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This paper contributes to understand the palaeoenvironment and the exploitation of vegetal resources during the Mid-Holocene in the southern Crimean Mountains. To address these questions, we apply a multi-proxy approach based on charcoal, seeds/fruits and phytoliths analyses from Neolithic layers (5800–5300 cal BC) of Buran-Kaya IV, a rock-shelter located in the south of Crimean Peninsula. Charcoal analysis shows that the Neolithic groups have exploited the Quercus petraeae forest belt composed mainly of Quercus, Carpinus and Acer. The identification of Fagus and a fragment of gymnosperm, which developed in upland areas, suggests the mobility of inhabitants of BK IV. According seed and phytolith analyses, it is more likely that the Neolithic groups did not practice agriculture on the site, and that their diet was not based on crop production. Furthermore, considering the probable absence of domestic animals in the layer 2, the economy may essentially be based on hunting-gathering at Buran Kaya IV.

Keywords: Archaeobotany, Woodland exploitation, Vegetal use, Archaeozoology, Holocene, Neolithic, Crimea Peninsula, Ukraine, South-Eastern Europe

Introduction

The Neolithic period in the Crimean peninsula is very poorly documented. Formozov (1962), Krajnov (1960) and Yanevich (1998, 2008) had published the main characteristics of the Neolithic period in Crimea. The Early Neolithic period in this region is characterised by the emergence of pottery making and changes in flint tool-making technologies (Kolosov 1985; Telegin 1977). The process of the Neolithic cultural expansion in Crimea is different from the one found in continental Ukraine. For that reason, Crimean archaeological evidences are often discussed separately in archaeological literature (Telegin 1985).

To date, very few archaeobotanical data are available in Crimea for the end of the Pleistocene and the Holocene periods. The main archaeobotanical data come from pollen investigation from archaeological sites, such as in Buran Kaya III, a rock-shelter closed to Buran Kaya IV (Gerasimenko 2007). The scarcity of archaeobotanical investigations at Mesolithic and Neolithic Crimean sites does not allow to characterise the nature and the process of domestic plants acquisition in these regions. In Crimea, the first evidence of domestic cereal consumption (*Triticum* cf. *dicoccum* and *Triticum* cf. *monococcum*/*T. dicoccum*) is recorded at Ardych-Burun, a shell-midden site dated to the middle of the 4th millennium cal BC (Motuzaite-Matuzeviciute 2013).

Moreover, the southern Crimea is considered as a potential forest refuge during the Last Glacial Maximum (Serebriany 2002). However, the chronology and distribution of the Post-glacial tree species in southeastern Europe have to be better understood (Cordova *et al.* 2009; Messager *et al.* 2013; Wright *et al.* 2003). The presence of different glacial tree refugia and the huge contrast between inland and littoral areas are hypothesised. Thus, the vegetation

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history of Crimea requires further investigations to understand the precise chronology of forest expansion.

This paper is thereby a contribution to understand the palaeoenvironment and the exploitation of vegetal resources during the Mid-Holocene in the Piedmont area of the southern Crimean Mountains. It focuses more precisely on the comprehension of the woodland composition and territories exploited for firewood collecting as well as the nature of plant economy and subsistence strategies during the second half of the 6th millennium BC in Crimea. To address these questions at Buran Kaya IV, we apply for the first time a multi-proxy approach based on charcoal, seeds/fruits and phytoliths analyses.

Setting

The rock-shelter of Buran Kaya IV (BK IV) is located in the south of Crimean Peninsula. Crimea constitutes a land bridge linking Ukraine and the western part of Caucasus and its southern part is mainly composed of mountain ridges (Crimean Mountains). The BK IV site is situated in the Belagorsk region, ca. 30 km northeast from Simferopol and 5 km south from Aromatnoe (Fig. 1). The rock shelter culminates ca. 330 m above sea level and overhangs ca. 9 m above the Burulcha river. It takes place in a Piedmont area at the transition between the steppes from the northern lowlands and the forests from the southern mountains. Today, the site is currently surrounded by a mid-altitude grassland with deciduous forest patches mainly composed of *Quercus* spp. and *Carpinus orientalis* woodlands. Mean summer temperature is 22°C while mean winter temperature is 2°C. Rainfall ranges from 350 to 600 mm/year.

