Late Bronze Age food storage in Lower Cerovačka Cave, Croatia: the archaeobotanical evidence

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ABSTRACT – *This paper presents new archaeobotanical data from the Lower Cerovačka Cave located in Dalmatia, Croatia. At the site a high density of carbonized plant remains was recovered, indicating the remnants of a burnt crop store dating to the Late Bronze Age. Overall, the assemblage is dominated by lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*), and to a lesser extent, emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) and broomcorn millet (*Panicum miliaceum*). In general, the large botanical collection from Lower Cerovačka Cave fits with what is already known about Bronze Age agriculture in Croatia, yet the unique nature of this site brings to the fore questions around storage practices and the use of caves in prehistory.*

KEY WORDS – *crop processing; carbonized chaff and grain; south-east Europe; cave storage*

Pozno bronastodobna shramba hrane v Spodnji Cerovački jami, Hrvaška: arheobotanični dokazi

IZVLEČEK – *V članku predstavljamo nove arheobotanične podatke iz Spodnje Cerovačke jame v Dalmaciji na Hrvaškem. V jami so odkrili mnogo karboniziranih rastlinskih ostankov, ki kažejo na ostanke požgane shrambe pridelkov iz pozne bronaste dobe. Med njimi prevladujejo leča (*Lens culinaris*) in neplevasta žita (*Triticum aestivum/durum*), manj pa je dvozrnice (*Triticum dicoccum*), enozrnice (*Triticum monococcum*), pire (*Triticum spelta*) in prosa (*Panicum miliaceum*). Na splošno se velik botanični zbir iz Spodnje Cerovačke jame ujema s tem, kar že vemo o bronastodobnem kmetijstvu na Hrvaškem, vendar izjemno mesto najdbe postavlja v ospredje vprašanja o praksah shranjevanja in uporabi jam v prazgodovini.*

KLJUČNE BESEDE – *predelava pridelkov; karbonizirano pleve in zrnje; jugovzhodna Evropa; shramba v jami*

Introduction

The seasonality of the agricultural cycle means that some degree of storage is inevitable. In prehistory, seasonal and intensive storage of major food resources for the short, medium or long-term would have been directly related to coping with seasonal variability in agricultural productivity and sedentary overwintering strategies (*e.g., Halstead, O'Shea 1989*). In addition, large-scale or centralized storage has been seen as an indication of social complexity, surplus production, and redistribution, as well as emphasizing socio-economic inequality (*e.g., Bogaard* et al. *2019; Forbes, Foxhall 1995*). Surplus

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also links to networks and trade, whereby an individual or group does not have to store everything themselves but can count on others to provide food at certain times (*Angourakis* et al. *2015; Hastorf, Foxhall 2017; Winterhalder* et al. *2015*). Subsequently, storage has been conceptualized in three different ways (*Ingold 1983; Soffer 1989*): (1) as intra-corporeal, where body fat helps survival through lean times; (2) social storage where formalized exchange systems and social obligations can be reconverted into food in times of shortage; (3) and material or practical storage that involves the processing and accumulation of food resources, and the construction of immovable storage features such as storehouses and pits that encourage permanent residence. Recognizing different modes of food storage in prehistory is therefore critical to assessing the roles that the environment, mobility, settlement size, and socioeconomic circumstances play in the development of different storage behaviours.

Interpreting the economic and/or social motives for storage facilities in prehistory is challenging. Was their use temporary, seasonal, or long-term? Were they managed by households, networks of extended kin, entire communities, or aspiring or established elites? Were they securing food resources, and/or other goods? In order to help with this interpretation scholars typically look at food storage and preparation facilities, as well as primary deposits of ecofacts, such as *in-situ* food storage (*e.g., Bogaard* et al. *2009; Sadori* et al. *2006*). Here we present unique archaeobotanical evidence of Late Bronze Age crop storage within Lower Cerovačka Cave, located in Dalmatia, Croatia. We will examine the use of caves as storage contexts and how this site can expand our understanding of Bronze Age communities in Dalmatia.

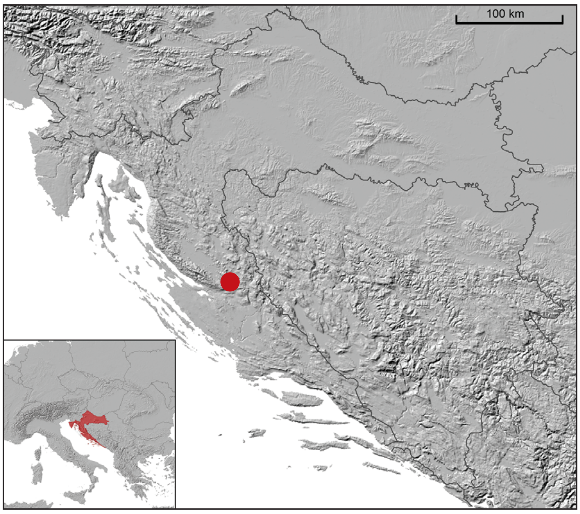

Fig. 1. Location of Cerovačke caves, Croatia.

The site

The Cerovačke caves are located on the south-eastern part of Mt. Velebit (Fig. 1), on the steep northern slopes of the massif of Crnopac, on the edge of Gračac field (elevation 550m). They are represented by three sub-horizontal cave channels, namely the Lower (Donja), Middle (Srednja) and Upper (Gornja) Cerovačka Cave. The Lower Cave was discovered in 1913 and since then the caves have been a focus for speleologists and other geoscientists (*Kurečić* et al. *2021*). The first exclusively archaeological excavations in the Lower Cave were conducted by Ružica Drechsler-Bižić in 1966 and 1967. They recovered fragments of ceramic vessels and a few metal artefacts attributed to the Late Bronze Age (*Drechsler-Bižić 1970; 1983; 1984*).

