the rachis internode of the glume wheat recovered from Chap II does not
320 resemble that of typical glume wheat belonging to *T. dicoccum* found in Europe. Comparing
321 the glume wheat internode bases from Chap II with those previously reported at the
322 *Linearbandkeramik* site of Ratniv-2 site located in western Ukraine [48], the curve between
323 glume and glume base at Chap II is straighter and *ca* 25% larger. Therefore, glume wheat at
324 Chap II could represent local Central Asian variety or be related to modern Chinese varieties
325 mentioned above. A few grains of glume wheats (but no chaff) have also been recently reported
326 from Kanispur site in Kashmir, dating by associated charcoals to a similar period as Chap II in
327 the third millennium BCE [49]. Further research is needed to understand why glume wheats
328 were used but later disappeared from the package of cultivars among mountain communities
329 of eastern Central Asia.

330

331 The archaeobotanical assemblage of Chap II is dominated by naked varieties of barley, which
332 became commonly cultivated across the Tibetan plateau [36,50]. The reason for the dominance
333 of naked forms of barley in the highlands of Asia is not clear, but it has been suggested that

334 cultural preference was the main factor for selecting naked over hulled barleys [50]. However,
335 naked barley is better adopted to highland environments, especially those characterized by
336 strong continental climates [51,52]. In mountain cultivation areas, naked varieties produce
337 higher grain yields, generate more overall biomass, and mature faster than hulled varieties [53].

338

339 The finding of highly compacted barley at Chap II is also particularly interesting as it reveals
340 what morphotypes were selected by early farmers inhabiting mountainous landscapes and gives
341 insight on crop adaptation in these highland regions during the third millennium BCE. Future
342 studies comparing metrical variation of lowland and highland barley grains and chaff could
343 lead to a better understanding of how barley varieties were advantageous in certain
344 environmental niches. Knüpffer [52] note that landraces of modern naked barleys collected
345 from the high-mountain regions of Central Asia are short with thick, lodging straw and have
346 grains that are more compact and spherical than those of taller barley varieties.

347

348 It has been suggested that plump forms of wheat and six-row naked barley, in particular, are
349 water-demanding crops that likely required irrigation or high amounts of rainfall for successful
350 cultivation in western Central Asia and the Near East [54]. The possibility that the inhabitants
351 of Chap II used irrigation in the Kochkor valley cannot also be ruled out. It is plausible that
352 irrigation technologies spread together with the first farming communities to the central Tien
353 Shan and further eastwards to China [55]. The occupation of Chap II during the second half of
354 the third millennium BCE coincides with the Subboreal climate period of dry and cold
355 conditions [56,57]. People may have been motivated to seek out high-mountain water sources,
356 such as perennial springs, when the lowlands were characterized by water shortages due to
357 glacial melt waters decreasing as precipitation diminished and ice sheets expanded. Moreover,
358 herding domesticated animals would have also motivated people to seek highland settlements

359 near rich, montane pastures, where they could have integrated pastoralist and plant cultivation
360 strategies through foddering with agricultural byproducts and dung manuring [16]. One of the
361 dominant species of wild plants at Chap II is *Carex* sp. (sedges), that normally grow in wetland
362 environments, which suggests widespread availability of water-saturated soils. Although the
363 archaeological deposition of sedges at Chap II remains may be the result of animal foddering
364 or craft production, the finding of sedges among cultivated crops at the Bronze Age Kültepe-
365 Kanesh archaeological site in Turkey led researchers there to suggest that crops were watered
366 by irrigation channels [58]. Currently, sedges grow along modern irrigation channels in the
367 Kochkor valley. At Chap II, the fields were probably located in close proximity to water
368 sources, either irrigated channels or natural streams that could be easily redirected. Stable
369 isotopic analysis of the grains recovered at Chap II is needed to examine watering regimes for
370 local plant cultivation, as has been previously applied elsewhere [59,60].

