The archaeobotany of large-scale hermetic cereal storage at the Hittite capital of Hattusha

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1.1 Introduction

Crop storage practice is a key organising principle of agricultural systems,[1] with wider implications for the sociality and politics of crop production.[2] In archaeology, storage practice is often subject to debate due to the difficulty of identifying and/or interpreting storage features. Hermetic storage is a technique particularly well adapted to long-term, large-scale storage, and preserves grain by restricting moisture and insect activity.[3] In 1999 the discovery of a large underground silo complex with intact grain stores at the Hittite capital of Hattusha allowed scholars the opportunity to investigate the architecture, technology and practice of underground hermetic storage on a massive scale. Excavation revealed that this facility had partially burnt down during the 16th century BC, perfectly preserving hundreds of tonnes of cereal grains, an unparalleled discovery in the Near East. This paper summarises the preliminary archaeobotanical work undertaken by Reinder Neef in 2000–2001, before outlining our ongoing analyses, which seek to elaborate on the specific nature of Hittite farming systems. This is followed by a brief overview of current interpretations of Hittite agriculture and the importance of large-scale storage facilities within the Eastern Mediterranean Bronze Age.

2.1 Hermetic Storage

Hermetic storage systems are a long-term means of storing agricultural produce by controlling air moisture content and insect activity. The most effective method of hermetic storage involves sealing crops in an airtight container, thereby preventing moisture from

1 Sigaut 1988.

2 Halstead 2014, 158.

3 Reynolds 1974; Seeher, 2000b; Villars et al. 2006.

the outside atmosphere from accessing the grain.[4] By protecting crops from outside humidity levels in a relatively dry artificial environment, seed germination and the growth of mould can be limited. Moreover, biological activity as a result of grain respiration within the container creates a low oxygen, high carbon dioxide atmosphere that is lethal to insects already present inside the stored produce.[5] By this method agricultural produce can be stored for extended periods of time, in some cases up to several years[6] as long as the airtight seal is left in place. Hermetic storage, however, does not stop grain deterioration entirely, but greatly reduces the rate at which decay occurs. Once the storage container has been breached, all goods must be removed as quickly as possible, as re-exposure to oxygen and moisture can again speed up the decomposition process, precipitate the germination of the grain or lead to re-infestation by insects.[7]

Hermetic storage of agricultural produce was the most commonly employed technique of large-scale grain storage up until the 18th century, and was used by societies worldwide.[8] More recently the development of modern refrigeration techniques and the rise of convenience foods have seen a reduction in this type of storage system, although modern grain silos still operate on the hermetic principle. Ethnographically, underground hermetic storage, on a much smaller scale, has also been documented in areas such as the Mediterranean for preserving cereal grains and pulse crops.[9] For example, in north-central Crete, houses often had a *goúva* (a circular pit) dug into the bedrock beneath the floor.[10] These pits were unlined, measured roughly 1–1.5m wide and 1–3m deep and were used primarily for household storage of cereal grain. Once the pit was full it would be covered with a cloth and made airtight by a layer of ash to prevent insects from attacking the grain. Cereals would then be stored in these pits for 2–3 years, although often the grain would be removed sieved and re-dried yearly. Similarly, on the Greek islands of Amorgos and Kos, underground pits were often used for long-term storage; these were lined with straw or chaff as means of limiting contact between the grains and surrounding soil.[11]

Archaeologically, indications of hermetic storage have been found worldwide. The unambiguous identification of these structures as examples of hermetic crop storage has, however, been uncommon.[12] Direct evidence, such as charred archaeobotanical material is often lacking, leading some scholars to suggest entirely alternative interpretations unrelated to plant storage.[13] Moreover, in cases where pits or other features have been positively identified as agricultural storage facilities, the use of hermetic long-term storage

4 Villers et al. 2006.

5 Reynolds 1974; Navarro – Calderon, 1980.

6 Weinburg et al. 2007.

7 Sigaut 1980.

8 Sigaut 1988.

9 Sigaut 1988; Forbes 1989; Halstead – Jones 1989.

10 Halstead 2014, 158.

11 Halstead 2014, 160.

12 Sigaut 1988; Christakis 2008, 1.

13 Strasser 1997.

must be considered alongside shorter-term methods, as both techniques entail radically different intentions and timescales for the crops being stored. Whilst short-term storage would have been used for everyday consumption, the nature of hermetic long-term storage means that stored produce could not be accessed without removing everything from the container. This would suggest that hermetic storage was used particularly for agricultural surplus stored against times of famine and poor harvests, and/or for seed corn that was to be sown the following year.

