No stone unturned: Using experimental archaeology and residue analysis to improve our understanding of Crimean plant exploitation during the Late Pleniglacial.

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Figure 1 Art Nouveau Cover Illustration. Illustration created specifically for this thesis including some of the wild plants used in the project like the cattail and wild carrot. (By D.A. Derzhavets).

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1. INTRODUCTION

1.1 UPPER PALAEOLITHIC DIET, CRIMEAN PENINSULA AND ITS PALAEOLITHIC PLANT EXPLOITATION

Understanding humans in the past is synonymous to understanding their environment and the interactions that happen within it. This has also been the case for human evolution and reconstructing human-plant relationships, primarily in the context of diets. In recent years various studies have emphasised the complexity and variability of Upper Palaeolithic (UP) (45kya-12kya cal BP) diets in Europe (Power & Williams, 2018; Revedin et al., 2015). The greater numbers of grinding stones collected from UP cultural layers compared to earlier periods confirm an increase of the processing and consumption of plants (Dobrovolskaya, 2005). In the absence of grindings stones, other proxies – such as phytoliths and isotope analysis – are used to identify the presence of plant matter and their potential purpose, such as food (Cachel, 1997).

The north Black Sea region, or the northern Pontic region (Fig. 2) which includes the Crimean Peninsula, has been a great source of information on Middle Palaeolithic (MP) and Upper Palaeolithic (UP) developments of human evolution (Demidenko, 2014; Demidenko et al., 2012; Marks & Monigal, 2004). Contributions of subsistence strategies, cultural aspects of engraved lithics and bone, hunting strategies and settlement patterns are all part of a greater understanding of the migrations and adaptations of both Neanderthals and AMHs (Chabai, 2004; Demidenko, 2014; Majkić et al., 2017, 2018). More recent studies however, have highlighted the need for revisiting the dating of key Crimean sites (Spindler et al., 2021). The region underwent a series of drastic ecological changes during the MP - UP, such as climatic and vegetational fluctuations that completely altered the landscape and possibly forced people to move from or enticed them to come to the region. One of the main causes of this was the

Figure 2 Map of Eastern Europe. The map indicated the location of the Crimean peninsula and zooms into it on the left. (Map by D. A. Derzhavets).

hydrology of the region during the Late Pleniglacial (LPG: 26.5–15 ka cal BP) (Tzedakis et al., 2013), a shift in the water flow caused by the melting water from the deglaciation of ice formed throughout the Last Glacial Maximum (LGM: 26.5 and 19 ka cal BP *sensu lato*)(Demidenko, 2021; Genov, 2016). The Crimean Peninsula, created by the deglaciation and filling up of the Black Sea, was a potential refugium, a place of refuge for organisms dealing with extreme environmental conditions in neighbouring regions or their place of origin (Dolukhanov, 2016; N. Gerasimenko, 2007). The diversification of species in refugia is a debated topic, very dependent on the size of the potential refugium as well as the scope of the species incorporated in the study and their dynamics within the environment (Dufresnes et al., 2016). Nevertheless, Crimea's favourable climate during the during the second half of the LPG (19-15 ka cal BP) was home to animals such as mammoths and woolly rhinoceroses, but also to a wide range of plants. Yet, when trying to understand the dietary behaviour and availability

for this region during the second half of the LPG, the focus of dietary research remains on the animal food with little to no mention of plant exploitation possibilities. It is not surprising that bones and stone tools make up most of the studied assemblages in this region or generally, considering their preservation and accessibility. However, this analysis alone is insufficient when trying to piece together a more complete idea of dietary behaviours and nutritional exploitation possibilities. A synthesis of the environmental composition of the region is therefore an integral part of this experimental research, not only for the vegetational part but also in order to consider the various nuances due to climatic fluctuations. Environmental reconstruction models, like the ones composed by N. Gerasimenko (2007) for the Crimean peninsula, are a great source of information and tap into the potential of vegetation exploitation, but their 'completeness' and therefore also their reliability can be problematic. Environmental data can contradict each other, like precipitation and vegetation models, and reliance on modern analogues can perpetuate uniformitarian assumptions (Faith & Lyman, 2019). Adding a layer to these models consisting of experimental archaeology that focuses on residue collection and survival rates, can provide a more complete view of the diet by considering more practical factors.

Creating new residue reference material for wild plants as well as supplementing existing reference collections with fresh data is one of the goals of this project. This data is produced by processing the plants, exposing some of them to the elements to assess the taphonomic signal and performing microscopic analysis on the tool samples. Three key sites on the Crimean Peninsula have been chosen as an archaeological reference point: Rock Shelter Skalisty, Buran Kaya III and Siuren I. Their rich and interesting faunal and lithics assemblages as well as the available palaeobotanical data, accessible documentation and them being located on the western Crimean Mountain ridge with similar ecological settings during the Late Pleniglacial period, make these sites a great baseline for building an archaeological experimental pilot study. Additionally, the grinding stone found at Siuren I with traces of cattail

processing imbedded into its surface serves as an indication that experimental plant processing research in this region should be employed more (Longo et al., 2021)

This research has the potential to expand our knowledge of vegetation exploitation for the Black Sea and interacting regions. Nutritionally and medicinally interesting herbaceous plants are visible in the pollen data (Gerasimenko, 2011) and environmental reconstruction of the region, yet no investigation into these plants or their role has been done. Such research has been undertaken in neighbouring areas like the Caucasus and the Balkans (Martkoplishvili & Kvavadze, 2015). These investigations also relied on recent ethnobotanical data from the region, which can be complimentary to the archaeobotanical data and the interpretation thereof. Ethnobotanical investigation and data has been proven to be helpful for archaeological research, specifically in identification of plants, their processing, storage, symbolism and overall handling and relationships between humans and plants in the past (Capparelli et al., 2015; Pearsall, 2023). Despite these known benefits of ethnobotanical exploration, well organised ethnobotanical data is difficult to find for Crimea. Due to a similarity in vegetation in the Caucasus and the Balkans, the data from these neighbouring regions can be used as a guideline and a comparison for potential plant exploitation. Therefore, the aim of this research lies in a twofold approach to resolve the gap in knowledge concerning plants and their exploitation by humans in the northern Black Sea region during the second half of the LPG.

1.1.1 Structural guide of the research

Firstly, all the possible ecological and archaeological region of this area were synthesised to see what additional information was lacking when it comes to the plant exploitation by AMHs during second half of the LPG. Environmental reconstruction and archaeological data were then combined to provide information on the availability and accessibility of vegetal material. This formed the skeleton on which the experimental procedure and choices were based. The availability of comparable plant material in the Netherlands and this background data allowed to make a selection of suitable plants to process. I explored the selected plants with different tools prior to engaging in a systematic experimentation.

The second part consisted of creating an experimental protocol for processing different plants/plant parts that have been selected based on potential availability in the region as well as the availability in the Netherlands. Ethnobotanical literature and preliminary experimentation with different plants and tools, aided in the construction of the experimental protocol. The experimental results incorporated not only the amount of residues found on the tools, which were specifically significant in the first post depositional stages, but also included interesting observations on the behaviour of plant material and the handing of the material with different tools. Such observations include prehension of the tool and the influence of plant biology (hydration, fibres, growth composition, etc.) on the tools and processing.

1.2 AIMS AND QUESTIONS

This research aims to further the knowledge of human-plant relationships in the Black Sea region during the Late Pleniglacial period (19-15 ka cal BP) through experimental and residues analyses, as well as looking at a broader contribution of these analyses in the archaeological context.