371

372 Wild plants and ruderal weeds recovered from Chap II are dominated by *Chenopodium* sp.,
373 which together with *Galium* sp., normally inhabit nitrogen-rich domestic settings modified by
374 intensive pastoralist herding and corralling [30]. The few faunal skeletal remains were
375 recovered from Chap II (~25 specimens), likely represent domesticated ruminant species. The
376 presence of domesticated sheep and goats dated to ~2700 cal BCE were identified by
377 mitochondrial DNA at Dali located in the Dzhungar Mountains of southeastern Kazakhstan
378 [16]. It is possible that pastoralist subsistence spread northward through the Tien Shan
379 mountains along the Inner Asian Mountain Corridor earlier than the occupation of Chap II [61],
380 although additional excavation of a wider area of Chap II will aid in the recovery of additional
381 faunal specimens. Judging from the rest of the wild plant and weed taxa, it is difficult to be
382 certain whether the recovered crops from Chap II were sown in the autumn or spring. Most of
383 the abundant wild plants, such as *Chenopodium* sp. and *Galium* sp., are attributed to summer

384 annual plants, which hints to spring-sown varieties of wheat and barley. Nonetheless, the
385 subsistence strategies in effect at Chap II during the second half of the third millennium BCE
386 likely involved intensive investment in plant cultivation of numerous cultigens with varied
387 cultivation schedules, in addition to people also engaging in pastoralist herding involving
388 varied mobility strategies.

389

390 **Conclusions**

391 The Chap II site yielded the largest crop assemblage dated to the third millennium BCE
392 between Pamir, Tien Shan, and Altai mountains, comprising thousands of cultivated cereal
393 remains with the presence of two species of free-threshing wheat (bread wheat and durum
394 wheat), glume wheat, and hulled and naked barley. Radiocarbon determinations derived
395 directly from wheat and barley grains show that Chap II was occupied between 2467-2047 cal
396 BCE. Analysis of the accompanying weed taxa recovered from Chap II hints at an open
397 landscape where pastoralist herding likely took place. The dominance of wetland plants in the
398 assemblage also suggests that cultivated crops may have been irrigated, which would imply
399 that this technology spread hand in hand the cultivation of southwest Asian crops. Finally, the
400 chaff and grain remains of glume wheat represents the first time this species was recovered in
401 the most eastern regions of Central Asia, which critically invigorates a new discussion about
402 why and where glume wheats became filtered out of crop repertoires as other southwest Asian
403 crops spread to the eastern parts of Eurasia.

404 **Acknowledgements**

405 This research is funded by the European Social Fund according to the activity ‘Improvement
406 of researchers’ qualification by implementing world-class R&D projects’ of Measure No.

407 09.3.3-LMT-K-712. We would like to acknowledge 14Chrono Centre at Queen's University
408 Belfast for providing radiocarbon dates at the collaborator's rate.