3.1 The Hattusha silo complex:

The underground silo complex at Ḫattuša-Boğazköy was first discovered as part of the 1960–3 excavations of the Lower City, which focused on the Iron Age and Byzantine levels in this area. Although work on the silo itself was brief, the remains of a large Hittite building were uncovered, and initial interpretations suggested that it had functioned as a magazine, though direct evidence for this function was lacking. The silo was re-excavated as part of the 1998–2000 field seasons under the direction of Jürgen Seeher; at this time other granary-type structures had been excavated on the mountain ridge of Büyükkaya, north of the Lower City, leading to a re-evaluation of the function of the large silo complex.[14] In 1999, a new trench was dug about 50m away from the earlier 1960s excavations, and ~~was able to locate~~ the foundations of the silo walls, as well as a burned mudbrick ~~construction~~. A large quantity of intact charred cereals was discovered alongside a silo wall, and this led to a much larger excavation of the entire silo complex area. In total it is thought that several hundred tons of charred grain are preserved underground in layers up to 1.2m thick. Excavation removed a total of c. four tons of cereals from five separate storage chambers, discussed further below.

3.2 Architecture

The silo complex is located underground on the north-west slope in the Lower City between Kizlar Kaya and the royal court area of Büyükkale, and behind the defensive postern wall.[15] The structure itself is situated in a natural depression ~~where~~ the bedrock ~~is not so close to the present day surface~~, and the postern wall seems to have been positioned so as ~~not~~ ~~to take up~~ the space which was planned for the granary. Although it is not known whether the construction of the wall pre-dates the silo or *vice versa*, it would seem that the two structures were planned at the same time, since they respect one another, and entrances through the wall are lacking in the area where the silo was located.[16] The silo structure is about 118m long and between 33–40m wide, and was divided into 32 chambers which were arranged in two rows of 16 chambers each. Constructed on stone foundations c. 0.8m thick, the chambers themselves were built from large mudbrick walls

14 Seeher 2006, 46.

15 Seeher 2000a.

16 Seeher 2006, 49.

about 1.5m thick.[17] Each chamber measured roughly 13–16m x 6m, but their depths varied depending on the height of the underlying bedrock, and the chambers' position on the slope. Overall, there appears to have been no standard chamber depth, and between one end of the silo and the other was a height difference of 15m.[18] Inside the chambers the mud brick walls were covered with a mud plaster coating, and each chamber also had a paved stone floor. In some instances timber beams also may have been used to stabilise the mud brick walls, although these were probably added as maintenance after the chambers had been in use for some time.[19] Each chamber, therefore, seems to have been constructed as an independent 'unit' of storage, making it possible to access, fill and empty each chamber separately. During excavation there was no evidence of an upper storey to the silo; instead Seeher[20] suggests that an earthen 'lid' would have capped the structure, and that this would have been visible above ground. Directly under the earthen lid or roof was straw and other insulating material, to spread the weight of the earth, and as a means of protecting the cereal grain. The earthen roof would have extended over the outer edge of the mudbrick walls as a means of directing rainwater away from the silo.

3.3 Use and destruction of the silo:

The filling of each chamber first required a thick packing of straw and reeds to line the walls; this insulation material is directly attested through charred remains in burned chambers, and as silicified material in unburned ones (see below). The straw/reed packing would have acted as a buffer against ground humidity, reducing contact between the stored produce and surrounding earth. The chamber would ~~then~~ have been filled to capacity before being capped with another layer of straw and the earthen 'roof'. Emptying the chamber necessitated the removal of this earth cover, and Seeher[21] proposes that the grain would have been taken out within a day to lessen the chances of grain germination and attack by ~~pests~~. Reconstruction of the complex has indicated that, if filled to capacity, the silo could have held around 7000–9000m^3 of cereal grain, enough food to feed 20,000-30,000 people for a year.[22] The division of the silo into 32 individual chambers, however, meant that the whole structure did not have to be in use all at once, and that it would have been possible to fill a number of chambers whilst leaving others empty. Partial use of the building is particularly clear after the destruction of part of the complex by fire, as Seeher suggests that the unburned north-western end of the structure continued to be used for a number of years.

Radiocarbon dating of the cereal grains indicates that the burning event itself occurred during the early 16th century BC, ~~and that this resulted~~ in the destruction of 12 of the 32 storage chambers. Of these 12 chambers, five have been totally excavated, and the charred

[17] Seeher 2000a.