BK IV was discovered in 1994 by A. Yanevich, from the National Academy of Science of Ukraine (NASU). Excavations began in 2008 under the co-direction of the NASU and the Tokyo Metropolitan University (M. Yamada). Since 2010, excavations are carried out by the NASU in collaboration with the French National Museum of Natural History (MNHN: S. Péan, L. Crépin, S. Prat and S. Puaud). BK IV consists of 5-m-thick stratigraphy with archaeological layers (ALs) extending from the Palaeolithic period to Medieval times. This paper focuses on the stratigraphic unit II (SU II), composed of sandy silts sediments, and attributed to the Neolithic Tash Air culture on the base of the lithic industry (Yanevich 1995, 1998). SU II is formed by a succession of ashy and charcoal deposits, with sometimes a rubefied layer, yielding lithic artefacts, faunal remains and plant remains (Fig. 2). However, the nature of the Neolithic economy of the rock-shelter remains unclear. Two archaeological layers (ALs) are distinguished on the base of the presence (AL 1) or absence (AL 2) of ceramic. Several radiocarbon dates on charcoal fragments place the Neolithic occupation between 6900 and 6300 BP at BK IV (Table 1). According to pollen data delivered from steppes and forest-steppe zones in south-western Ukraine, climate around 7500 and 6000 BP is characterised by more pronounced seasonal variations (winter and summer temperatures, respectively, slightly lower and higher than today), whereas average yearly precipitations values are similar to modern climate (Kremenetski 1995). Specifically in Crimea, climate is assumed to be controlled by marine influence around 7000–6500 BP as it is shown by Cordova and Lehman (2005) in the Heraklean Peninsula.

Materials and Methods

The SU II of BK IV was sampled during three field surveys in 2008, 2011 and 2012. Samples were taken from fireplaces levels both in the excavation surface (for charred macroremains) and the cross section of the test-pit (for phytoliths). In such context, ecofacts may be derived from the sequence of combustion activities such as cooking, lighting and heating.

Seeds

Sediments for seed analysis were sampled in AL 1 and AL 2 during the 2008 field season. Some samples from the AL 2 were sterile. The study is based upon 17 samples from the AL 1, which correspond to 290 l of sediments floated at the nearby river through a 300-µm mesh. Despite the caution in sampling, the flotation samples contained charred, mineralised, desiccated/un-charred plant remains, and modern rootlets. All un-charred seeds were contaminants, probably transported to lower levels *via* rodent activity, modern root growth, and other past disturbances. In the end, a total of 32 charred seeds were identified.

Charcoal

Sediments for charcoal analysis were sampled during field missions in 2011 and 2012 in the AL 2. Samples from the AL 1, initially processed in 2008 for seeds analysis, were added to the charcoal dataset. The study is based on 16 samples and corresponds to about 90 l of sediments sieved by flotation (250 µm to 3 mm).

A total of 1211 fragments were fractionated manually according to the anatomical observation of three planes. Those fragments were identified under a microscope optical reflection (X50 to X500) with the help of reference collection of temperate and mediterranean woods as well as comparison atlas (Schweingruber 1990). Each time a new taxa is identified, we identify 50 additional charcoal fragments to stabilise the 'saturation curve' (Asouti and Austin 2005: 7) and to overview of past vegetation in temperate areas (Salavert