The topic of plant exploitation in this particular region is understudied and no experimental studies have been undertaken as of yet. That is why the main question of this thesis is:

- How can experimental archaeology and residue analysis help in understanding the plant exploitation possibilities and plant-human relationship in the region of Crimea during the second half of the Late Pleniglacial (19-15 ka cal BP)?

The following sub-questions have been asked to aid in this research:

- What kind of evidence is there in the archaeological record of plant availability and exploitation in the Crimean Upper Palaeolithic?
- How much and what kind of residues are being collected from lithic and grinding stone tools when processing wild plants?

- What kinds of processes influence the degradation of the residues and how much of an impact does the short term (± 3 months) post depositional taphonomic processes have on the potential archaeological visibility of the plant residues?
- In what way can we use the results of this experimental project to better understand the archaeological record and what we should be looking for in relation to plant material residues on stone tools?

2. Literature review: Current state of knowledge of the occupation and environment of the Crimean Peninsula during the Late Pleniglacial period

In this chapter I elaborate on relevant literature regarding our current state of knowledge of the occupation and environmental make-up of the Crimean peninsula between 19-15 ka cal BP. This includes a general overview of occupation and investigation of key sites, the geological formation of the peninsula that influenced the vegetation composition and development, and the environmental reconstruction during the second half of the LPG.
sites and the selection of plants.

2.1 Archaeological overview of the Crimean occupation during 19-15 ka cal BP

For the Crimean Palaeolithic, the materials that are mainly studied are that of mineral composition, bone, stone and sediment. Much like in other parts of Europe, various materials are linked to specific cultures or in the case of stone tools, technological complexes. These are assemblages of stone tools with distinct morphological features that are associated with a specific period in time. Terminology and identification of these technocomplexes are debated and the naming depends on the researcher and the environment in which they work, as well as the historical period in which these assemblages were first described. European Palaeolithic research uses umbrella terms that stem from the French school of archaeology and thus are named after French sites. Crimean Palaeolithic research uses both local (Olenkovskiy, 2010) and French terminology. More recently it has been vastly explored by dr. Yuri Demidenko and therefore I decided to adhere to his terminological style, which is primarily French school. The technological complexes of the Gravettian, named after La Gravette (33 ka to 22 ka cal BP), is succeeded by the Epigravettian (21 ka to 15 ka cal BP). The Epigravettian technocomplex was

first identified in Italy, of which the distribution today spreads from northern Italy to the western banks of the Volga river in Russia, following the Mediterranean and Black seas. This complex is characterised by a vast presence of elongated backed flint tools, retouched end-scrapers and microliths. The number of retouched and backed pieces varies greatly between sites in Eastern Europe, but the microliths show a consistent appearance.

The archaeological evidence from the sites attributed to these Upper Palaeolithic cultures does not accumulate in a vacuum. The settlements and cultures that produced this evidence, were a product of interactions taking place at a specific time and within a specific environmental context. The Late Pleniglacial is the period during which the Crimean Peninsula as we know it today was slowly taking shape. This period is characterised with a large number of climatic oscillations that had different effects locally and regionally. As the Black Sea basin was slowly filling up from the deglaciation of the Eurasian icesheet, vegetation adapted to this rise in water supply, change in temperature and precipitation through a series of shifts, eventually arriving at a semi-stable subdivision (Fig. 3).

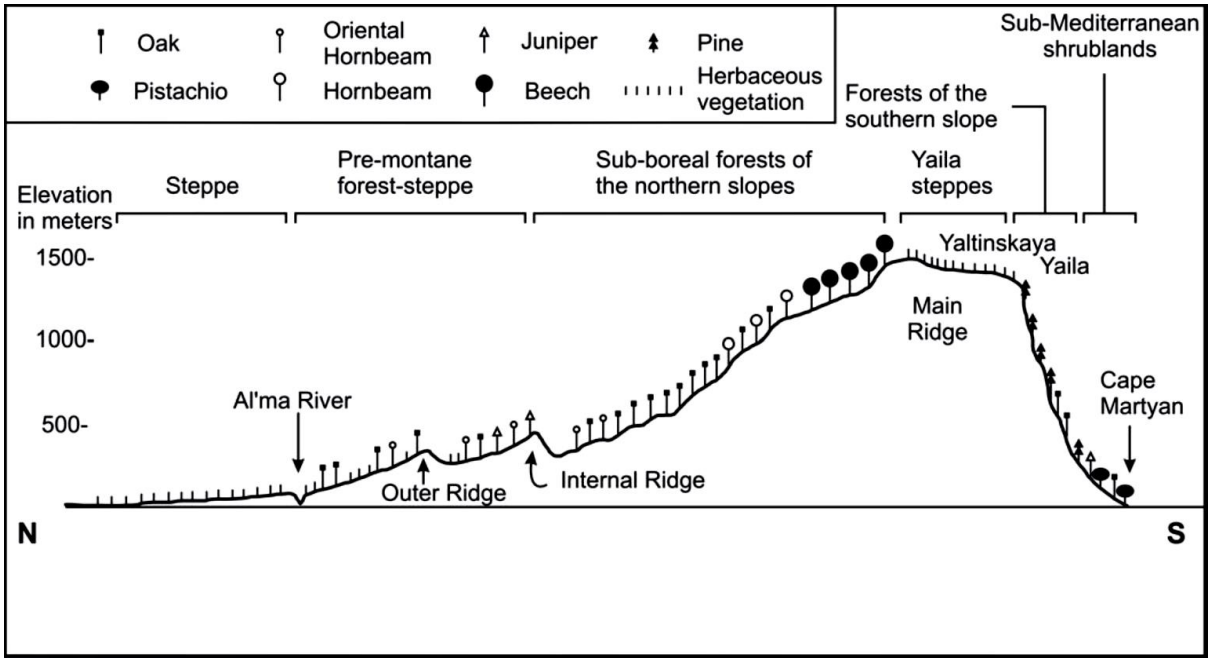


Figure 3 Post LGM vegetation types of Crimea: Simplified representation of Crimean Mountain vegetational transect. (Cordova et al., 2011).

Geomorphology of the peninsula, with eastern mountains and western low plains, was the main divider of these vegetational areas. The north of the peninsula was dominated by a combination of steppe and mixed forests (pine and birch) with a high indication for herbaceous species in the pollen record (Cordova et al., 2011; Gerasimenko, 2011). Central Crimea was a steppe environment and consisted primarily of shrubs, grasses and some herbaceous plants that are associated with steppe environments, such as Asteraceae, Lamiaceae and Linaceae families. The Crimean Mountain range consisted of a mixture of broad-leaved trees. In all the different types of environment, herbaceous plants were identified, many of which many are associated with medicinal use like Artemisia and species from the Plantaginaceae family (Kvavadze et al., 2022).