[18] Seeher 2006, 50.

[19] Seeher 2000a.

[20] Seeher 2006, 50.

[21] Seeher 2006, 46.

[22] Seeher 2006, 81.

remains of stored cereals were found in layers of 0.8-1.2m thick.[23] This material ranged from unidentifiable white ash to well-preserved complete grains, chaff and weed seeds.[24] There are no indications of how the fire started, although Seeher[25] states that spontaneous combustion can be ruled out; instead it is likely that the fire ignited above the complex, spreading to the mud-brick walls, timber beams and finally to the stored crops. Due to the hermetic nature of the silo, however, the fire burned at relatively low temperatures (200–380°C) and without much oxygen, charring much of the grain rather than reducing it to ash. In areas where the cereals had been completely destroyed there is evidence that the collapse of the burnt walls increased the amount of oxygen available, thus allowing the fire to burn at much higher temperatures. Overall, it is likely the silo complex was on fire for a number of weeks and would have been difficult to extinguish from above. Although, as noted, parts of the silo remained unburned and possibly continued to be used, there is no evidence that the silo was repaired or rebuilt, and complete abandonment of the complex had clearly occurred by the time the Iron Age settlement was established c. 900 B.C.~~.~~[26]

4.1 Preliminary archaeobotanical results

During the excavation of the Hattusha silo complex about 4 tonnes of charred archaeobotanical material were removed from five burnt chambers.[27] This included both charred grain and remains of the straw insulation material, the latter found as both charred macrobotanical remains and as phytoliths. The archaeobotanical material was directly recovered, without flotation, and about 100kg of the ~~most well~~ preserved grain was eventually selected for export as a cross-section of all five chambers. The samples selected derived from a number of different arbitrary spits through the grain fills of the chambers ~~as~~ a means of exploring each chamber's internal stratigraphy. The remaining material was then re-buried or kept at the Hattusha dig-house.[28] Preliminary identification and analysis of the exported samples ~~was~~ undertaken by Reinder Neef at the Deutsches Archäologisches Institut and ~~was~~ published in 2000.[29]

In total, 36 samples from the five separate chambers were studied by Neef. Due to the differing levels of preservation observed in each chamber, however, the number of samples analysed per chamber varies significantly (see *Table 1*). The vast majority of plant remains was preserved through charring, an exception being seeds of *Buglossoides* (Boraginaeceae), which are naturally calcareous and can survive without charring.[30] In terms of the plant spectrum recovered from the silo complex, it was observed that hulled barley was the primary cereal crop being stored. Glume wheat was also present in all five chambers,

23 Dörfler et al. 2011.

24 Neef 2001.

25 Seeher 2006, 49.

26 Seeher 2006, 50.

27 Seeher 2006; Dörfler et al. 2011.

28 Seeher 2006, 46–47.

29 Neef 2001.

30 Pustovoytov et al. 2004.

although in much lower abundance than hulled barley. The only exception to this was chamber 32, which was identified as a dedicated glume wheat store. Glume wheat was commonly found in spikelet form, with the glumes still attached to the grain. Storage in spikelet form may have been a means of protecting the grain from pests and fungus[31] and/or, as Neef[32] suggests, because glume wheats are sown as spikelets. Certainly to remove glume wheat grain from the glumes requires a labour intensive de-husking process that is normally only carried out before human consumption. Hulled barley grains, mostly with adhering lemma and palea intact, were associated with some rachis material. The presence of chaff in association with grain suggests that the hulled barley and glume wheat were stored in a semi-processed form;[33] some of the cereal material was also found as ears or ear parts.

Other cultivars identified included a number of pulse species such as grass pea; lentil, bitter vetch and *Vicia faba var. minuta*, a miniature form of Celtic bean.[34] Most pulse crops occurred at low levels in few samples, suggesting that these taxa were contaminants of the primary cereal crops.

Perhaps the most interesting feature of the silo complex, however, is the large quantity of wild/weed taxa that are present in every sample. Over 70 different taxa have been identified so far, and most show a preference for calcareous, loamy soils, similar to the conditions found in the area of Hattusha.[35] All weed taxa identified are also indigenous to Anatolia, consistent with the hypothesis that this grain was locally produced. Finally, the substantial numbers of wild/weed seeds would seem to indicate that the fields in which the cereal crops were growing were not being intensively weeded, and provide further evidence that the crops had been subject to limited processing/cleaning before storage.