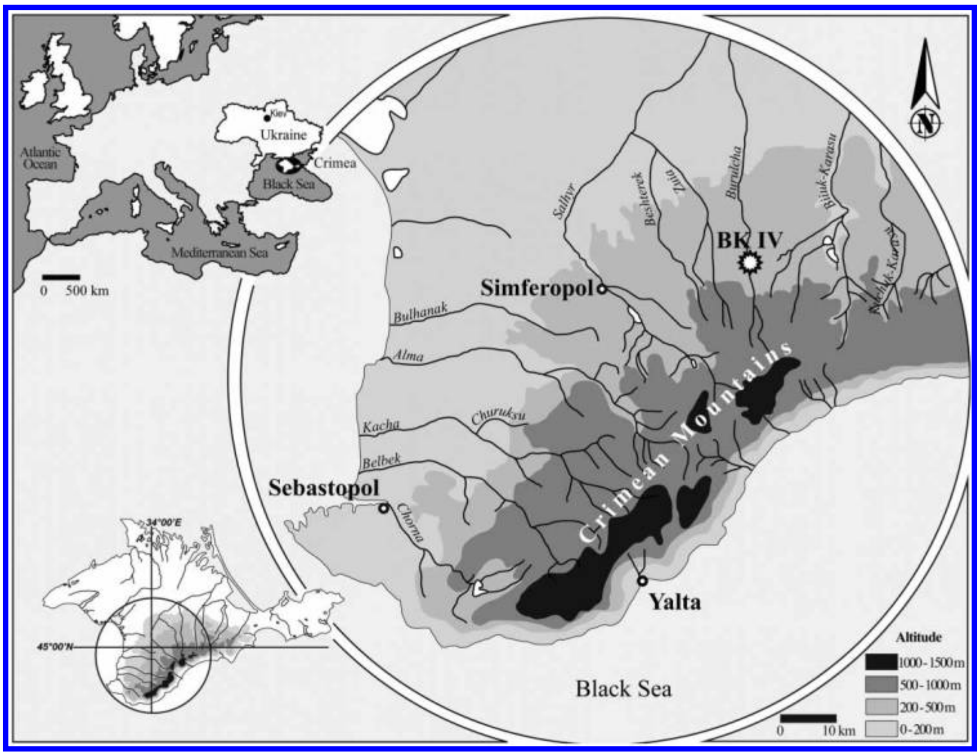

Figure 1 Location map of Buran-Kaya IV in Crimea (from Péan *et al*. 2013).

et al. in press). The total number of samples studied at BK IV assures the reproducibility of results in the SU II and thus the palaeoecological information delivered by the charcoal analysis.

Phytoliths

Ten samples of sediment were collected in Neolithic deposits, both in the test-pit cross section and the excavation surface. Phytoliths were extracted from the sediment samples using HCl and H_2O_2 baths, sieving, clay removal and densimetric separation (Lentfer and Boyd 1998). After cleaning, the residue was suspended and observed under a 'Zeiss Standard™' Microscope at 600× magnification. Each phytolith was classified according to its morphology, following several systems (Fredlund and Tieszen 1994; Mulholland 1989; Twiss *et al*. 1969) and the International Code for Phytolith Nomenclature

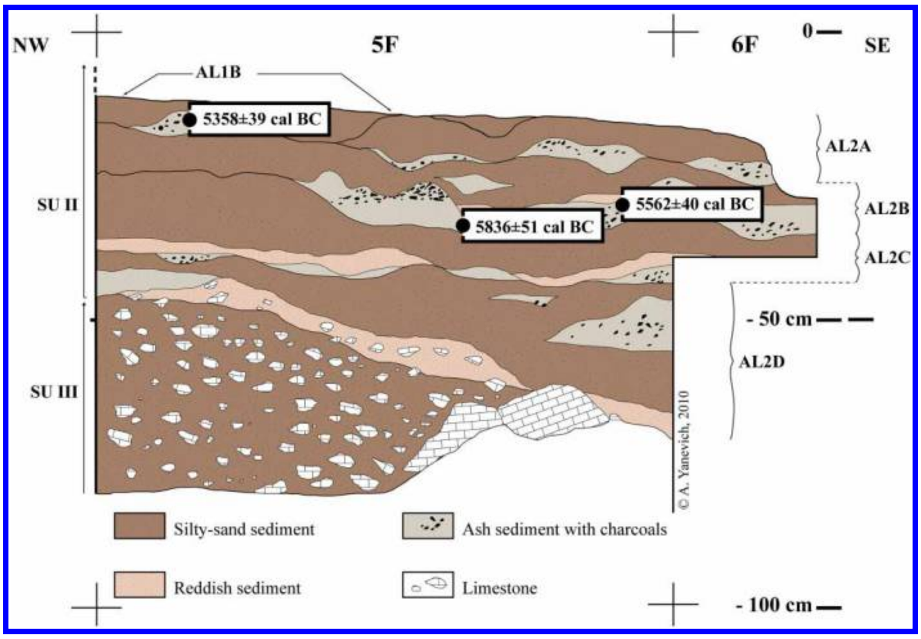

Figure 2 Upper part of the stratigraphy of BK IV rock-shelter (sector A). Stratigraphical unit II (AU II) corresponds to Neolithic occupations. The archaeological layer (AL) 1 was completely excavated during the survey and only the lower sub-layer (B) is thus represented on the figure (©A. Yanevich).