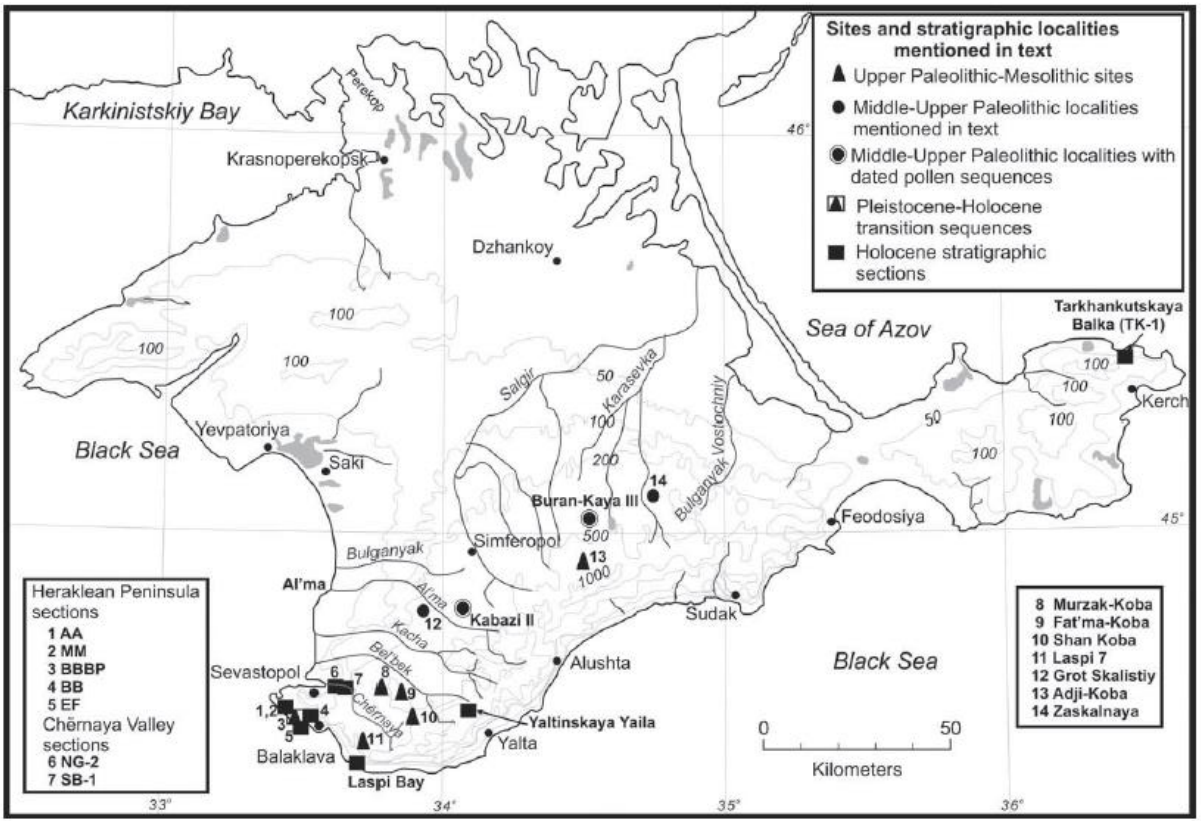


Figure 4 Archaeological sites of Crimea: Palaeolithic and Holocene sites and stratigraphic divisions of soils (legend on the left) on the Crimean Peninsula. (Cordova, et al. 2011).

The Crimean Mountain range is known for its rich archaeological significance for the Palaeolithic period and has been a key region in understanding human evolution (Fig. 4) (Cordova et al., 2011). The site of Siuren I is located in this mountain range and a grinding stone from the Aurignacian technological and chronological layer was recovered from there. Epigravettian layers have been identified at this site but the research dates back to early 20th century and needs to be revisited both in terms of material culture and dating (Demidenko 2014, 9; Demidenko 2014*, 4-9; Longo at al. 2021, 2-5). No indications of distinct grinding stones have been observed in other sites with a large material assemblage, though their presence or some kind of a grinding device is not excluded. All sites of the Crimean Mountain range yield a complex and saturated lithic assemblage throughout many periods. Some sites have isolated lithic tools with no trace of animal bones or other objects, other sites have large assemblages including many materials, but no plant material – with the exception of the grinding stone – has been recovered from any of the sites (Demidenko 2014, 3; Yanevich et al. 2009). The analysis of lithic technocomplexes indicate certain kinds of behaviours, one of them being dietary needs, or the use of tools for dietary needs. The dietary reconstructions so far primarily resulted in identification of faunal exploitation, specifically that of the bison, which went extinct on the peninsula at the end of the Upper Palaeolithic. This conclusion comes from the bone assemblages found across all of the peninsula and the type of tools made for such hunting, arrow and spearheads primarily (Cohen & Stepanchuk, 1999). The investigation of plant-processing in this region has only recently been gaining speed and importance, as technologies have improved and collaborations with foreign archaeologists have increased. However, the period itself, Late Pleniglacial, has not yet been subjected to elaborate vegetational mapping except for pollen records per site. Additionally, there have only been a handful extensive experimental studies looking into the potential of processing plant material and the application of residue analysis, but none for the Late Pleniglacial.

Nevertheless, neighbouring regions like Georgia have performed investigations within the caves of Bondi, Kotias Klde, Dzudzuana, Satsurblia with a focus on the use of plants as

medicine, through pollen analysis. The study focused on local and endemic plants to better understand their origins as well as their role and continuous use within the region. Human remains, teeth, were only found in the Dzudzana and Satsurblia cave and have not yet been analysed in relation to the potential plants at the site (Margherita et al., 2017). This study stresses the importance of these plant investigations since similar research is still limited in numbers. Furthermore, the current plant research in this region is insufficient to provide substantial insights into the utilization and significance of plants in the lives of Upper Palaeolithic people around the Black Sea (Martkoplishvili & Kvavadze, 2015). When we consider this unexplored and underused data, many questions come to mind about the vegetation potential and methodologies that can be applied, some of which have been explored in this research.

2.1.1 Key occupation sites

The number of sites investigated in Crimea have gradually increased in the last 30 years and resulted in improved reconstructions of the environment as mentioned in the previous section. Siuren and Adji Koba were one of the first sites to be elaborately investigated and since their examination, a total of 12 large sites have enriched the Crimean Palaeolithic record, with

Figure 5 Sites on the Crimean Peninsula. A map of the relevant archaeological sites on the Crimean peninsula. (Map by D. A. Derzhavets).

many ongoing surveys and investigations. The two original sites, Siuren and Adji Koba, have a more continuous occupation whilst the recently investigated sites have intervals of no occupation before being used during the Late Pleniglacial period again (Demidenko, 2014). Continuous habitation at these sites is dependent on several factors, like fluctuations in climate – and thus also in flora and fauna – and the availability of easily accessible and sustainable shelter constructions. But it is notable that all rich sites are located on the south of the peninsula and almost all in or around the Crimean Mountains, just like the key sites, Buran Kaya III, Skalisty Rock Shelter and Siuren I, discussed in this project (Fig. 5).

The vegetation is comparable among the three, but sea-level fluctuations can cause significant changes, particularly in shoreline and accessible mountain foot hill caves. For this project, I have chosen Siuren I, Buran Kaya III and Skalisty Rock Shelter – also known as Grot Skalisty – specifically because of their location and occupation during the LPG. They are on the border between a steppe-forest and mountain-forest type of environment, where there is evidence of abundance in herbaceous plants during warmer periods within the LPG. All three have rich cultural Epi-Gravettian deposits that include characteristic flint and stone tools as well as ornamentation, such as backed elongated flakes and blades (Demidenko, 2021). Additionally, a grinding stone – albeit from an older layer – was recovered from Siuren I with grinding traces and cattail starches (*Typha sp.*), which inspired this project (Longo et al., 2021). A brief context of the sites in a north-south order is provided below.