4.2 Renewed archaeobotanical work

Ongoing collaborative work by the present authors on the archaeobotanical material from the Hattusha silo complex firstly involves refinement of cereal crop identification, as well as identification of all wild/weed taxa to the species level, where possible. The weed identifications will be incorporated into a functional ecological analysis of the arable weed assemblage using the FIBS technique (Functional Interpretation of Botanical Surveys). This method is used to monitor the ecological variables underlying weed species' distribution by identifying relevant characteristics that enable species to thrive under particular conditions.[36] Functional ecological analysis of modern weed surveys are used as a means of comparing archaeological material to weed assemblages from known agricultural regimes with the aim of establishing ancient plant growing conditions and the nature of

31 Seeher 2006, 78–79.
32 Neef 2001.
33 Hillman 1984; Jones 1984.
34 Neef et al. 2012, 214.
35 Dörfler et al. 2011.
36 Jones 2002.

crop husbandry practices at Hattusha.[37] Alongside this work, stable isotope analysis will also be carried out on the crop material as a means of understanding specific aspects of arable management. Stable nitrogen $\delta^{15}N$ isotope ratios can be used to assess soil nitrogen composition, from which manuring status can be inferred,[38] while stable carbon $\delta^{13}C$ isotope ratios reflect water availability.[39] The integration of crop stable isotope analysis with weed functional ecology will generate complementary data to facilitate the reconstruction of growing conditions and arable land management practices.[40] The results should afford new insights into the nature of Hittite farming and the resources needed to generate the substantial quantities of produce stored within the Hattusha silo complex.

In order to gain an initial impression of compositional variation amongst the samples, we carried out correspondence analysis (CA) on the preliminary archaeobotanical data[41] from the Hattusha silo complex assemblage. This ordination technique is used ~~primarily~~ to explore major trends of variation among individual samples.[42] By producing two-dimensional scatter plots, positive or negative associations among samples or taxa can be used to identify patterns within the data that are not immediately obvious from the raw data itself due to the high number of variables (taxa) involved. CA was carried out using the CANOCO software,[43] and the results were plotted using CANODRAW.[44] In each of the following graphs, axis 1 (which accounts for the most variation) was plotted horizontally and axis 2 (the next most powerful axis) vertically. Positive or negative associations between samples or different taxa are indicated by the direction in which they deviate from the centre of both axes (the origin), whilst their distance from the origin indicates how 'unusual' this association is. CA, however, tends to emphasize the importance of rare taxa, leading to the production of scatter plots that are heavily skewed by outliers.[45] To avoid this problem, rare taxa were excluded to ensure a more even spread of data points.

An initial analysis was carried out on all samples, excluding the single sample from chamber 28 (*Table 1*), and 39 of the most prevalent taxa (*Table 2*), producing well dispersed scatter plots of taxa and samples (*Figs. 1 and 2*). *Fig. 1* is a bi-plot showing both samples and taxa, coded by the four chamber numbers, while in *Fig. 2* samples are represented as pie-charts showing ~~percentage content in terms~~ of seven major plant categories. From *Fig. 2* it is evident that hulled barley grain content dominates the first (horizontal) axis, with samples containing high proportions of barley concentrated at its negative (left) end. By contrast, the second (vertical) axis distinguishes a small number of samples containing a high proportion of glume wheat at the positive (top) end from those samples domi-

[37] Jones et al. 1995; Bogaard et al. ~~2015~~.

[38] Bogaard et al. 2007.

[39] Wallace et al. 2013.

[40] Bogaard et al. ~~2015~~.

[41] Neef, 2001.

[42] Jones et al. 1995.

[43] ter Braak 1988.

[44] Smilauer 1992.

[45] Jones 1984, 1991; Lange 1990, 73–76.

nated by wild taxa at the negative (bottom) end. What is also notable from this analysis is that samples located towards the negative end of axis 1 contain hulled barley grain to the (virtual) exclusion of other plant items, whereas samples containing glume wheat and wild taxa tend to have a more mixed composition.