Table 1 Radiocarbon dating on charcoal of Neolithic layers (SU II) of Buran Kaya IV*

Archaeological layer	Sub-layer	Taxa	mg C	BP	cal BC 1σ	N° cible
1	B	*Quercus*	1·30	6360 ± 35	5358 ± 39	SacA 24016
2	B	*Quercus*	0·53	6610 ± 35	5562 ± 40	SacA 24018
	B	*Quercus*	1·40	6955 ± 40	5836 ± 51	SacA 24017

*The CalPal Online Radiocarbon Calibration program has been used for calibrated BC dating.

(ICPN Working Group *et al.* 2005). The observed phytoliths were classified into 12 different categories: (1) elongate, (2) elongate dendritic, (3) acicular, (4) bulliform, (5) rondel and trapeziform short cells, (6) sinuate trapeziform, (7) bilobate, (8) polylobate, (9) globular, (10) jigsaw, (11) point-hair and (12) blocky. Each morphotype's relative abundance was calculated as a percentage of the sum of classified phytoliths.

Discussion about the Dataset

The number of botanical remains studied could be the main limitation for data integration. Concerning the macroremains, charcoal and charred seeds, the number of samples is almost the same, respectively 17 and 18, but the number of identified remains is unequal. Indeed, more than 1200 charcoal fragments and only 32 seeds are identified (Table 2). This difference may be partly due to the charcoal fragmentation which causes their over-representation compared to seeds. However, seed analysis is based on ca. 300 l of floated sediment, whereas charcoal analysis rests upon 90 l. Furthermore, sampling contexts and sieving method are the same for both proxies. Numerous and quite well preserved charcoal fragments as well as the substantial taxa diversity in each sample are evidences for a good preservation of charred seeds. Thus, we assume that the absence of carbonised seeds is not due to taphonomy or methodological bias but probably to minimum human involvement into plant seed gathering.

Table 2 List of taxa identified at BK IV

Material	A	S/F	P
Number of samples	16	17	4
Sample volume (liters)	92	290	
Number of macroremains	1211	32	
Latin name/vernacular name			
Trees			
Angiosperm dicotyledon/deciduous tree			X
Quercus f.c./Oak	X		
Carpinus betulus/Hornbeam	X		
Corylus/Hazelnut	X		
Ulmus/Elm	X		
Prunoideae	X		
Type Maloideae	X		
Maloideae	X		
Salix/*Populus*/Willow/Poplar	X		
Acer type campestre/Maple	X		
Fagus/Beech	X		
Cornus/Dogwood	X		
Cornus cf. *sanguinea*/cf. Common dogwood		X	
Sambucus/Elder		X	
cf. Sambucus/cf. Elder	X		
Fraxinus/Ash	X		
cf. Leguminoseae	X		
Gymnosperm/coniferous tree	X		
Pinus cf. pinea/Italian-stone Pine		X	
Wild plants			
Asperugo procumbens/Madwort		X	
Chenopodium sp./Goosefoot		X	
Galium aparine/Cleaver		X	
Galium sp. (*small*)/Bedstraw		X	
Lamiaceae/Dead Nettle Family		X	
Lithospermum officinale/Common Gromwell		X	
Mentha sp./Mints		X	
Panicoideae			X
Poaceae		X	X
Pooideae			X
Rubia peregrine/Wild Madder		X	
Setaria cf. *viridis*/Green Bristle-grass		X	
Solanum dulcamara/Bittersweet		X	

C, charcoal; S/F, seeds/fruits; P, phytoliths.

Results

Seeds

For charred seeds, only a taxonomic list is presented due to the low number of remains identified on the site. A total of 14 taxa is identified (Table 2). Due to the fragmentary level of preservation, only a few plants were identified to species level. No cultivated cereals or pulses are recorded. All fruit and seeds represent wild plants. The small quantity of recovered seeds makes impossible any determinations as to whether these plants were gathered deliberately for food. The seeds could also have been brought accidentally with firewood to the archaeological site. Nonetheless, the wild species, particularly ones identified to species level, inform us on the palaeoenvironment surrounding the BK IV rock-shelter during the Neolithic occupation.