In 2019 new archaeological excavations were conducted in the Lower Cave in response to the construction of a new visitor's path running 120m from the entrance (Fig. 2). Excavations covered an area of 173m^2, *i.e.* 120m in length and from 0.5–6m in width. Six phases were identified; Phase 1 was the bedrock, Phase 2 the first human occupation at the beginning of the Late Bronze Age, Phase 3 a further Late Bronze Age layer, Phase 4 the end of the Late Bronze Age, Phase 5 which dated to the Middle Ages (13th century AD), and Phase 6 which dates to the modern era. The Late Bronze Age Phases 2 to 4 were thin layers that together did not exceed 10cm.

A large amount (3.5 tons) of Late Bronze Age pottery fragments were recovered, as well as several objects made of bronze, amber, bone, ceramics and stone, identified mainly as dress ornaments. Only a small number of animal bones and utilitarian objects (needles, awls, vertebrae) were found, suggesting that the cave was not used regularly. Instead, it is suggested that the cave functioned mainly as a storage location during the Late Bronze Age, with periodic episodes of temporary occupation. Three radiocarbon dates (tooth, charcoal and grain) were taken from different locations within Phase 4 and all had similar dates of *c.* 2870–2910 BP (Tab. 1). Phase 3, dated to *c.* 2950 BP, and Phase 2 to *c.* 3090 BP. It is likely that the period of use was relatively short and ended abruptly at the same time in the whole occupied area of the cave, possibly due to fire, resulting in large areas of burnt archaeological features. This was particularly evident in quadrant D21 where a large deposit of carbonized plant material was found, along with possible remains of a woven basket or other type of receptacle, as well as ceramic fragments (Fig. 2). In the same area three postholes were discovered, which may indicate the presence of a wooden structure, possibly linked to some sort of storage shelf or structure. Clusters of carbonized plant remains were also found in other layers, but in much smaller numbers and are largely isolated cases (*Tresić Pavičić 2020*).

Materials and methods

Twenty-three samples were collected for archaeobotanical analysis during the 2019 excavation (Tab. 2). Four samples were taken from Phase 6, sixteen from Phase 4, two from Phase 3 and one from Phase 2. Soil samples and hand-picked archaeobotanical remains were collected. The samples were taken to the Division of Botany, Department of Biology, University of Zagreb. No flotation was conducted due to the high density of plant material in the soil samples, and instead the samples were dry sieved to allow easy sorting under the microscope (*Radaković 2021*). All samples were 100% sorted, except samples U-130, U-131, U-132 and U-134 (Tab. 2). Due to the high density of the remains, further subsampling was required for samples U-130, U-131, U-132, U-134 and U-135, where the >1mm fraction was fully sorted, but only 1/3 of the <1mm fraction was sorted, including only a 1/3 of the chaff remains (*Radaković 2021.15*). Subsequently, the Supplementary Data contains the multiplied estimates for the plant macroremains identified within these samples and not the actual subsampled counts.

The carbonized plant remains were sorted and identified under a zoom stereo microscope at a magnification of 7–45x with the help of reference literature/ seed atlases (*Cappers, Neef 2012*), as well as the modern carpological collection (under establishment) of the Division of Botany. The nomenclature of scientific plant names follows Daniel Zohary and Maria Hopf (*2000*) for cultivars and the Flora Croatica Database (*Nikolić 2018*) for wild plants. Whole grains were counted as one, and two longitudinal fragments and embryos of grains were also counted as one. Glume bases were counted as one, while whole spikelet forks were counted as two glume bases. Cereal remains classed as fragments had to be at least 1/4 of the original grain/seed, and anything smaller was not counted. The fruit and weed seeds were counted as one, even when only a fragment was found, except where large seeds were broken and clearly represented the same parts of the same seed (*e.g., Quercus* sp.).

Results

All 23 samples contained carbonized plant macroremains, totalling approximately 1 179 000 items (see Supplementary Data). Lumps of broomcorn millet (*Panicum miliaceum*) were recovered from U-201 (20ml, Phase 3) and U-137 (20ml, Phase 4) and have been estimated to contain up to 4000 grains per sample (Fig. 3a). Overall, preservation was good, especially the plant remains recovered from quadrant D21. The bulk samples taken from Phase 4 had the highest density of remains that were dominated by lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*) grains, as well as emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) grains and chaff and broomcorn millet. The other phases have generally very low quantities of remains, since the plant remains were handpicked during the excavation. For Phase 2 a few acorn fragments (*Quercus* sp.) were picked out, while four lentil seeds were identified from Phase 3, along with a lump of broomcorn millet grains, approximately 20ml (≈4000 grains). Phase 6 contained mostly broad beans (*Vicia faba*) and a few cereal grains and acorn fragments, totalling no more than 76 items.