Table 1 The number of samples per chamber

Chamber	No. of Samples
12	5
28	1
29	4
30	21
32	5
	36

Table 2 List of taxon acronyms used in correspondence analysis (CA), and the full taxa name

CA taxon acronym	Taxon name
adoni	Adonis
alyss	Alyssum
biforad	Bifora radians
bitvet	Bitter vetch
brom	Bromus
buniori	Bunias orientalis
buple	Bupleurum
calyst	Calystegia
camesat	Camelina sativa
caucpla	Caucalis platycarpos
centa	Centaurea
cephsyr	Cephalria syriaca
ftwra	Free-threshing wheat rachis
galisma	Galium small
galitra	Galium tricornutum
gwgb	Glume wheat glume base
gwgr	Glume wheat grain
hbargr	Hulled barley grain
hbarra	Hulled barley rachis
lallibe	Lallimentia iberica
lepid	Lepidium
litharv	Lithospermum arvense
loli	Lolium
medipod	Medicago pod
neslpan	Neslia paniculata
oat	Avena
onobare	Onobrychis cf. arenaria
papilar	Papilionaceae large
papisma	Papilionaceae small
ranuarv	Ranunculus arvensis
rumcarp	Rumex with carpels
rumex	Rumex
silene	Silene
stachy	Stachys
thlasp	Thlaspi
turglat	Turgenia latifolia
umbel	Umbelliferae
vacc	Vaccaria
verohed	Veronica hederifolia

From *Fig. 1* it appears that the ~~specific~~ composition of each chamber is quite distinct. Chamber 32 is concentrated towards the negative end of axis 2 and the positive end of axis 1, with samples dominated by wild taxa (see *Fig. 2*). Samples from chamber 12 are similarly located towards the positive end of axis 1, although slightly closer to the origin on axis 2 than those from chamber 32, reflecting a higher proportion of glume wheat in these samples. The samples from both chambers 12 and 32 also seem to be widely distributed, indicating that intra-sample variability was high in these two chambers. By contrast, samples from chambers 29 and 30 are divided into two other, tightly clustering groups. About half of the samples (11) from chamber 30 and two samples from chamber 29 are grouped towards the negative end of axis 1 and are dominated by hulled barley grains. The remaining 10 samples from chamber 30 and a further two samples from chamber 29 are situated towards the positive end of axis 2, indicating that these samples are associated with larger percentages of glume wheat grains. Thus, these two chambers each contain two distinct compositional 'types'.

Due to the exceptionally large number of weed taxa identified from the Hattusha silo complex, a further analysis was performed on the basis of wild taxa only, as a means of exploring this aspect of variation among the samples separately from crop composition. This analysis was based on the ~~39~~ most commonly occurring wild/weed taxa in the assemblage. *Fig. 3* shows a bi-plot of wild taxa and samples together, the latter coded by chamber number. A striking feature of this graph is the tight clustering of all points from chamber 30 towards the negative end of axis 1. In *Fig. 1* the samples from chamber 30 were divided between those dominated by hulled barley grains, and those dominated by glume wheat grains. Despite these differences in crop content, *Fig. 3* shows that *all* samples from chamber 30 ~~have~~ a distinctive wild/weed taxon composition. *Fig. 3* also indicates that the samples from chamber 29, which clustered closely with samples from chamber 30 in *Fig.*

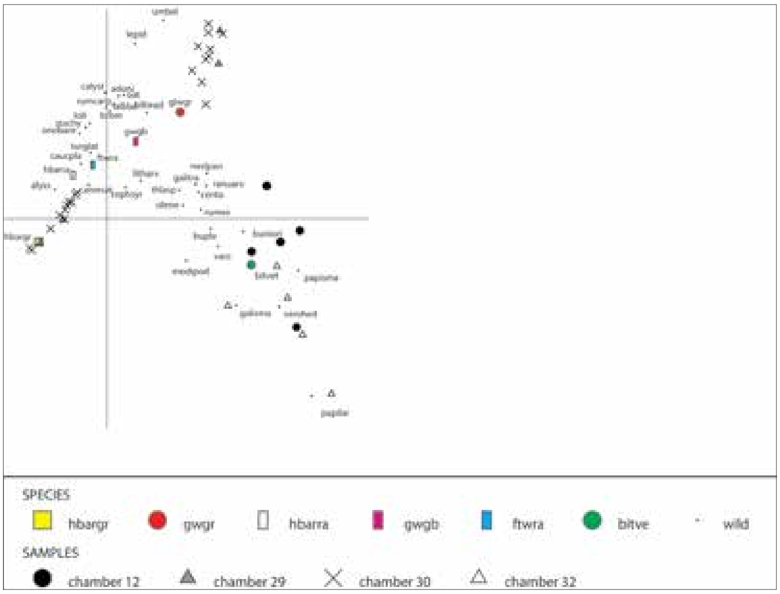

Figure 1 Correspondence analysis plot of 35 samples on the basis of 39 taxa, coded by chamber. Axis 1 is plotted horizontally and axis 2 vertically.