Woodland is represented by *Cornus* cf. *sanguinea* (kernels), *Sambucus* (seeds) and *Pinus* cf. *pinea* (nut-shells). *Lithospermum officinale* inhabits hedges, bushy places and woodland borders, usually on basic soil (Clapham *et al.* 1987). *Galium aparine* grows on limestone scree, hedges and wastelands and could have grown at the BK IV site *in situ*. It is likely that *Rubia peregrina* also grew *in situ* at the site, since its natural habitat is dry and stony soils (Hanf 1983). Similarly, the Lamiaceae plants can grow in shady, damp woodland areas and close to human occupation (Clapham *et al.* 1987). *Asperugo procumbens*, *Mentha* sp. and *Solanum dulcamara* grow in moist, nutrient-rich soils (Hanf 1983). The remains of nutshells, a few burned berries, and starchy parenchyma fragments (oak acorns?) indicate that people were probably exploited forest resources and consumed in small quantities these various wild plants for food.

Charcoal

For charcoal, number of remains identified in each levels of AL 1 and AL 2 are presented. A total of 14 wood taxa are identified in Neolithic levels of BK IV (Table 3). This number is consistent with the taxa diversity in Neolithic charcoal assemblages of temperate Europe (e.g. Kreuz 2008; Salavert *et al*. in press).

The dominant taxa, deciduous *Quercus, Carpinus* and *Acer* type *campestre*, are identified in each level of AL 1 and AL 2. *Quercus* and *Carpinus* bring together between 82 and 96% of the charcoal assemblages depending the sub-layer (Table 3). *Quercus* generally dominates. *Acer* is ranging between 0·5 and 14% of the charcoal assemblage and is more important in sub-layers D and C of the AL 2. The secondary species are *Cornus*, Rosaceae (Maloideae, Prunoideae) and *Ulmus*. Each taxa is identified in at least three levels. Rosaceae are only recorded in the layer 2. The minor taxa, *Fraxinus*, *Fagus*, cf. *Sambucus*, *Salix*/*Populus*, a gymnosperm and Type Leguminoseae, are determined in two or less levels and never exceed 1·5%.

Considering the charcoal assemblages, no obvious vegetation change is recorded between the lower (AL 2, without ceramic) and the upper (AL 1, with ceramic) layers of BK IV Neolithic deposits (Fig. 3). It can be noted that the taxonomic assemblage is more diversified in AL 2 (13 taxa) than in AL 1 (7 taxa). The higher numbers of samples and fragments analysed in AL 2, notably in the sub-layer B, could explain this difference. Indeed, in AL 2, four to seven taxa are present in sub-layers A, C and D, that is quite equivalent to the number of taxa identified in the sub-layers of AL 1. Thus, there is no distinct woodland composition difference between the sub-layers and the two neolithic layers (AL 1 and AL 2).

The main taxonomic assemblage of charcoal recorded at BK IV during the Neolithic was composed of *Quercus*, *Carpinus* and *Acer*. At BK IV, most of the charcoals might be directly derived from fuelwood and therefore indicate the composition of local woodland exploited for fire activities. Based on species ecology and their current distribution in Crimean Mountains (Cordova and Lehman 2005; Drescher *et al*. 2007; Onyshchenko 2009), it is assumed these three genus together with *Cornus*, *Corylus* and *Fraxinus*, correspond to the modern plant community of the *Quercus petraeae* forest belt, which develops today in humid northern slope of Crimean Mountains between 300 and 600 m. a.s.l. Within this vegetation type, Rosaceae and cf. *Sambucus* could be interpreted as indicators of open areas, such as forest edges. *Ulmus* together with *Fraxinus*, *Salix*/*Populus*, *Corylus* and *Cornus* could be related to the riparian forest developed near BK IV along the Burulcha River. *Fagus* and the gymnosperm could refer to woodland from the northern slope of the Crimean Mountains, growing over 1000 m. above sea level with important moisture.