409

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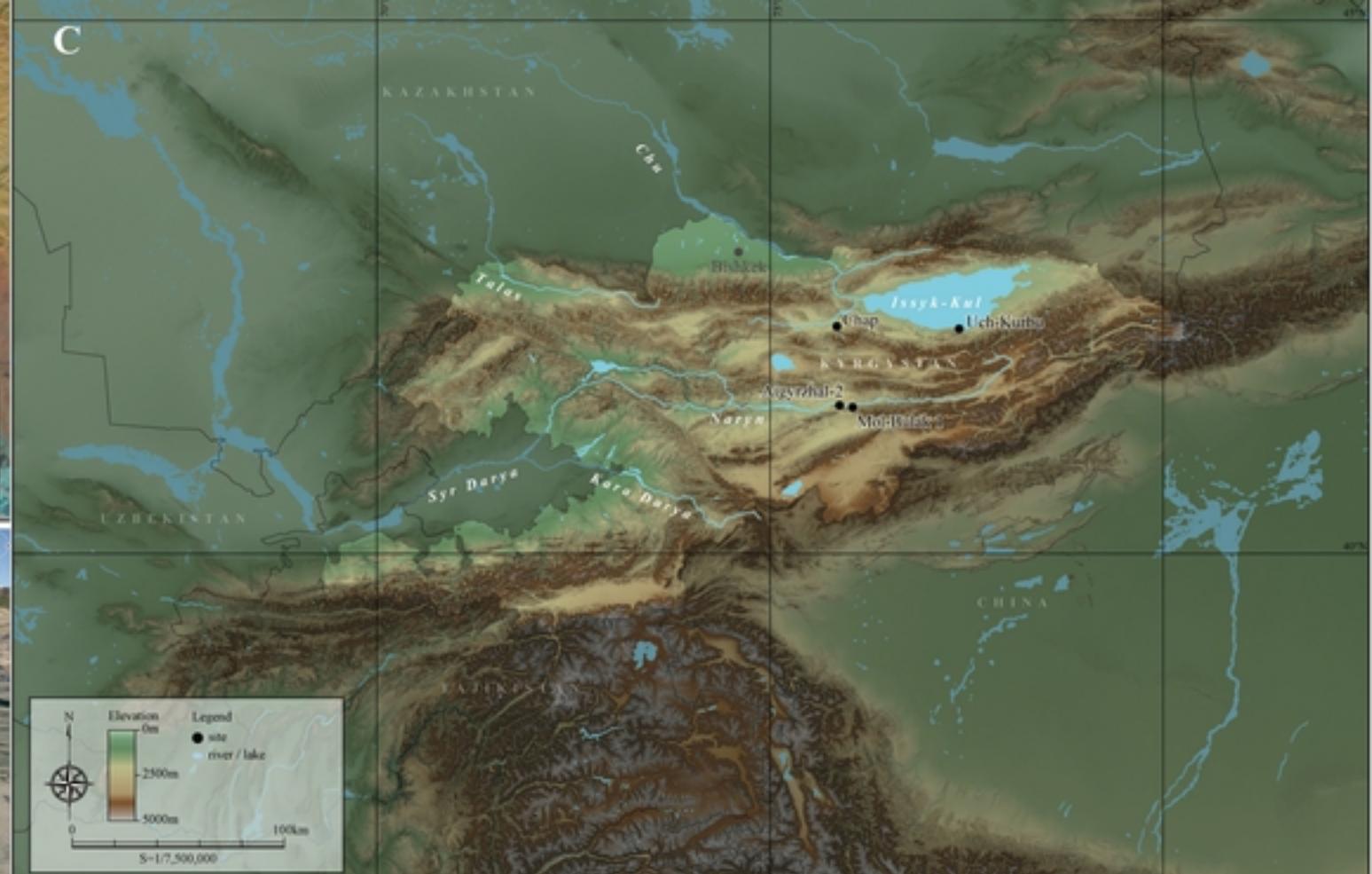
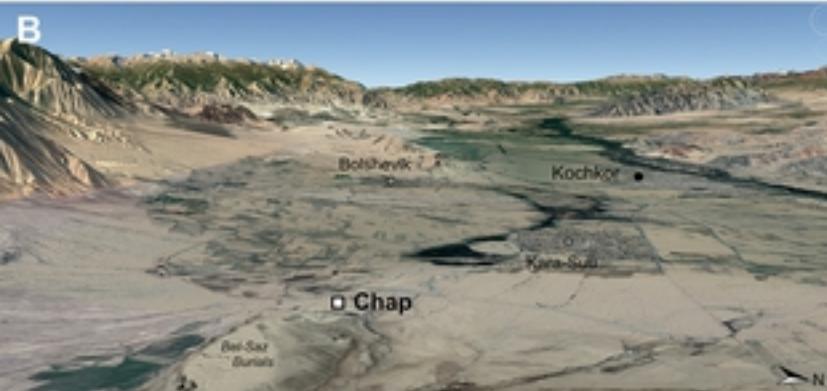
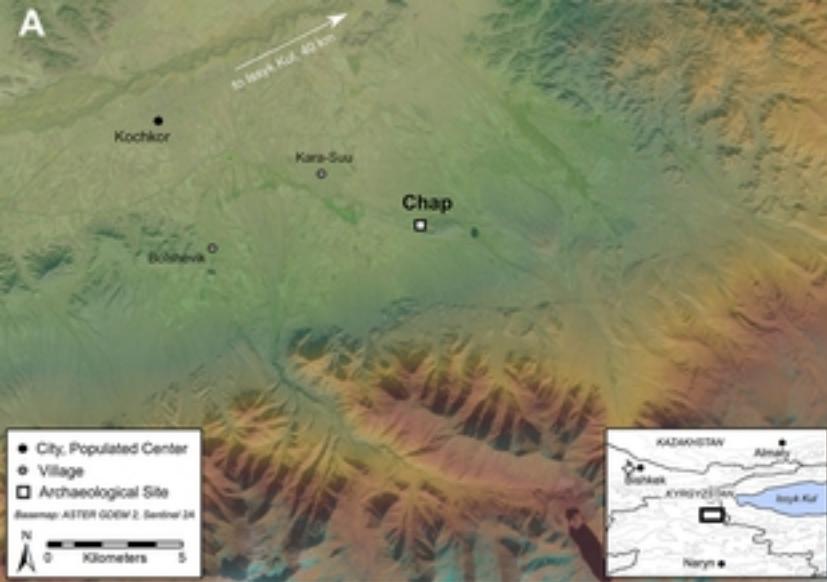