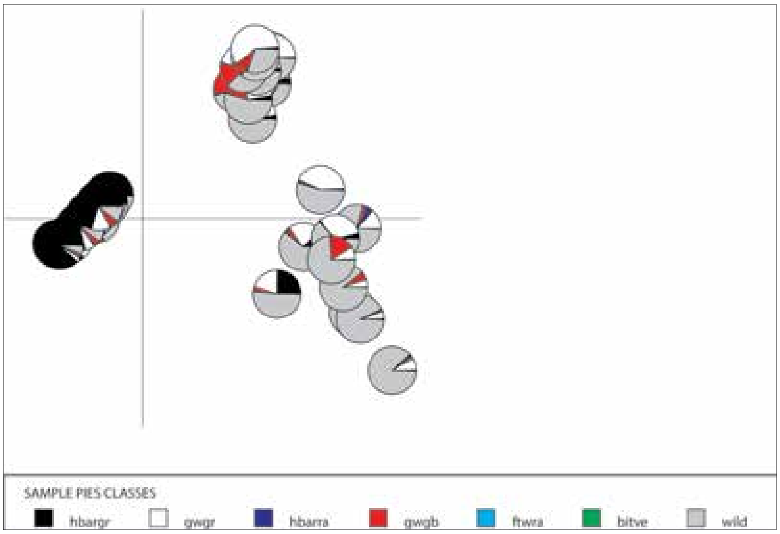

Figure 2 Correspondence analysis of 35 samples on the basis of 39 taxa, with samples represented as pie charts showing proportions of major categories.

1, are distinct in their wild/weed composition. *Fig. 3* further emphasizes the differences in sample composition, seen initially in *Fig. 1*, between chambers 12 and 32. Samples from chamber 32 appear to be grouped towards the positive end of axis 1, reflecting a particularly high proportion of large legume seeds. By contrast, samples from chamber 12 are widely dispersed towards the positive ends of both axes, reflecting a varied wild/weed composition. Another prominent feature of *Fig. 3* is the distribution of the wild/weed taxa themselves along the axes. The majority of species are clustered towards the negative ends of both axes, whilst the positive end of axis 1 is dominated by large-seeded legumes. This suggests that samples from chamber 29 and chamber 30 in particular are characterised by a broad range of wild/weed taxa. By contrast, samples from chambers 12 and 32 contain a smaller range of wild taxa, and are dominated by large-seeded leguminous types. The above correspondence analysis, therefore, suggests that the crops stored in the silo com-

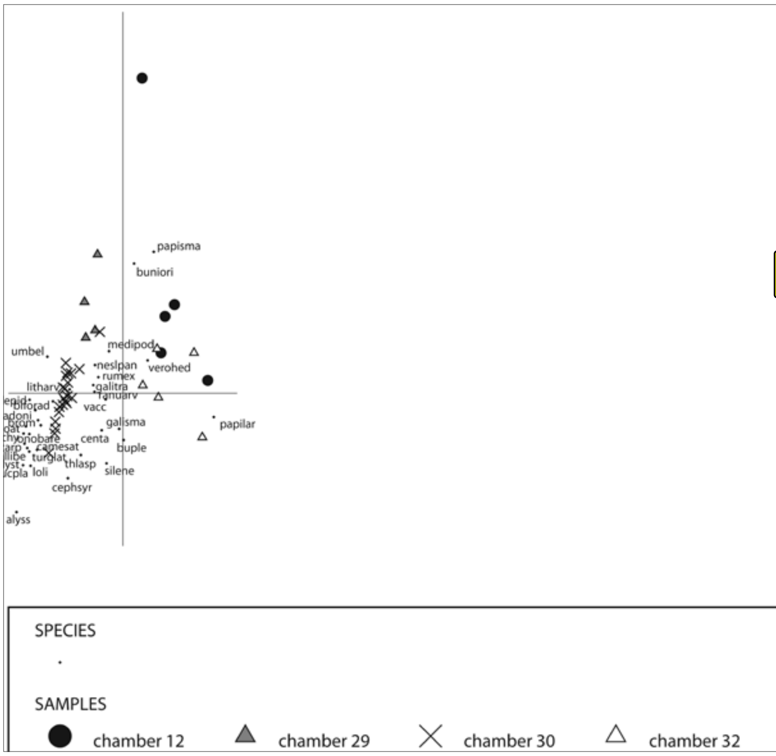

Figure 3 Correspondence analysis of 35 samples on the basis of 33 wild taxa, coded by chamber

plex were being cultivated in multiple locations with distinctive weed flora, and potentially also under somewhat different growing conditions. Ecological analysis of the weed assemblage, complemented by stable isotope analysis of crop material, will shed further light on the nature of this variability.