Phytoliths

Phytoliths data are presented in a diagram showing the relative abundance (%) of the different morphotypes in each sample. Phytoliths are not abundant in the levels of BK IV. Among 10 samples, only four yielded a sufficient amount of phytoliths. The assemblages are homogeneous and dominated by phytoliths from the Poaceae family (Grasses) (Fig. 4). Among phytoliths of Poaceae, the morphotypes 'rondel trapeziform' and 'sinuate trapeziform' allow us to identify the subfamily Pooideae, a typical group of temperate ecosystems. The subfamily of Panicoideae (mainly subtropical plants) was occasionally identified with the form 'bilobate' (1–2%). The morphotype 'elongate dendritic', known to come from chaff (seed coating, e.g. glumes and lemma) of Poaceae, is almost absent (1% in a single sample). The Dicotyledonous group was recorded, although their characteristic phytoliths remain relatively rare in the assemblages (1·5–5%). This group is poorly represented in phytolith spectra from BK IV, as usually in temperate environment (Brémond *et al*. 2004; Messager *et al*. 2010), because plants of this group in temperate ecosystems produce very few characteristic and well-preserved morphotypes.

Discussion

The Neolithic groups of BK IV have exploited mainly *Quercus*, *Carpinus* and *Acer*. The presence of post-pioneer species in charcoal assemblages, such as Maloideae, supported by Prunoideae and *Cornus*, indicates the exploitation of transition zones between open and forested areas. The low frequencies of *Ulmus* and *Fraxinus*, and the absence of *Alnus*, reveal that the Neolithic groups have little or not directly exploited the vicinity of rivers that is currently located few meters from BK IV. However, the pollen diagram retrieved from the neighbouring site BK III highlights the presence of *Alnus* since the beginning of the Holocene (Gerasimenko 2007). Actually this difference, that is to say the high rate of *Alnus* in pollen records vs. the low rate in charcoal ones, is frequently observed during the Holocene, as it is shown by Leroyer *et al*. (2011) in the Paris Basin. Preservation of *Alnus* charcoal or location of the wood gathering areas could explain the difference

Table 3 First results of the charcoal analyses of the SU II

Layer	2						1			
Level	A	B	C	D	Total		A	B	Total	
Number of samples	2	5	2	2	11		1	4	5	
Number of charcoal fragments	194	461	145	81	881		102	256	358	
Taxa	nb	nb	nb	nb	nb	%	nb	nb	nb	%
Acer type *campestre*	1	8	21	7	37	4·2	1	6	7	2·0
Carpinus betulus	58	101	6	22	187	21·2	19	170	189	52·8
Cornus	14	1	3		18	2·0	4		4	1·1
Corylus		4			4	0·5				
Fagus		1	1 cf.		2	0·2				
Fraxinus	1				1	0·1		1	1	0·3
Gymnosperm		1			1	0·1				
Maloideae	3	12		1	16	1·8				
Prunus type *avium/padus*	2	14			16	1·8				
Quercus f.c.	115	304	113	51	583	66·2	72	76	148	41·3
Salix/Populus		7			7	0·8				
cf. *Sambucus*								3	3	0·8
Ulmus		3	1		4	0·5	6		6	1·7
Indeterminate 1 (cf. Leguminoseae)		5			5	0·6				

nb, number of fragments; %, percentages.

among archaeobotanical proxies. *Fagus* and a fragment of gymnosperm attest also to the exploitation of upland areas about 15 km further south. Therefore, a local to regional mobility of BKIV inhabitants has to be considered for fuel supply. The BK III pollen diagram also shows the development of broad-leaved trees, among them *Quercus* and *Carpinus*, during the Atlantic period (Gerasimenko 2007). Both pollen and charcoal data of BKIV record the occurrence of the broad-leaved trees. However, herbs still dominate the pollen assemblages with rates higher than 75% (Gerasimenko 2007). This dominance might underline the scarcity of the tree-cover. It might be interpreted as the pollen signal of a forest-steppe though pollen taphonomic process cannot be excluded between Holocene and Pleistocene layers in BK III. The charcoal analysis indicates that fuel supply areas are quite limited around the rock-shelter, but precluding riparian vegetation. Evidence of regional mobility may be related to economic territories of Neolithic groups. Thus, the BK IV inhabitants may have exploited either the main components of the deciduous forest as well as their edges areas, or the forest-steppe, for the firewood supply during the Neolithic.