The largest quantity of plant remains were from the burnt area identified in quadrant D21 (Fig. 4). Samples U-130, U-131, U-132, U-134 and U-135, in particular, contained a large quantity of cereal grain and chaff (Fig. 3b), as well as pulses, but only a small proportion of wild/weed type taxa (Fig. 5a). The composition of these samples is relatively similar except for U-134, a posthole, which has a higher proportion of broomcorn millet grains and less glume wheat chaff. The proportion of crops within Phase 4 is dominated by lentil and free-threshing wheat, while the remaining crops only represent up to 5% of the assemblage (not including the cereal chaff, Fig. 5b). The diversity of wild/weed type taxa identified is extremely low,

Sample no.	Laboratory number	Type	Phase	Conventional ±30 BP	Calibrated age (cal BC, 95.4% / 2σ hpd range)
7	Beta-533949	Tooth	4	2890	1133–978
140	Beta-533951	Grain	4	2870	1127–931
152	Beta-533952	Charcoal	4	2910	1209–1011
185	Beta-533953	Charcoal	3	2950	1236–1051
228	Beta-533954	Charcoal	2	3090	1427–1277

Tab. 1. Radiocarbon dates from Lower Cerovačka Cave.

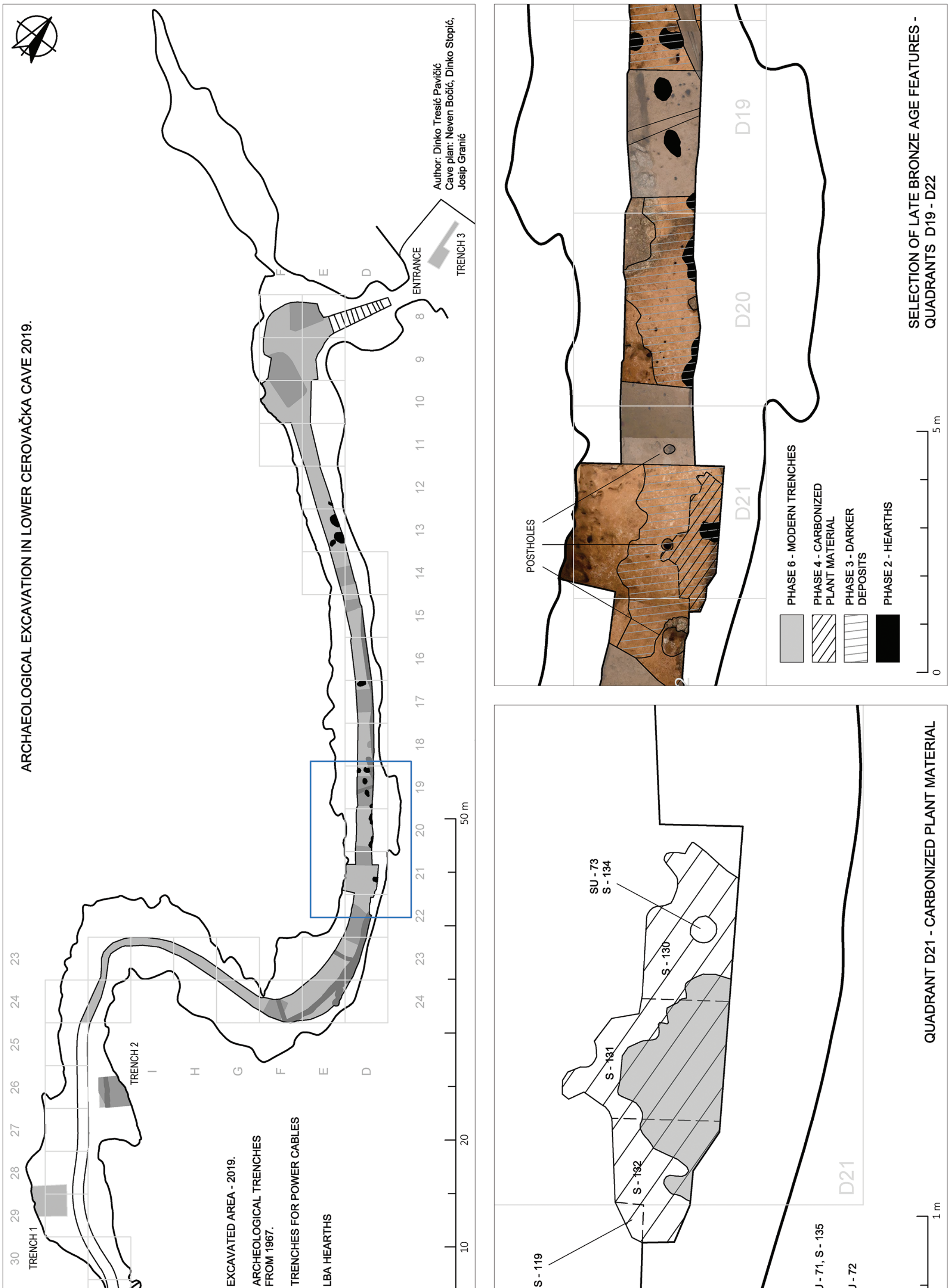

Fig. 2. Plan of the 2019 excavation in Lower Cerovačka Cave, focusing on area D21.