Buran Kaya III

The Buran Kaya III (BKIII) site is a multi-layered rock shelter that is located on the north-eastern side of the Crimean mountains (Fig. 5) with occupation layers ranging from Middle Palaeolithic (MP) to the Neolithic. As the indication in the name already suggests, there are multiple lavels/sites called Buran Kaya, each having a certain occupation period, some with overlaps. The BKIII site changed and added to the way the Crimean UP fit into the European UP context. Together with Siuren I it is the only *in situ* and multilevel site in grottos with an abundant fauna and lithic assemblages (Demidenko, 2014).

The excavation of BKIII in 2001, 2009-2011 concerned 9 MP and UP archaeological occupational layers attributed to Eastern Szeletian, Micoquian, Aurignacian, Gravettian and Final Palaeolithic. It is a key site for understanding MP-UP transition because the site is a temporal and technological outlier. The rich presence of stone and bone tools, bodily ornaments, ochre and human skull fragments have been dated between 38-34 kya cal BP, showcasing a Gravettian complex in the east of Europe, whilst the larger concentrations of this technocomplex in the west, would only arise 2000 years later (Bennett et al., 2019).

Skalisty Rock Shelter

The Skalisty Rock Shelter is located on the south-eastern shore of the Crimean peninsula, deep into the mountain ridge of the Crimean Mountains (Fig. 5). It known for its interstratification, meaning that during the occupation of the grotto during the UP, many types of lithic technologies, and thus also people, have lived in the grotto. The first excavations were held at 1988-89 by a team lead by Yu. G. Kolosov, then again between 1992 and 1995 led by V. Yu Cohen. Between 2004 and 2008 a rescue mission for the grotto was called into action as the forces of nature started to chip away at the archaeological layout and the stability of the rock shelter. Flooding was the main issue that had started to destroy the top archaeological layers of the site. The current situation of the site comprises of 30 square meters of excavated area that is 6 m deep. 38 cultural layers have been identified of which the UP groups have been classified with VII-IV , with an approximate dating between c. 14ka BP and 15.500 ka BP (Cohen 1996Manko 2010, 246-247). Based on chronological and typological interpretations, the flint assemblages found at the grotto reflect a transitional stage, that of the Upper to the Final Palaeolithic.

Siuren I

The site of Siuren I has a unique and remarkable archaeological history. Up until 1990 it was believed to be the only site that represented the full scope of the Crimean Upper Palaeolithic industrial as well as chronological succession, supplemented with an Early Palaeolithic occupation layer at its base. The site is located near the main road that goes from Bakhchisarai to Yalta, near the village Biuk-Siuren (now known as Tankovoe). There are two palaeolithic rock shelters in total, with Siuren II being a Final Palaeolithic site. The Siuren I rock shelter is large south-facing site, 15 m deep, 43 m wide and 9-10 m thick, elevation is around 15-17 m above present-day level of the Belbek River. Within the Aurignacian layers of Siuren I, a grinding stone was recovered containing starch grains of cattail. Several experimental studies have been done inspired by this find, including the experimentation at the centre of this thesis. Initially, this site harboured doubt on whether it was an actual

occupational site. Only after 40 years has it been recognised as one of the most important sites of Crimean Palaeolithic archaeology. The cultural layers excavated over the past century have a complex composition. Initially, three cultural layers were identified, separated by giant limestone blocks, and they were corelated to Lower, Middle and Upper Aurignacian. This identification was not supported and Solutrean and Magdalenian were added to the mix in the process. The most recent effort (2009-2011) to identify a more accurate stratigraphy using literature, a new examination of lithic assemblages, and new dating of cultural layers, resulted in complex reorganisation. The dating was done using ungulate bones, though for some of the layers within units F, G and H dating is not final as the Oxford labs could not date some of the bones(Demidenko et al., 2012). One important implication to consider is that the survival of Micoquian Neanderthals alongside AMHs in Crimea occurred relatively late, possibly making it one of the most recent instances in Europe (Demidenko, 2014). Unit A-E are the relevant units for this project and four occupations layers were identified, starting with the Late/Evolved Aurignacian (c. 27, 000 BP?), the Late Gravettian (c. 24/23,000-20,000 BP?) and the Epi Gravettian (c. 19/18,000-15,000 BP?) (Demidenko et al., 2012).

2.2 THE FORMATION OF THE PENINSULA AND ENVIRONMENTAL COMPOSITION

The environment of the northern Black Sea region between 19 ka and 15 ka cal. BP is complicated due to geomorphological complexity and high fluctuations in climate and sea levels, leading to heterogeneous vegetation. The sites used in this study are all situated on the Crimean Peninsula which itself has had a dynamic formation process that needs to be understood before diving into the possibilities of vegetational exploitation by hominins. Therefore, this chapter will elaborate on the state of the region – consisting of both Crimean Peninsula and a part of the north Black Sea region – in various climatic and ecological stages, the most significant factors that constructed the landscape during the Late Pleniglacial and how human activity has been fitted into this dynamic landscape.

2.2.1 Last Glacial Maximum and the Black Sea basin

Understanding water levels of the Black Sea basin is crucial to reconstructing the environment. Hydrology does not only influence its own environment, that of waterbodies, but inevitably has an effect on the plants and animals that live with and in the waterbodies. Changes in waterbodies are also responsible for local and eventually global climatic fluctuations primarily seen through precipitation in the palaeoclimatic reconstruction. Understanding such complexities allows for a recreation of a more complete image of all the factors that are responsible for the lifecycle of the vegetation and their developments. The Black Sea is a 2.2 km deep basin with connections to the Mediterranean Sea trough the Bosporus Strait. This connection is generally thought to be the controlling agent in the salinity of both seas, seeing how the Black Sea would become a fresh lake during cooler periods and overflow during warm intervals to discharge excess water and sediment supplied by the Dnieper, Dniester and the Danube rivers (Lericolais et al., 2011). The current precipitation of eastern Crimea (400-450mm) is lower than in western Crimea (500-550mm) and the peninsula is covered in gullies, ravines and steep valley river slopes. The sites considered for this project are based around the Crimean Mountains which are located on the slopes of a cuesta (steep slope or cliff), formed in Cretaceous Palaeogene limestone residing at 240-315 m above sea level. The cuesta plateau is covered by meadow-steppe on chernozems (black and hummus rich grassland soils) (Gerasimenko, 2011).

The LGM concerns the most recent cold climatic event. The ice coverage at 26.5 ka BP and 20-19 ka BP was the last largest one and consisted of several ice sheets covering primarily the northern hemisphere. At the time of the LGM, steppe and taiga covered the permafrost (Fig. 10) land and the Black Sea basin was a smaller freshwater NeoEuxinian lake (Fig. 7). Several studies over the course of nearly 30 years have been trying to map the geological layout of the Black Sea basin since the LGM. One of the more recent studies showed that the estimated water level must have been –105 ±2 m below present-day sea level (bpdsl), in contrary to previously calculated -120 m and -90m (Genov 2016, 15). The study used

standardisation of seismoacoustic sections of the northern region of the Black Sea and correlated these with palaeoenvironmental evolution model for the Black Sea during the LGM period, as well as using published radiocarbon ages. The composition of the Black Sea basin started to shift drastically around 20ka - 19ka cal. BP, due to the onset of deglaciation caused by warming up of the atmosphere and a global change in water circulation, which also caused a reinforced reaction for the deglaciation during several intervals. The deglaciation of the Eurasian Ice Sheet Complex (EISC) was responsible for a vast amount of water being transported to the Black Sea. At the time, the landcover varied per region depending on temperature, climatic oscillations, vegetation presence and its adaptation to rapid changes, but remained largely a steppe-like area.