The phytolith assemblages are derived from the local herbaceous vegetation, probably growing in the vicinity of the rock-shelter. The phytoliths ‘elongate dendritic’ are very rare in the Neolithic deposits of BK IV. This phytolith coming from Poaceae chaff is produced by many grasses, whether domesticated or not. But agricultural archaeological sites do yield

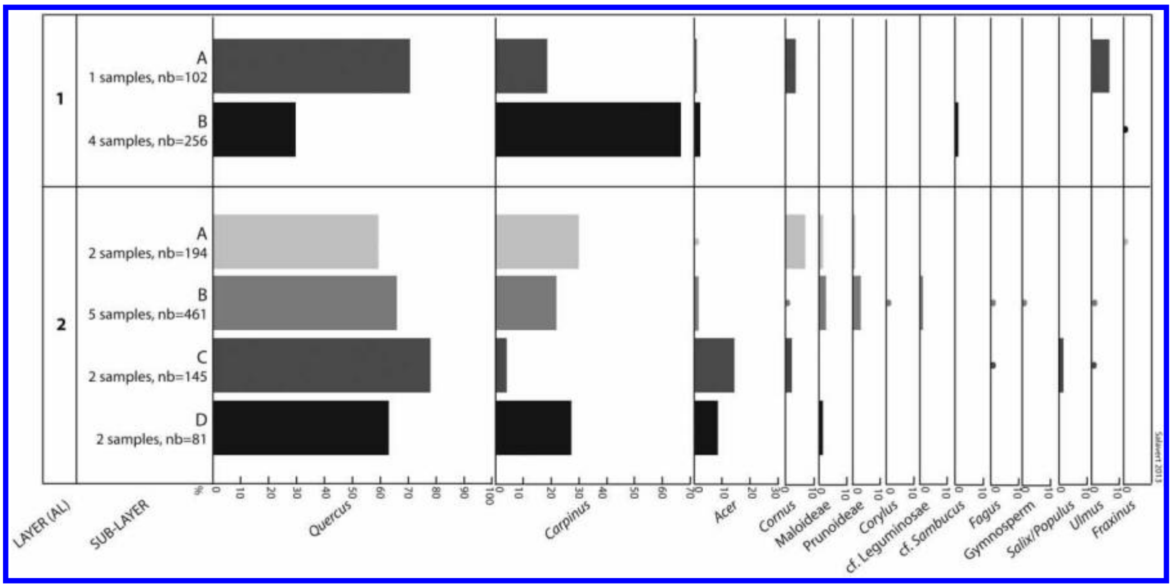

Figure 3 Charcoal diagram of the SU II. nb, number of fragments.