Sample (U)	Stratigraphic unit (SJ)	Quadrant	Phase	Archaeological context	Litres (L)	Litres analysed
192	87	D21	2	Fill	0.01	0.01
201	109	D19	3	Deposit	0.02	0.02
216	132	E13	3	Deposit	0.01	0.01
119	72	D22	4	Deposit	0.01	0.01
130	72	D21	4	Deposit - North	28.7	2
131	72	D21	4	Deposit - Centre	34	2
132	72	D21	4	Deposit - South	19.4	2
134	73	D21	4	Fill - Posthole	1	0.33
135	71	D21	4	Deposit	3.5	3.5
137	72	D21	4	Deposit	0.02	0.02
139	72	D21	4	Deposit	0.01	0.01
148	95	D20	4	Deposit	0.01	0.01
153	97	D20	4	Deposit	0.01	0.01
156	98	D20	4	Deposit	0.01	0.01
159	93	D20	4	Deposit	0.01	0.01
172	104	D21	4	Deposit	0.01	0.01
211	168	E13	4	Hearth	0.07	0.07
246	69	E14	4	Deposit	0.01	0.01
252	200	D16	4	Deposit	0.01	0.01
116	42	D22	6	Fill from 1967 trench	0.01	0.01
117	42	D22	6	Fill from 1967 trench	0.01	0.01
118	42	D22	6	Fill from 1967 trench	0.01	0.01
233	194	D17	6	Fill from 1967 trench	0.01	0.01

Tab. 2. List of archaeobotanical samples from the Lower Cerovačka Cave.

size of the wheat and pulses correspond with measurements taken from Late Bronze Age Kalnik-Igrišče; a site located to the north-east of Lower Cerovačka Cave in continental Croatia (*Radaković 2021*).

Discussion

Crop processing

The high density of plant remains in the five samples from quadrant D21 and the clear evidence of burning in and around the deposit indicate that the plant remains were burnt *in-situ*. Unfortunately, the similarities in composition of the plant remains recovered from the different areas in D21 prevent any assumptions about how or where the different crops were stored. Instead, we can look at the level of crop processing that may have occurred before storage. Predictive models have been created to identify which stage of the crop processing sequence an assemblage represents, based on the assumption that each stage produces a characteristically different ratio of cereal, chaff and weeds within the sample (*Hillman 1984; Jones 1984; Van der Veen 1992; Van der Veen, Jones 2006*). Here we can examine the ratio of glume bases to glume wheat grains, as

consisting of grasses, mainly *Bromus arvensis* and *B. secalinus*, and cleavers (*Galium aparine* and *G. spurium*), which can all be found as weeds in cereal crops.

Measurements were also taken of emmer, einkorn, spelt and free-threshing wheat, lentil, and broad beans recovered from quadrant D21 (Tab. 3). The

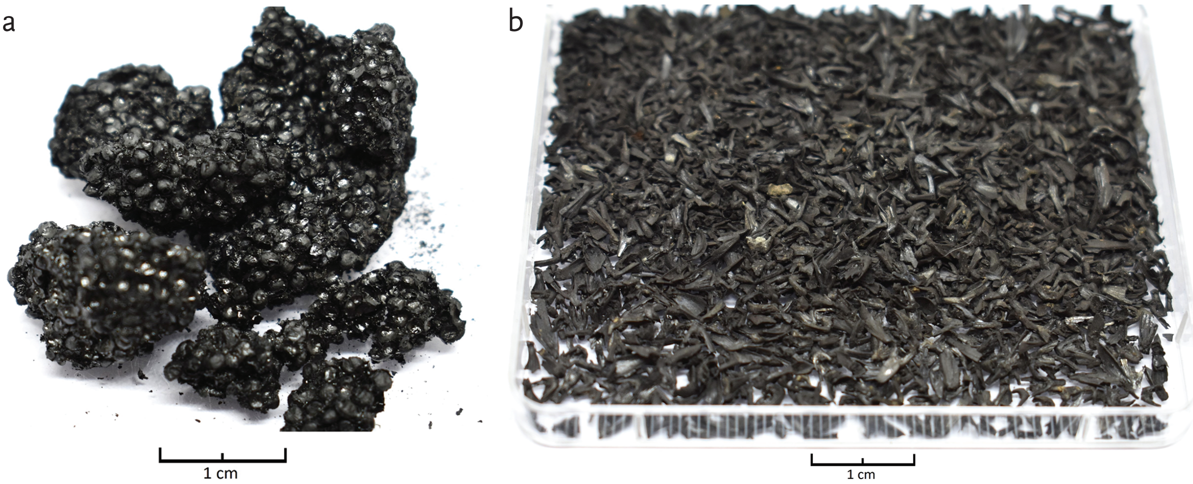

Fig. 3. Carbonized (a) lumps of broomcorn millet (**Panicum miliaceum*****) from U-134 and (b) glume wheat (*****Triticum monococcum/dicoccum/spelta*****) glume bases from quadrant D21, Lower Cerovačka Cave.***

well as the number of weeds to the number of grains to help determine what crop processing has occurred. Unfortunately, the third ratio looking at the number of rachis internodes to grains is not possible, as these were not recovered for the free-threshing wheat or barley. This could be for several reasons, including poor preservation, as experiments have shown a taphonomic bias against chaff, especially under oxidizing conditions and high temperatures (*Boardman, Jones 1990*). However, the most likely reason for the absence of rachis remains is that the free-threshing wheat and barley were already cleaned by the time they reached the cave. This is because both barley and free-threshing wheat grains easily detach from the chaff during the early stages of crop processing (*i.e.* threshing, winnowing and coarse sieving), whereas glume wheats require a further dehusking stage to remove the glumes from the grains (*Van der Veen 1992.81*).

Fig. 4. Image of the layer of carbonized botanical remains recovered from stratigraphic unit 72, quadrant D21.