Figure 6 LGM Map of Europe: European palaeoenvironment during the Last Glacial Maximum with indications of icesheet territory, Neoeuxian lake (Black Sea basin) and variation in habitable zones according to temperature. (Map by Becker et al., 2015).

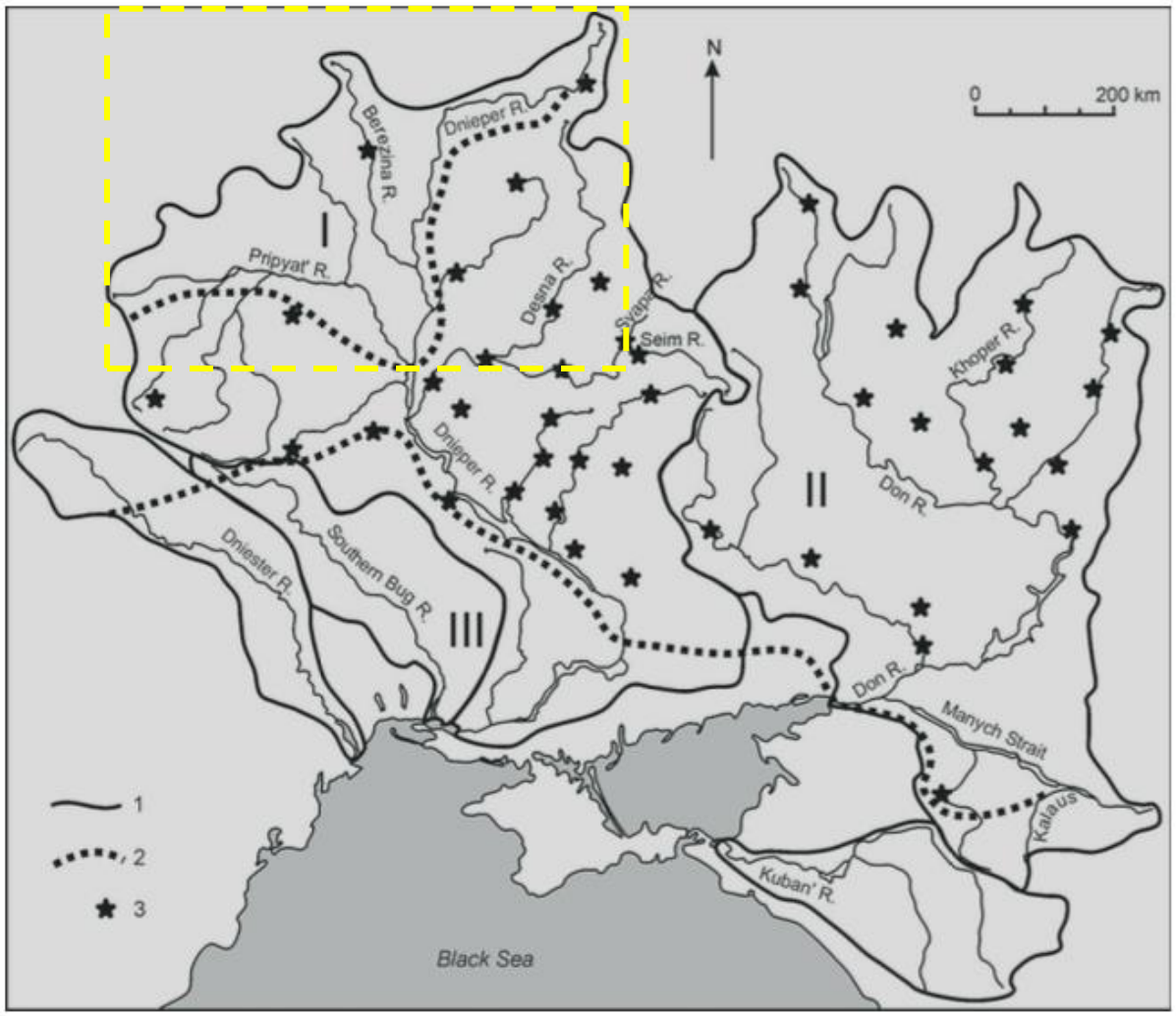


Figure 7 Glaciation Map of Central Ukraine. Late Valdai (late Weichselian) glacial and Pleniglacial features. Key: (1) river basin boundaries; (2) region boundaries; (3) data sites with large paleochannel remnants. Yellow dotted line indicating location of Figure 11. (Sidorchuk et al., 2011).

Sidorchuk et al. (2011) recalculated the annual post glacial runoff into the Black Sea basin, correlating it with the Greenland ice core climatic reconstruction and paleoenvironmental reconstruction through palaeobotanical analysis. The calculations identified three stages (Fig. 7), an initial stage (18ka -15ka BP) with precipitation lower than today but with a high meltwater influx from glacial lakes (Fig. 8), a middle stage (15 -14 ka BP) with higher temperatures and an increase in surface runoff aiding in the formation of