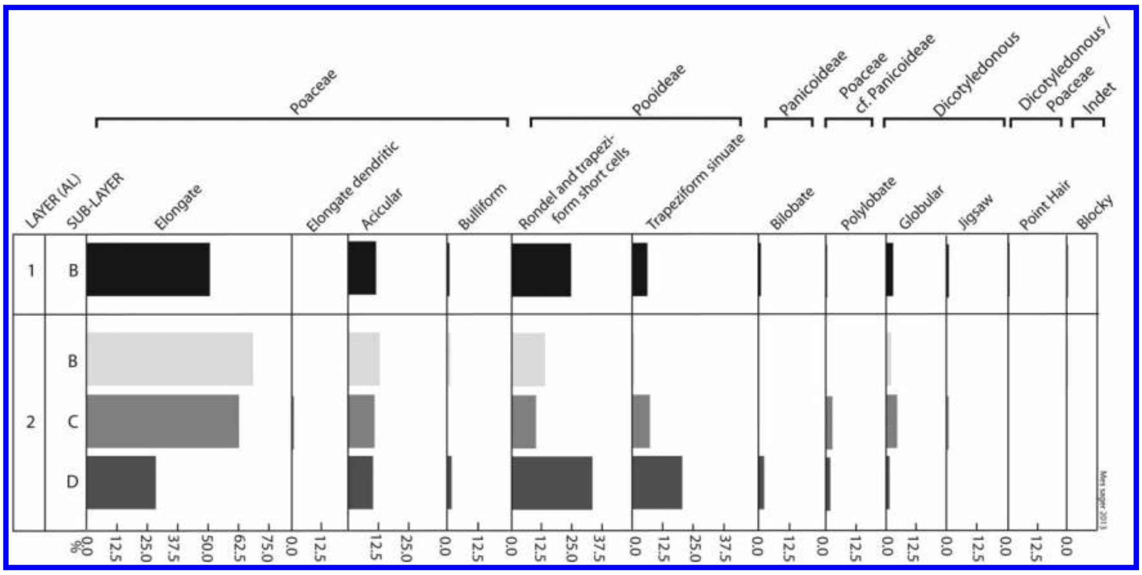

Figure 4 Phytoliths diagram of the SU II.

this phytolith in abundance because the spikelets (producing it) were deliberately brought to the site in large amounts to recover cereal grains. Since domesticated cereals are selected for their abundant grains, this morphotype might be especially abundant in archaeological sites in which cereal have been processed. For instance, in several Neolithic and Early Bronze Age sites located in Georgia (Kakhiani *et al.* 2013, Messager, unpublished data), the percentages of 'elongate dendritic' can reach 20–30%. But, in the Neolithic layers of BK IV, this class of phytolith is almost absent. In that way, seed analyses demonstrate the absence of cereal use and no other evidence from the material culture indicates any possible farming activities by Neolithic groups at BK IV. It could be proposed that they were bringing back agriculture products already processed in the rock-shelter that is to say that threshing, winnowing and sieving activities took place outside the rock-shelter. However, even if grains have been brought to the site and consumed, the quantities might have been too scarce, escaping to the charring and to the subsequent retrieval by flotation. Moreover, plant remains that could potentially be consumed as food by Neolithic populations are very rare at BK IV. Then, one may say that human focus in other activities than wild plant exploitation.

The preliminary results of the faunal analysis of Neolithic layers add essential clue to define Neolithic economy at BK IV (Bayle, in preparation). This work is based on about the half of the 20 000 remains sorted in 2011 from the AL 2. Bones are highly fragmented mainly because of human activities resulting in a significant number of burned remains, cut-marks and exploitation of animal carcasses. The remains of wild boar and small ruminants are the most significant. To date, no evidence of animal domestication has been demonstrated.

Conclusion

The paper is an important contribution to understand Neolithic socio-economic framework during the 6th millennium cal BC in Crimea. The charcoal analysis of Neolithic layers documents the wood species collected for fire. It shows that either the main components of deciduous forest (*Quercus*, *Carpinus* and *Acer*), or the forest-steppe, have been exploited for firewood at least since 5800 cal BC while the riparian vegetation has not been collected. The number of carbonised seeds and fruit is very low. The ones identified to the species level indicate the presence of woodland and wet areas around the site while no cultivated plants has been discovered in Neolithic layers. Phytoliths analysis shows the absence of dicotyledones and no plant processing on the site.

Considering first archaeozoological results, the probable absence of domestic animals in the aceramic AL 2 deals with the economic model already outlined by the seeds and phytoliths analyses. The economic model may be based on hunting-gathering at BK IV. It is more likely that the Neolithic groups did not practice agriculture on the site, and that their diet was not based on crop production between 5800 and 5300 cal BC. While further archaeozoological analysis in AL 1 are in progress, the actual bio-archaeological data of BK IV do not indicate food producing often associated with the Neolithic economy. The minor environmental impact caused by hunter-gatherer activities and/or the discontinuity of BK IV occupation may have limited the anthropogenic pressure on the local vegetation and thus, the persistence of the exploitation of broad-leaved species for burning activities during five centuries. The mobility of the Neolithic groups is inferred from the identification of wood taxa characteristic of higher mountains areas in the charcoal assemblage.

Further charcoal analysis on BK IV earliest stratigraphical units, as well as pollen analysis of natural sequences cored in south of Crimea are needed and planed to deliver a comprehensive framework of the forest dynamic since the end of the Late Glacial period. This new dataset will also give additional data in the debate on characterisation of the Neolithic, which remains unknown in this part of South-East Europe.

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