5. Discussion

5.1 Hittite agriculture - the historical and archaeobotanical evidence

There is little documentary evidence concerning Hittite agriculture and rural economy. Hittite daily life was rarely recorded on clay tablets and has, therefore, traditionally not been a focus of scholarly research.[46] Much of what is known historically has been pieced together from entries in the Hittite Law Code, which deals with the division of cultivable land, agricultural taxation and service obligations to the state.[47] This evidence, combined with additional information from cadastral documents,[48] has contributed to the reconstruction of a highly variable agricultural economy. Hittite farming seems to have encompassed relatively small-scale, independent household farming, large 'feudal' estates allocated to high-ranking individuals that were worked by serfs and/or slaves and the sharecropping of crown land. From the Law Code we also know that all Hittite subjects

46 Dörfler et al. 2011.

47 Hoffner 1974, 54.

48 Yakar 2000, 260.

(excluding the elite and those with special dispensation from the king) had to perform *luzzi* service on crown-owned agricultural lands.[49] Each independent household, depending on the size of the family and the number of draught animals, was obliged to send a number of adults and oxen to cultivate crown lands on average twice a week. This system was controlled by district governors, and any produce would have been directly owned by the king. Agricultural goods produced by rural communities were also subject to taxation by the state. Article 56 of the Hittite laws discusses the *sahhan*, a tax requiring the provision of food products, wool, manufactured goods and livestock to the crown.[50] Grain gathered through taxation, as well as tribute from vassal states and crops harvested on the crown lands, was stored in large grain depots throughout the empire, and Bryce[51] identifies the Hattusha silo complex as one such facility. Such storage facilities would have been vitally important to the Hittite economy as they enabled a certain portion of society to be free from agricultural work and mitigated against future harvest failures.[52] Central Anatolia, »a land chronically vulnerable to the vagaries of climate«[53], is subject to very cold winters, hot, dry summers and variable amounts of rainfall. Consequently, drought and famine were common occurrences. The taxation of agricultural produce and the planning of centralised storage facilities, such as the Hattusha silo complex, would therefore have been essential as a source of famine relief.

In terms of the range of crops grown, Hittite texts contain six terms referring to cereals, four terms for wheat and two terms for barley.[54] Direct evidence for the cereal spectrum is provided by archaeobotanical material from multiple sites including Hattusha itself,[55] Kuşakli-Sarissa[56] and Kaman-Kalehöyük.[57] From these sites at least five major cereal cultivars have been identified: the glume wheats emmer and einkorn; free-threshing wheat; and two- and six-row hulled barley.[58] Of these species, barley (*halkiš*) is the most commonly mentioned in Hittite documents[59] and, especially given frost-resistance and tolerance ~~of poor growing conditions~~ in modern barley varieties, is thought to have been the primary crop.[60] After the harvest, barley grain was used to make a type of flat bread as well as groats, both of which have been found in carbonised form at Kuşakli-Sarissa, and also to brew beer. Hulled barley grains do not need to be de-husked for brewing, and the two-row form is particularly favoured due to its low protein content.[61] Other uses of barley

49 Yakar 2000, 263.

50 Yakar 2000, 266.

51 Bryce 2002, 77.

52 Seeher 2006, 82.

53 Bryce 2002, 73.

54 Hoffner 1974, 59; Yakar 2000, 274.

55 Neef 2001; Pasternak in Schachner 2011.

56 Dörfler et al. 2011.

57 Fairbairn – Omura 2005.

58 Dörfler et al. 2011.

59 Hoffner 1974, 62.

60 Dörfler et al. 2011.

61 Brouwer 1972, 309.

include as fodder for livestock (mentioned in the text as ŠÀ.GAL), and barley straw has also been identified as the tempering agent in mudbrick.[62] Wheat was also ~~an~~ important ~~cultivar~~ for the Hittites, and the archaeobotanical identification of several different species may indicate that different varieties of wheat were grown for different purposes. At Hattusha itself there is some evidence for above-ground storage of free-threshing wheat and possibly naked barley in *pithoi* (e.g. magazines containing large storage vessels around Temple I in the Lower City), in contrast to the below-ground hermetic storage of glume wheat and hulled barley, suggesting differences in the storage and consumption of naked versus hulled cereal types.[63]