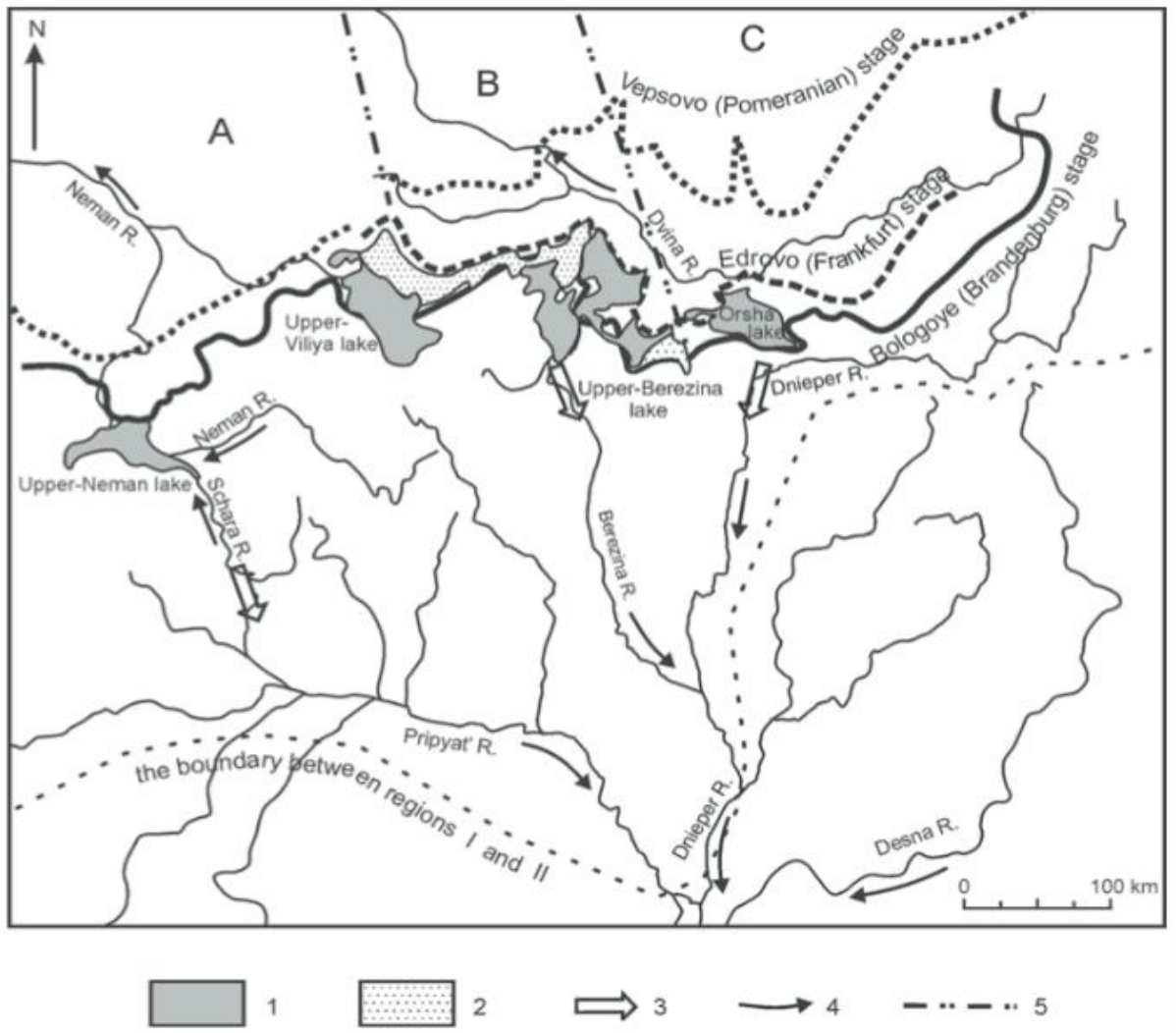


Figure 8 Location of glacial lakes. Black Sea drainage basin at the time of deglaciation after LGM location of which is indicated in yellow dotted line on Figure 7. Key: (1) deposits of proglacial lakes; (2) sandy fluvioglacial deposits; (3) meltwater blow-out channels; (4) present-day direction of flow; (5) boundaries between ice sectors. Boundaries of the Last Glaciation stages and keys 1 and 2 are after Faustova and Chebotareva (1969). Key 3 is after Kvasov (1979) with corrections based on space images. (Sidorchuk 2011).

meandering channels, and a third stage (14ka-10ka BP) with short-term climatic oscillations with a non-steady decrease of surface runoff and a rise in winter temperatures. Additionally, during the middle stage, the Caspian Sea flooded and supplied water to the Black Sea through the Manych Strait. At different points in the last the runoff decreased due to high evaporation despite increasing precipitation (Sidorchuk et al., 2011). The Black Sea has experienced several filling events since the LGM. The Black Sea initially was identified as the Neoeuxian basin or lake (Fig. 6), with three stages since the LGM. These stages include a regression of the basin

between 22-16 ka BP, a transitional stage between 16 ka - 6 ka BP and a transgressive stage with 6ka BP onward. These stages overlap in such a way with the precipitation and water run off stages, that the gradual level rise can be seen and accounted for (Svitoch, 2010).

Measuring and calculating the complex changes in this basin was and still is difficult but has been getting more attention now due to the basin's unique composition and formation as well as Crimea being an important research area for understanding glacial refugia and ecological dynamics. By combining seismosonic data, the calculated annual runoffs and the palaeoecological reconstruction through vegetations, two significant warm periods can be observed during which not only the sea levels rose allowing for the Crimean Peninsula to take shape, but it also shifted the vegetation on the peninsula to have broad leaved tree species populations.

2.2.2 Soil, climate and vegetation

The interaction of solar radiation with the terrestrial geography and atmosphere is what shapes the dynamic climate of this planet. The distribution and absorption of this radiation across the surface together with the ice sheets and bodies of water have been the key controls of the Quaternary climatic fluctuations (Lean & Rind, 1999). In this section I elaborate what kind of influence this dynamic has had on the liveable environment, both on and in the soil. The three stages defined by hydrological processes described above have also been corelated with palaeoenvironmental and vegetational stages defined for the Crimean Peninsula during the Late Pleniglacial period (citation). The samples for the analysis of these environments were taken in close proximity of archaeological sites. In her research she identified several units based on pedostratigraphic and pollen investigation, which are: the Vytachiv Unit consisting of several subunits dated between 75,000±4,000 BP and 28,840±460 BP; Bug Unit dating to 25,500±2,000 BP; the Dofinivka Unit dating between 18,860±220 BP and 14,570±140 BP; and the Prechernomorsk Unit dating between 13,500±2,000 BP and 10, 580±60 BP. The dating of these units is dependent on the archaeological sites from which the material has been retrieved and thus some variation may present itself when looking at other sites and their

sedimentology and archaeological layering. The units that are relevant for this research are the Dofinivka (Df) and the Prechernomorks (Pc) (Gerasimenko, 2011) and overlap with the water run off stages defined by Sidorchuck et al. (2011).

The Df unit consists of two to three weakly developed soil alternating with? and being connected by thin loess beds. These weakly developed soils, or pedosediments, have high content of calcium carbonate and have elevated dry salt content compared to other units and were likely formed by pulses of incipient soil formation loess accumulation alternation. These soils are considered Haplic Calcisols, which means that the soil overall has a high content of lime and is supplemented by sandy loam. This type of soil is often typical for a more semi-arid and elevated environments. However, in the Crimean Mountains the climate was much wetter than in the lower Bug unit and the Df unit recorded further north. This climatic condition allowed for the establishment of forest steppe in the west of Crimea and meadow steppe in the east. Palaeogullies serve as indicators of amelioration of the climate during the Df unit, where distinct vegetational changes are only detected in wetter areas. Soil development controlled by a decrease in loess storms, indicates stability of the sedimentary environment and thus regional decrease in aridity (Gerasimenko, 2011).