For emmer and spelt the ear generally contains two grains and two glumes, so the ratio of 2:2 = 1, while einkorn has one grain and two glumes, so the ratio of 1:2 = 0.5. If we apply this to the glume wheats in quadrant D21, we see that nearly every sample has a high to very high ratio of glumes to grain (Fig. 6, based on estimated numbers of remains). This means that there is significantly more chaff than grain in the samples. If we look at the ratio of grains to weed seeds, a ratio of 1:1 = 1, the ratio is extremely low. Of the crop processing stages, this could indicate that the glume wheat grains had been cleaned but not processed through the additional dehusking stages, which would remove the broken spikelet forks (see *Hillman 1984; Jones 1984; Stevens 2003*). Thus, the grains could have still been in their glumes when they reached the cave. Once at the cave, dehusking could have occurred piece meal, as and when grain was required, and the chaff discarded onto the floor of the cave or kept aside for other purposes. Similarly, two different types of storage could have occurred where cleaned grains were stored in containers and the glume bases in another. Cereal by-products could be used for a range of purposes, such as a building material, for fuel, or as fodder for livestock (*Van der Veen 1999; Valamoti, Charles 2005*). Cereal chaff is also used as temper in pottery, as seen at Bronze Age Monkodonia, Istria (*Hellmuth Kramberger 2017.418*), as well as in Eneolithic loom weights found at a Slovenian pile-dwelling sites (*Tolar* et al. *2016*). In Palestine, ethnographic observations noted chaff was laid on top of stored grain before the underground jar-shaped receptacles were sealed with clay (*Turkowski 1969.101–112*). Thus, there could be several reasons to find chaff in this context. Comparing Lower Cerovačka Cave with similar finds of cereal storage at two Late Bronze Age caves in southern France, glume wheat chaff is strongly underrepresented in relation to grains, suggesting that the glume wheats were dehusked before storage (*Bouby* et al. *2005*).

Multi-cropping and mono-cropping

Multi-cropping, or maslins, have been used to describe the growing of more than one crop in a sin-

	Length (mm)	Width (mm)	Thickness (mm)
Triticum aestivum	5.58 (4.66–6.25)	3.59 (3.11–4.08)	2.98 (2.47–3.4)
Triticum dicoccum	6.3 (5.6–7)	3.14 (2.75–3.57)	3.03 (2.64–3.35)
Triticum monococcum	5.97 (4.56–7.42)	2.53 (1.93–2.88)	3.06 (2.35–3.51)
Triticum spelta	6.79 (5.56–7.82)	3.11 (2.45–3.69)	2.42 (2.04–2.85)
Vicia faba	7.31 (5.82–10.37)	5.72 (3.94–8.24)	5.64 (4.36–7.96)
		2r (mm)	
Lens culinaris		3.21 (2.55–3.99)	

Tab. 3. Measurements of free-threshing wheat (*Triticum aestivum*), emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), and spelt (*Triticum spelta*) grains, and broad bead (*Vicia faba*) and lentil (*Lens culinaris*) identified from Quadrant D21 at Lower Cerovačka Cave.

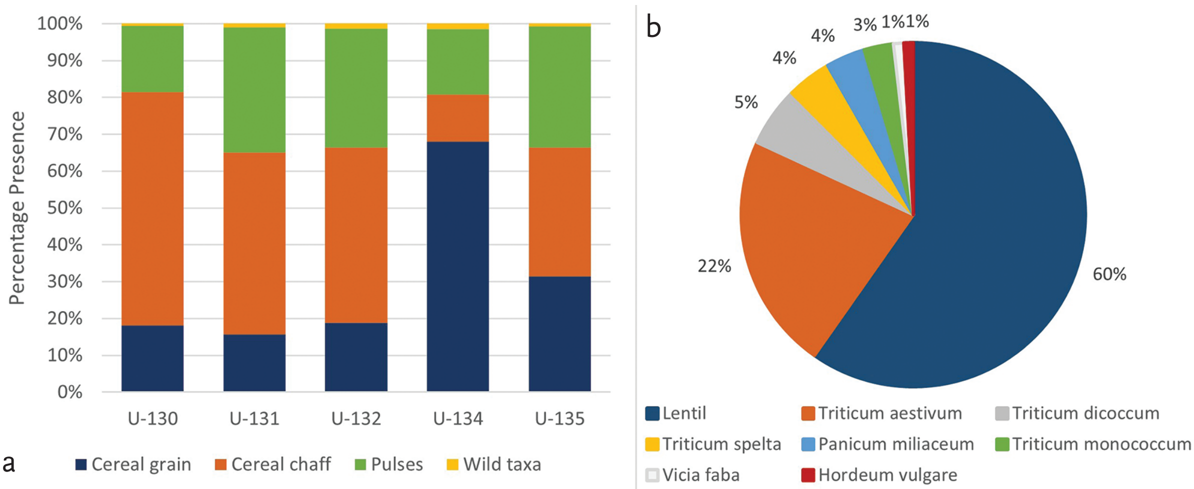

Fig. 5. Composition of the carbonized seed assemblage for (*a*) each sample in quadrant D21, and (*b*) the proportion of cereal grains and pulses,excluding cereals chaff, in total from Phase 4, Lower Cerovačka Cave.

gle season on the same land (*Halstead, Jones 1989; Jones, Halstead 1995; Petrie, Bates 2017*). It is suggested that a mixed crop could have been more reliable than a single-grain crop. For example, if the season was colder then rye would flourish, but if the season was hot then wheat would do better. The crops are usually those with similar maturation and/or crop processing stages, but a recent study by Alex C. McAlvay *et al.* (*2022*) highlights other benefits of multi-cropping. This crop practice is distinct from monocropping where only one crop is grown on the same plot for one of more years. Although there are benefits to multi-cropping in terms of reducing risk of total crop failure, what type of grain crop grown would have depended on the local soil and climate, balanced with socio-economic demands.