Figure 1

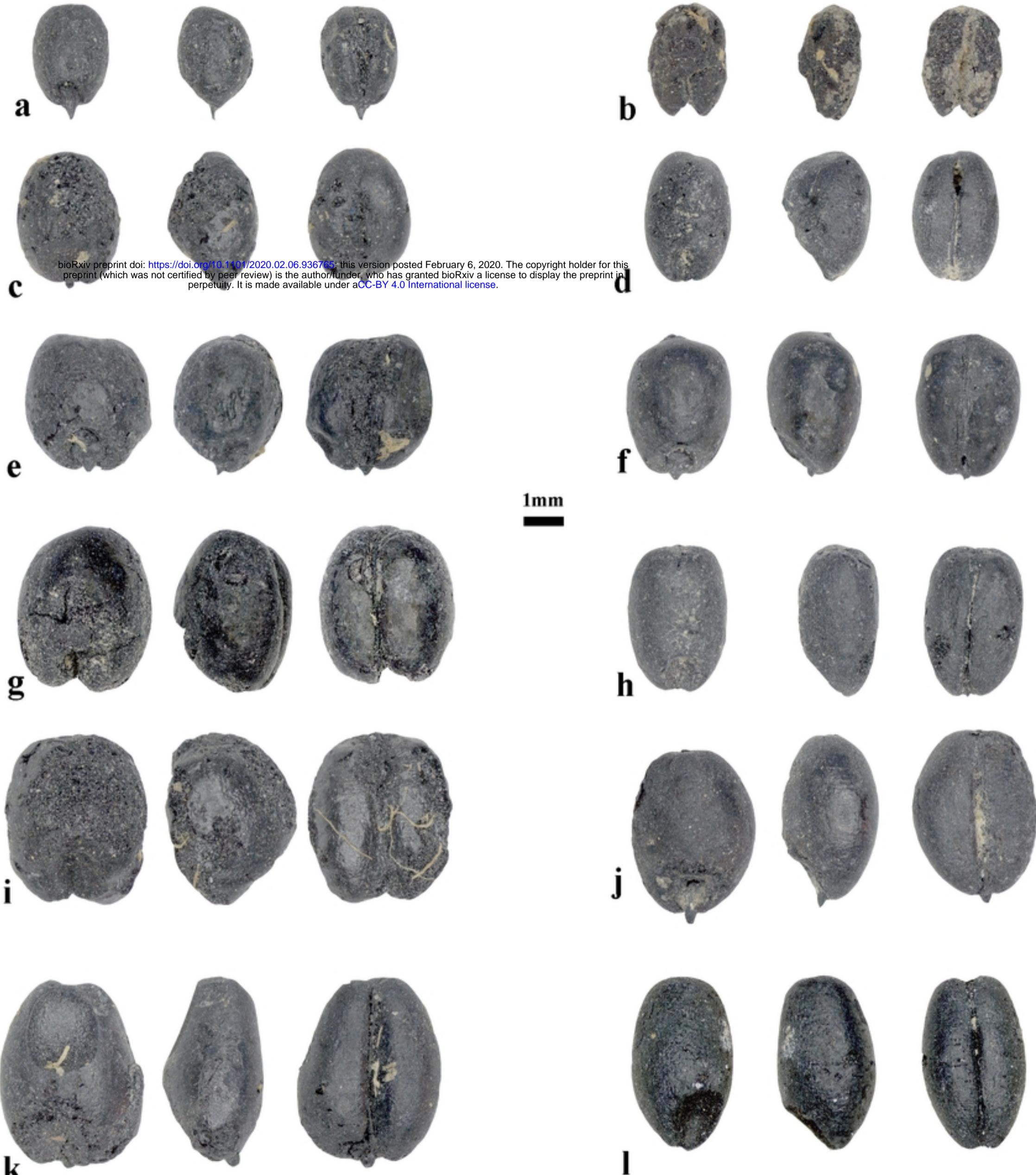


Figure 2

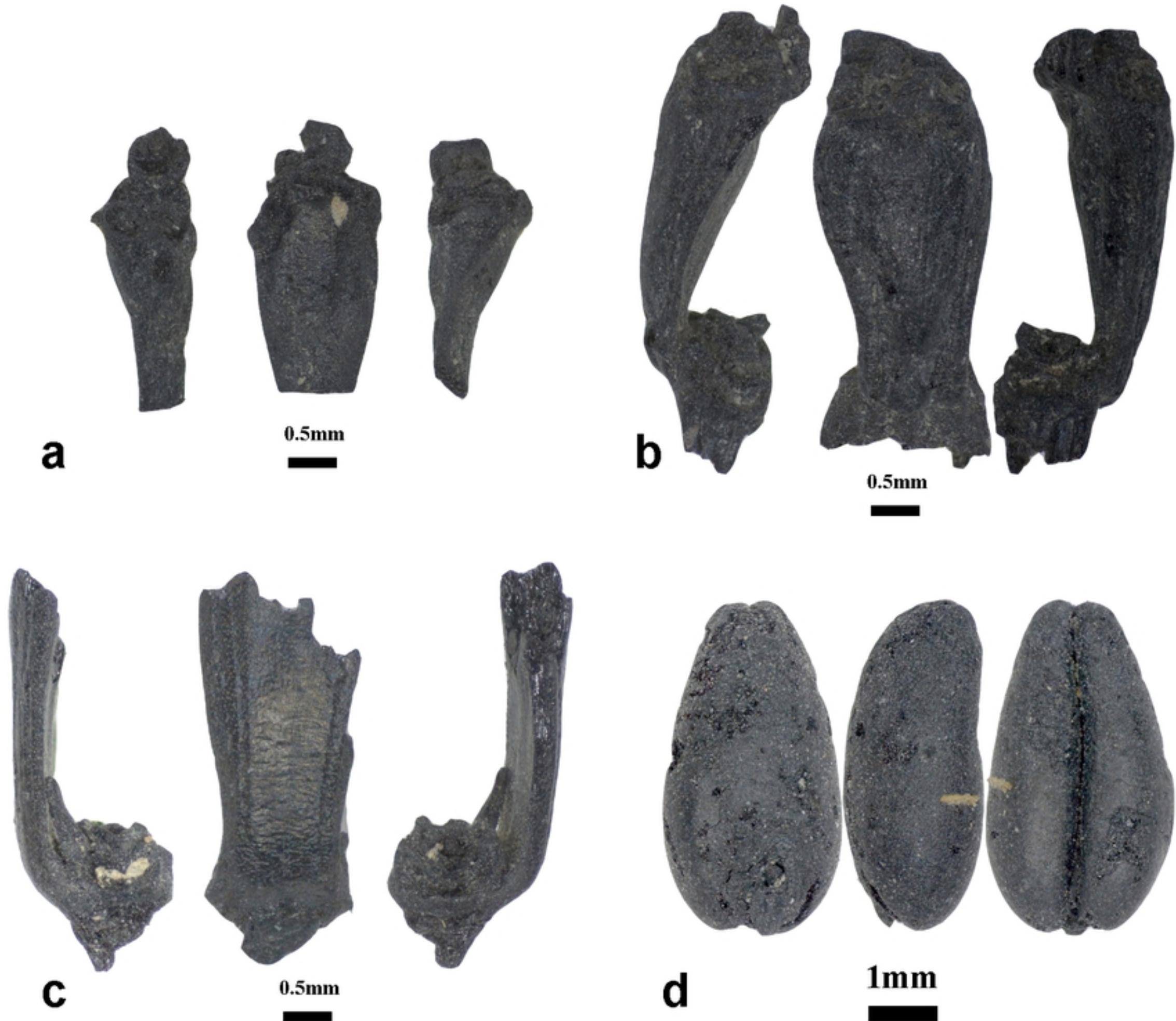


Figure 3



a



b



c



d

1mm



Figure 4



Figure 5



2469-2297 cal BCE
[UBA-41507]

0.5mm



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2462-2208 cal BCE
[UBA-41508]

0.5mm



2284-2038 cal BCE
[UBA-41509]

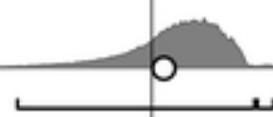
0.5mm



Figure 6

Chap II

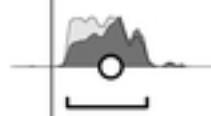
Start of occupation



Ash deposits

Pit 2

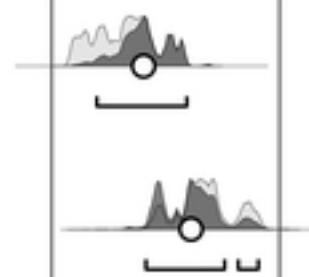
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Pit 1

UBA-41508

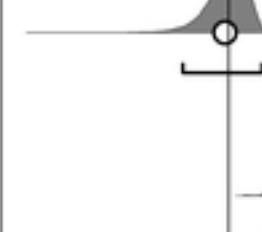
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End of occupation



Start of Chap I



End of Chap I



5000 4500 4000 3500 3000 2500 2000 1500 1000 500

Modelled date (BC)

Figure 7