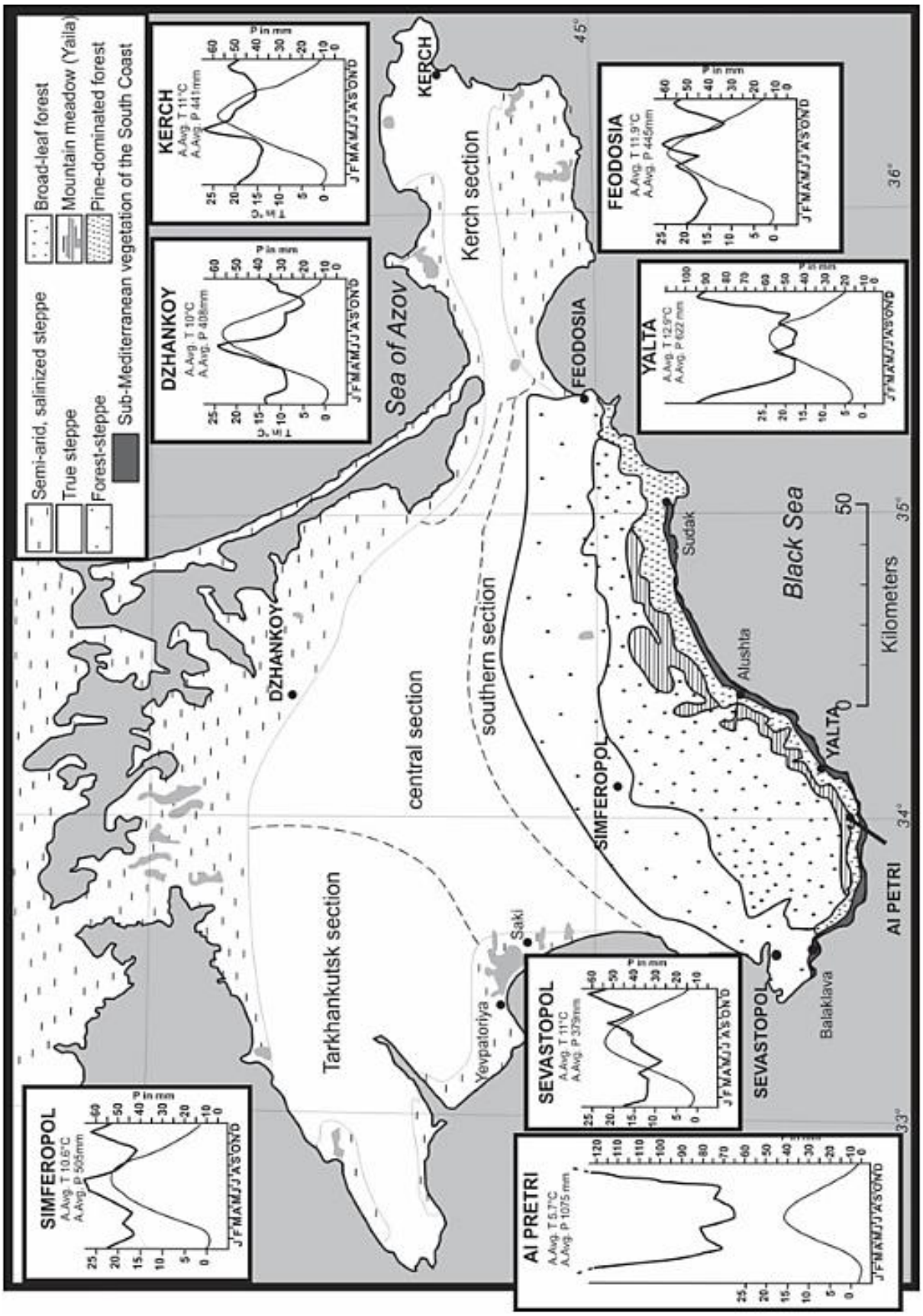


Figure 9 *Crimean Vegetation Distribution. Map of vegetation and precipitation graphs of sites post LGM on the Crimean Peninsula. (Cordova 2011).*

Pollen analysis

Pinus pollen dominated the plateau or higher zones, whereas eastern Crimea shows *Juniperus, Salix, Betula* and *Alnus* and western Crimea only single grains of broad-leaved taxa are represented. There is significant difference between herbaceous plants in the depressions and the plateaus of the Crimean Peninsula. Pollen of *Asteraceae*, *Artemisia* and *Chenopodiaceae* are heavily represented in the plateaus. *Herbetum mixtum* dominates the depressions and prevails over the xerophytes, with very low *Artemisia* counts (Cordova et al., 2011; Gerasimenko, 2011). These vegetation types, today are found at a higher altitudes, which indicates a lower average temperature during this interstadial period than today (Gerasimenko, 2011).

Figure 9 and 10 indicate that the Crimean foothills show a low content of *Pinus, Juniperus, Betula* and *Alnus* pollen granules, which is interpreted as arboreal vegetation being restricted to gullies and valleys (Gerasimenko, 2007). The Crimean plane is made up of dry *Artemisia – Poaceae* steppe kind of environment, but most likely contained a mixed herbaceous presence of plants like *Apiaceae, Rosasea* and *Plantaginaceae*, just to name a few. The second subunit, the incipient soil, is rich in composition in Crimea but contains low pollen grain counts of *Quercus, Tilia, Corylus, Carpinus, Fagus* and *Ulmus.* Xerophytes increase towards the end of the Pc unit, specifically *Artemisia* and *Ephedra* (Gerasimenko, 2011). The third subunit in Crimea has no pollen of broad-leaved trees except for a few *Corylus* grains. The xerophyte count is much lower between the second and the third subunit transition, whereas at the bottom of subunit three the *Herbatum mixtum* becomes increasingly significant. Although a mixed forest, in western Crimea *Juniperus* and *Pinus* dominate the woodland and the appearance of Arcto-boreal species in rock shelters are indications not only of a dry but also a very cold type

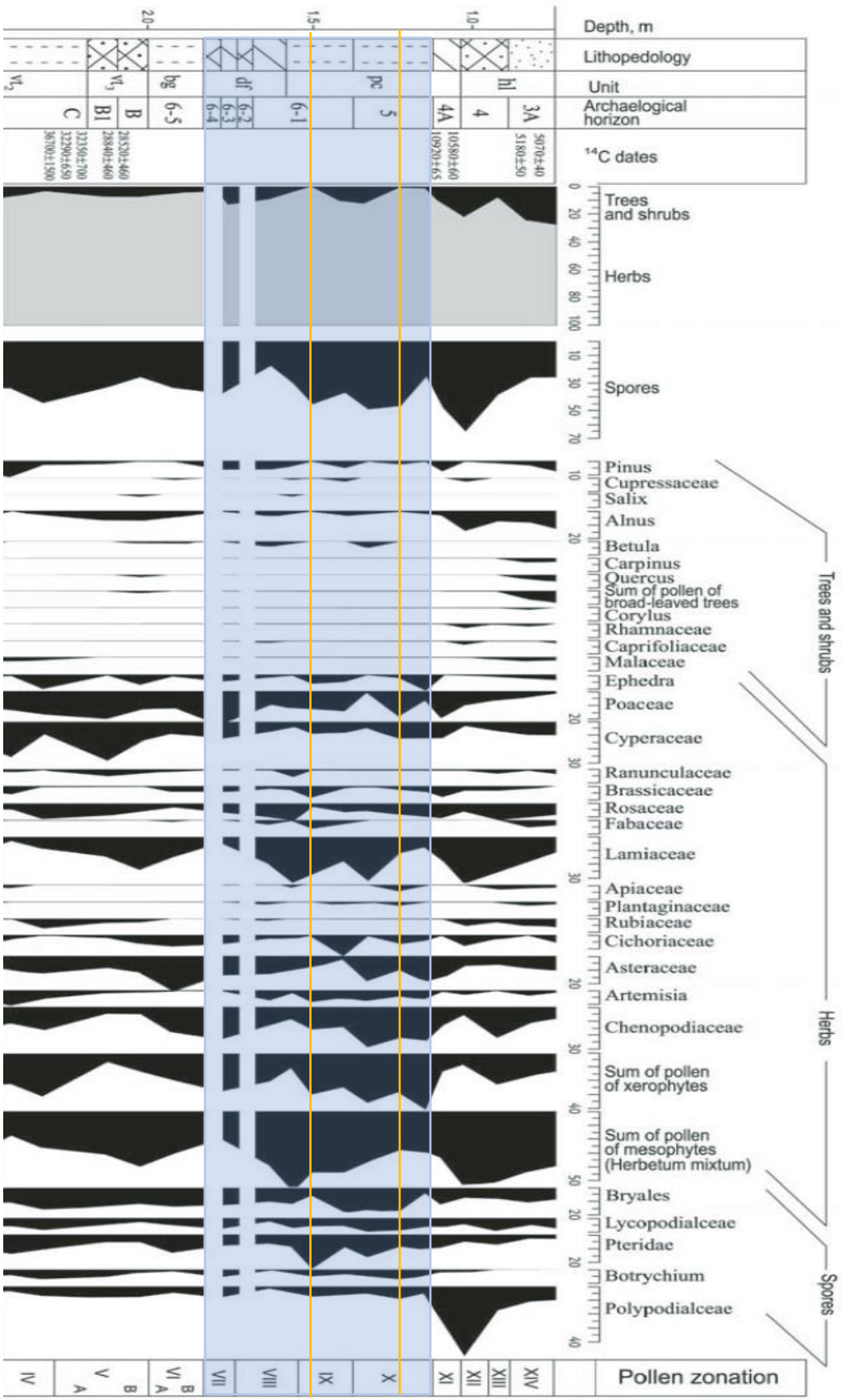


Figure 10 Buran Kaya III Pollen Sequence. Pollen diagram of the Buran Kaya III site on the Crimean peninsula indicating the presence of a variety of plants in different soil types and layers. An indication of the relevant layers in blue and herbaceous spikes in yellow are incorporated. (Gerasimenko, 2007).

of climate defining this time period. This unit is corelated with the Bølling-Allerød stage during which the temperatures increased in comparison to the Df unit. However, the dry spell did not last through the whole unit, there was a sharp change in humidity in the upper layers of the Pc unit corelated with the Allerød interstadial, that could have contributed to the herbaceous spike. Fluctuations in temperature during this time were more frequent but towards the end of it (c. 12,000 BP) the overall temperature was higher than during the Bolling period. This allowed for the establishment of a much more diverse broad-leafed forest in the southern parts of Crimea (Gerasimenko, 2011).