Where and when multi-cropping may have occurred in the past is debated, and identification in archaeological contexts can be difficult. Marijke Van der Veen (*1995*) compared the relative proportion of grain types and analysed the weed assemblages in relation to growing conditions in different crops to determine that wheat and rye were probably sown together in medieval western Europe. Weed ecology, such as phytosociology, autecology and FIBS (Functional Identification of Botanical Surveys), have been used to understand cropping practices in the past (*e.g., Van der Veen 1992; Stevens 1996; Charles* et al. *1997; Bogaard* et al. *1999; Jones* et al. *2010*). Ethnographic observations by Glynis Jones and Paul Halstead (*1995*) on the Greek island of Amorgos found that sown proportions of up to 80% wheat and 20% barley were considered mixed intercrops by farmers, although this proportion could change depending on the environmental conditions. However, they also highlighted issues of contamination resulting from crops from previous growing cycles becoming incorporated in that season's crop (*Jones, Halstead 1995*). Overall, these methods require the archaeobotanical remains to have enough weeds to study the weed ecologies and be representative of one harvest. However, plant remains that survive in the

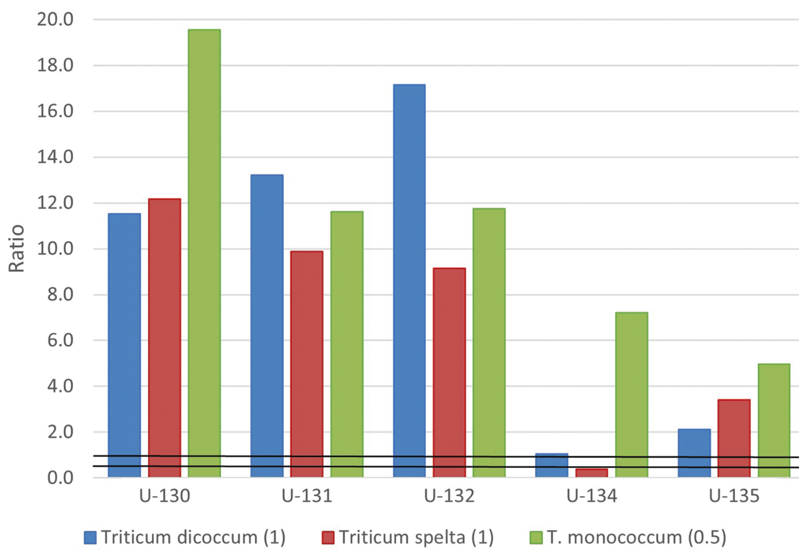

Fig. 6. Ratio between the number of grains and number of glume bases for emmer (*Triticum dicoccum*), spelt (*Triticum spelta*) and einkorn (*Triticum monococcum*) for each sample in area D21, Lower Cerovačka Cave.

archaeological record are typically either discarded waste or accidentally preserved remains, which generally result in contexts where crops from different sources are combined over tens or even hundreds of years, preventing any secure identification of crop husbandry practices (*Jones, Halstead 1995; Van der Veen 2007*).

In prehistoric contexts some suggest that the glume wheats emmer and einkorn were grown as maslins during the Neolithic (*Kreuz 2007*). Einkorn and 'new' glume wheat are also thought to have been cultivated together as a mixed crop during the Neolithic and Bronze Age (*Jones* et al. *2000; Kohler-Schneider 2003*). More recently Rebecca A. Fraser *et al.* (*2013*) examined the stable isotopes of wheat and barley from an LBK storage deposit at Vaihingen in Germany, and found they shared distinctively low $\delta^{13}C$ signatures relative to other samples, suggesting that they grew in similar conditions, possibly in a similar location as a mixed crop.

Whether inter-cropping was practiced by the farmers who used Lower Cerovačka Cave to store their crops is hard to determine. There are very few weeds, which prevents the analyses of weed ecologies. Most cereal remains are free-threshing wheat, with only a very small quantity of barley grains present, far less than 20% if we go with an 80/20 ratio outlined by Jones and Halstead (*1995*). Thus, the presence of barley could simply indicate contamination of the free-threshing wheat crop, maybe from a previous harvest, or could be remnants of a previously stored crop. The glume wheats, emmer, einkorn and spelt are found in smaller quantities, and again it is unclear from the context whether they were grown together. Instead, they could represent smaller harvests or remnants of previously stored crops.

Storage location and containers

The utility of each type of storage depends on perishability and distribution, the predictability and duration of lean periods, as well as the settlement patterns and social ethos of the society (*Testart 1982*). A huge range of food-keeping practices have therefore evolved. Ethnography, historical documents, and imagery highlight a wide range of storage facilities, such as caves, pits, built silos, cellars, and barns, a variety of accompanying equipment used, such as bins, baskets, barrels, sacks, suspension hooks, jars or chests, as well as different preservation methods, such as drying, parboiling, fermenting, *etc.* (*e.g., Peña-Chocarro* et al. *2015*). For cereals and legumes, controlling the humidity is the most important part of maintaining the nutrient quality and usability of the crop (*Păun* et al. *2021*). Before storage, grain must be dry (*i.e.* have a low moisture content) to minimize infestation by insects and microorganisms (bacteria, fungi, *etc.*), and to prevent germination (*Rajendran 2003*). The main objective of storage systems is to therefore preserve food for an extended period with minimal loss.