5.2 Storage in the Hittite Empire and the Eastern Mediterranean

The excavation of the large silo complex at Hattusha is important both because of the archaeobotanical information provided by the charred material, and because storage is a useful index of past socio-political organization. For the Hittites, hermetic underground storage, known by the cuneiform word ESAG, meaning storage pit, seems to have been used throughout the empire as a method of preserving agricultural produce over a long period of time. At Hattusha itself, 11 other storage chambers/pits were found during excavations in the 1990s in the area of Büyükkaya, a ridge to the north of the Lower City. Although not on the same scale as the silo complex, these large rectangular pits had limestone paved floors and would have had a collective estimated capacity of between 128–648m^3 [64]. Large-scale storage facilities have also been found at other Hittite sites: for example, at the site of Kuşakli-Sarissa c. 30 x 50m D-shaped features were found partially cut into the bedrock, and with layers of rotted organic material on their floors.[65] Similarly, at Alaca Höyük a number of c. 13 x 8m rectangular silo pits have been excavated, and are thought to have been part of a much larger storage structure.[66] Charred plant remains have also been found in large storage pits dating to the Old Hittite period at Kaman-Kalehöyük.[67] This site, located 100km south-east of Ankara in the Kirşehir province, was occupied from c. 2000 BC, and recent excavations provide evidence for both short-term storage of staples at the household level and five large, underground 'round structures' (RS). The largest of these pits, RS3, was *c.* 2m deep and 7m in diameter, and contained phytolith remains of a protective lining, comparable to the lining of the silo complex at Hattusha, constructed of cereal straw and grass.[68] Direct archaeobotanical evidence supports the explanation that these pits were used for agricultural storage, and the construction of a large masonry building alongside them signifies that they may have been part of a system of central surplus control.

62 Seeher 2000a.

63 Dörfler et al. 2011.

64 Seeher, 2006, 80-81.

65 Mielke 2011.

66 Bryce 2006, 12.

67 Fairbairn – Omura 2005.

68 Fairbairn – Omura 2005.

The use of large-scale underground hermetic storage is not unique to the Hittite empire; roughly contemporary cases have been found throughout the Eastern Mediterranean. Perhaps the most famous examples come from Minoan Crete, where the discovery of large storage facilities has traditionally been seen as the embodiment of elite control of local surplus.[69] The function of the *kouloures* (large, circular pits) at Knossos and Phaistos has been a subject of debate in Minoan archaeology, with some scholars rejecting the granary explanation due to the lack of archaeobotanical evidence.[70] The size of these pits, and similar square structures identified at Malia and the southern site of Ayia Triada, however, is comparable with the storage pits excavated at Büyükkaya. Also, like the silo complex at Hattusha, these structures are often located in prominent places (courtyards) that would have made them easily accessible and visible to people inside the palace. Other examples of large granary-like storage structures have also been found at Ugarit[71] and at the Egyptian Middle Kingdom site of Kahun.[72] The precise function of these Minoan, Egyptian and Levantine structures *vis a vis* hermetic crop storage is difficult to ascertain due to the lack of direct archaeobotanical evidence. Nevertheless, continued examination of the Hattusha silo complex can shed new light on the use and implications ~~about~~ this type of agricultural storage in a Hittite context, and raise new questions about the ecological and political significance of these practices elsewhere.

6.1 Conclusions

Large-scale hermetic storage in the Hittite empire allowed the preservation of significant quantities of grain crops for a long period of time. Control of these facilities is thought to have been centrally organized, and documentary evidence confirms that the Hittite king was the direct owner of all taxed agricultural produce. This central storage system not only freed a portion of society from agricultural work, but also allowed the king to exert power over other cities and vassal states by giving or withholding food in times of famine. The discovery of the Hattusha silo complex and the extraordinary quantity of archaeobotanical material excavated there will allow us to refine current interpretations of Hittite agriculture. Preliminary results presented here suggest that the produce stored within the silo derived from a number of distinct growing locations and perhaps conditions. The sheer quantity of wild/weed taxa identified is consistent with the hypothesis that these crops were growing in fields that were not subject to high labour inputs and were in general poorly tended. Our ongoing work seeks to integrate the results of full primary archaeobotanical analysis with weed ecology and crop stable isotope determinations, allowing a more in depth discussion of crop-specific growing conditions and arable land management techniques. It is hoped that this work will shed new light on the nature of Hittite farming in the 16th century BC, and the techniques used to produce the large quantities of surplus crops mobilised by the state.

69 Privitera 2014.

70 Strasser 1997.

71 Curtis 1985, 42.

72 Kemp 1986.

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