The recovery of cleaned cereals and pulses in Lower Cerovačka Cave, along with other contextual evidence, suggests that the remains represent stored crops. The cave itself would have had its own micro-climate, though it is uncertain what the conditions would have been in the Bronze Age. Today the dark well-ventilated cave, with low but fluctuating temperatures, could make a practical storage location (*Tresić Pavičić 2020*). Yet the cave has a very high humidity (around 90%), which could cause significant spoilage of the crop, activating sprouting in the surface layer of a store, as well as encouraging contamination by micro-organisms, especially mould. This was noted at Baume Layrou, a Late Bronze Age cave situated in southern France, where the high humidity in the cave was thought to have caused germination in the stored grain (*Bouby* et al. *2005*). Yet in Anatolia, caverns in tuffs have been used for food storage in the past and are still regularly used today for wine and to extend the shelf life of fruits and vegetables. The caves maintain a relatively constant temperature of around 13°C, with good airflow, and humidity can be as high as 80% in places, although it's suggested that the tuff rock holds dehumidifying properties making them ideal caves for short-term food storage (*Emir, Daloğlu 2012; Aydan, Ulusay 2013*). Experiments also show that at low temperatures moisture changes in wheat occur relatively slowly, compared to those stored at higher temperatures (*Pixton, Griffiths 1971*).

At Lower Cerovačka Cave germinated grains were not identified. This may suggest that the crops were not stored for long periods within the cave, or that these specific grains had not been in the cave for enough time to allow germination before they were carbonized. Storing grain in their chaff is also suggested to be a way of protecting glume wheat grains and could have helped preserve the glume wheats discovered in Lower Cerovačka Cave (*e.g., Meurers-Balke, Lüning 1992*). As Laurent Bouby *et al.* (*2005*) conclude, the conditions within the cave probably suggest occasional short-term storage, possibly through periods of insecurity. They suggest that both caves in southern France are characteristic of refuge caves; being difficult to access, have hidden entrances and lack light. These characteristics are also shared with Lower Cerovačka Cave.

One of the main problems with understanding storage practices in prehistory lies in finding direct evidence of storage, especially if more perishable items such as woven baskets are used, as well as identifying what exactly was being stored. At Lower Cerovačka Cave fragments of ceramic vessels and thin carbonized strips of vegetal material were found within quadrant D21, which could suggest the presence of some sort of wicker basket (Figs. 7 and 8). The carbonized strips have not been identified yet, so it is unclear what type of plant could have been used. Braided plant fibres and basketry are rarely found in archaeological contexts, and mostly in waterlogged contexts, so it is unclear the extent to which these were used in prehistory. The discovery of post holes at Lower Cerovačka Cave could also suggest the presence of a wooden structure, or shelf, that could have stored items off the ground. Several methods of storage could thus have been used within the cave that could have allowed short- to long-term storage, under the right conditions.

Baskets and textiles are both the result of the intentional weaving of fibres. The terms 'basket' and 'textile' are often definitionally separated, perhaps somewhat arbitrarily, by both end-use and construction technique. Baskets generally serve as vessels or other containers or as mats for sitting and sleeping on, floor coverings, in the construction of mud-brick architecture, and as burial shrouds and grave liners. Textiles, which are made from softer and more pliable fibres, are used for clothing, bed linens, and to create soft bags or other containers that need to have more flexibility than a basket. A large variety of fibres are used in weaving textiles and baskets, including bast fibres from plants and trees as well as hair and wool. Textile fibres generally receive more pre-treatment than the fibres used in basket making. Baskets are created from plant fibres that are generally thicker and more resilient than textile fibres, and they are often treated with splitting, heating, dying, bending, and bundling. Moreover, baskets are never woven on a loom and generally have a different end-use than textiles (*Adovasio 1977.1; Crowfoot 1954. 414; Wendrich 1999.31–35*). Tools such as awls and needles are often used in the construction of a basket, and thread or cordage may be used to create a more secure weave or to fasten the end of the weaving bundle or the baskets edge. The techniques of basket making are generally classified into three weave types: twining, coiling, and plaiting. Within each of these three classes are many sub-classes; all are mutually exclusive based on technique or "*features of manufacture*" (*Adovasio 1977.1; Wendrich 1999.41–42*).

The archaeological visibility of storage methods and stored goods varies widely, making it difficult to determine the character, organization and importance of storage within a specific context. For the prehistoric Balkans a range of different storage methods have been identified, but usually from indirect evidence, such as the discovery of large vessels, clay bins or subterranean features, and are usually interpreted from ethnographic analogies (*Filipović* et al. *2018; Papaefthymiou-Papanthimou* et al. *2013*). Observations on construction techniques and methods and materials used for lining and sealing stored crops highlight the wide range of practices that can be used (*e.g., Mobolade* et al. *2019; Peña-Chocarro* et al. *2015*). When storing crops, especially cereals, it is important to keep both moisture and temperature levels low if the items are to be stored succes-

Fig. 7. Thin carbonized strips of vegetal material, possibly from a wicker basket, found within carbonized botanical remains in quadrant D21 Lower Cerovačka Cave.

Fig. 8. Image of the carbonized vegetal material, possibly from a wicker basket, found in quadrant D21 Lower Cerovačka Cave.

sfully for long periods (*e.g., Reynolds 1979; Currid, Navon 1989*). Grain aeration is a technique that is still used today to improve the storability of grain by maintaining a cool, uniform temperature throughout the storage. However, this only works if the aerated air has a relative humidity below the grain's moisture content, otherwise the grain would still slowly absorb water from the air (*Jones, Hardin 2017*). Sealed, airtight, storage is an alternative method to control moisture, and various methods have been observed where things like dung, clay and straw have been used to help seal containers or pits to keep moisture levels low (*e.g., Singh* et al. *2017*). In Syria, clay lined baskets have been observed, as well as sacks and wooden silos (*Al-Azem 1992*). While in Palestine *burgur* and *frikkeh* were seen stored in cloth sacks or in lined straw baskets with some form of protective cover (*Turkowski 1969*).

Lower Cerovačka Cave in Bronze Age Croatia

The discovery of such a large archaeobotanical collection at Lower Cerovačka Cave is unique in Dalmatia and Croatia as a whole. Although Bronze Age material culture has been identified at several cave sites along the Dalmatian coast, only one other site has so far produced botanical remains. Grapčeva špilja, a cave on the island of Hvar in Croatia, yielded only a few plant remains from early and middle Bronze Age occupation horizons, including a few wheat grains (*Triticum* sp.) and acorns (*Quercus* sp.; *Borojević* et al. *2008*). The cave is thought to have had ritual connotations, but the botanical data is inconclusive and could simply suggest transient occupation. Burials in caves are also seen. A recent study at the Middle/Late Bronze Age (1430–1290 BCE) Bezdanjača Cave, located slightly inland in the Lika region of Croatia, identified notable quantities of C4 plant consumption, most likely millet, in 16 individuals (*Martinoia* et al. *2021*). At Pupićina Cave, located in NE Istria, evidence suggests the use of the site periodically by herders as well as for other, as yet unknown activities from the Neolithic through the Iron Age, though a hiatus is noted from the Late Neolithic to middle Bronze Age (*Miracle, Forenbaher 2005*). The use of caves as animal stabling is also suggested for four caves in the Trieste Karst, north-eastern Italy (*Boschian, Montagnari-Kokelj 2020*). Caves were thus utilized in different ways along the Adriatic coast.

At present only 17 sites have published archaeobotanical evidence from Croatia as a whole, and the quality and quantity vary greatly (*Reed* et al. *2022a*). Along the coast, we see a very limited repertoire of remains, with only the settlement at Monkodonja providing any clear evidence of crop cultivation, including emmer (*Triticum dicoccum*), barley (*Hordeum vulgare*) and grape pips (*Vitis vinifera*). In continental Croatia, the Late Bronze Age site of Kalnik-Igrišče revealed thousands of plant remains within a burnt down house, with broomcorn millet, barley, free-threshing wheat (*Triticum aestivum*) and broad bean predominating (*Mareković* et al. *2015; Reed* et al. *2021*). Broomcorn millet, barley and free-threshing wheat are also frequently found at other sites in the region by the Late Bronze Age (*Reed* et al. *2002a*). Recent research on the introduction and adoption of millet has shown its arrival into Croatia by the middle Bronze Age (*Filipović* et al. *2020; Reed* et al. *2022b*), but it is not until the Late Bronze Age that we see clear evidence of its cultivation as a crop within the Croatian assemblage. Overall, the range of taxa identified from Lower Cerovačka Cave fits well with what is already known about Late Bronze Age agriculture in Croatia.

What is absent at Lower Cerovačka Cave is evidence of the collection of fruits and nuts, such as cornelian cherry (*Cornus mas*) and Chinese lantern (*Physalis alkekengi*), from the local environment, which we commonly see at settlement sites during this period in Croatia. We do find a few remains of acorns, although these are largely present in Phases 2 and 6, with only one fragment found in Phase 4. There are many species of acorn, both sweet and bitter and unfortunately here we have not been able to identify to species. Acorns are nutritionally comparable to cereals, being a good source of carbohydrates, fats, proteins, and vitamins, mostly A and C, and have been consumed in the form of bread, soups, porridge, or even as herbal coffee throughout history (*Sekeroglu* et al. *2017*). Acorns have been found at other Bronze Age sites, including Kalnik-Igrišče (*Mareković* et al. *2015*), but it is unclear whether the few acorns recovered here represent deliberate collection.

Conclusion

At Lower Cerovačka Cave the unique discovery of a large quantity of burnt plant remains dating to the Late Bronze Age indicate crop storage in the cave. Significant mixing of the crops prevents any assumptions about how or where the different crops were stored. Yet the significant quantity of remains indicate the storage of lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*), as well as emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) and broomcorn millet (*Panicum miliaceum*). The large quantity of glume wheat glume bases could also suggest a multifunctional space where glume wheats were also processed, or alternatively the separate storage of chaff for other purposes. Whether the cave was used for short- or long-term storage is debatable, as the high humidity could cause crop spoilage. At the Late Bronze Age caves in southern France, it was concluded that the caves were used for short-term storage, owing to the high humidity, and that people took shelter in these 'refuge caves' during disturbed times (*Bouby* et al. *2005*). However, if air-tight storage is used then crops can be stored for longer. At Lower Cerovačka Cave possible evidence of woven containers is present, but it is unclear whether these were sealed or simply used to contain each of the crops separately. The large quantity of other materials found within Phase 4, such as bronze dress ornaments and jewellery, and the short date range (*c.* 940–960 BC), could indicate a period of instability.

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