In the pollen diagrams peaks of herbaceous plants are presented from the sites of Kabazi II, Buran Kaya III and Skalisty rock shelter, during what seems two warmer events, highlighted in the *Herbatum mixtum* (indication on diagram in Fig. 10 and 11). Besides the unique location of the Black Sea basin and its ecology, one of the points raised in this project is trying to involve vegetational data more in the reconstruction of diet and use these pollen diagrams for experimental purposes to better understand the diet possibilities of the AMH.

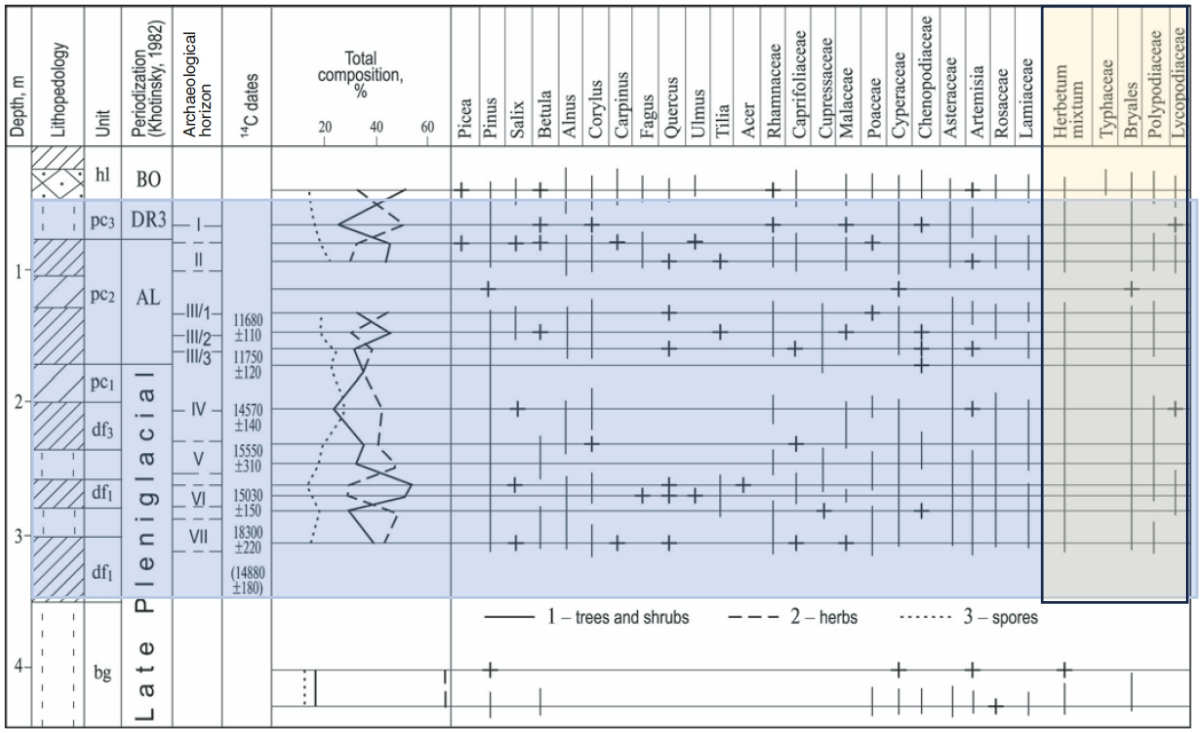


Figure 11 Pollen Skalisty Rock Shelter. Pollen and their location in the different layers for the Skalisty rockshelter. Blue indicating the relevant period and yellow the plants within the Herbatum mixtum. *(Gerasimenko 2007)*

3 EXPERIMENTAL ARCHAEOLOGY AND RESIDUE ANALYSIS

This chapter will elaborate on the most relevant experimental archaeological research for this project and the choices behind the wild plant selection for the experimentation.

Experimental archaeology is a tool that allows the researcher to uncover human and environmental processes that underline archaeological residues and signatures that further our understanding of past human decision-making. It has been used to understand early onset of millet domestication in Asia by replicating tools out of various materials, testing them on specific millet species and comparing starch residues and use-wear patterns (Liu et al., 2017), as well as studies focusing on butchery marks to understand the means of processing the animals and the standardisation of study methods within this specific research topic (Okaluk & Greenfield, 2022; Seetah, 2008; Vettese et al., 2022). Lemorini et al. (2020) successfully conducted a series of experiments where preservation of foodstuffs using ashes was analysed, based on a hypothesis derived from use-wear patterns found on archaeological lithics within the Quesem Cave, Israel (Lemorini et al., 2020). This particular study incorporated the use of underground storage organs (USOs) as foodstuffs which were selected based on vegetation similar to the Quesem Cave environment of the research period and the availability of the plant material today. When conducting experiments with plant material, ethnobotanical investigation is often incorporated not only to understand the potential use of said plant but also identify the material that resembles the archaeological material the closest. Ethnobotanical approaches focus on present-day human-plant relationship as a mirror for the past, in order to understand the varying applications of plants, their processing and general role within past societies. For this project, I made use of available experimental data of the Black Sea region to test these ethnobotanically-derived hypotheses about plant use in the Crimea. In this chapter I discuss previously mentioned applications of these methods in the region, and then explain the methods and process that I used for this study.

3.1 EXPERIMENTAL ARCHAEOLOGY OF THE BLACK SEA REGION

The period between roughly 19ka -13 ka BP has gotten little attention when it comes to understanding the processing of plants by the humans occupying Crimean Peninsula or the northern Black Sea region. Although a variety of stone and bone tools has been found that could potentially be used for processing plants, so far environmental data has only been used to imagine landscapes, not how they were exploited in the context of present vegetation. This lack of focus on plant exploitation may be due in part to problems of preservation: botanical material does not preserve as well as other types of material and finding traces of use, as well as intentionality, can be extremely difficult. Several studies have been executed in neighbouring regions, as well as analyses that have been done on tools from the same region, though for an earlier period. Gathering and synthesising the data from other studies can prove to be a great analogue for the experimentations that are being considered for this study. The most relevant studies have been chosen based on the environmental setting, and thus availability of plants, the tools present at sites and their potential similarities in use and the way that these studies have approached experimental ethnobotanical and archaeological analyses, specifically their reliability and methodologies. Furthermore, the properties of the selected plants are discussed in light of their nutritional and medicinal potential before diving into the experiments and the methodology thereof.

One of the studies that has inspired the experimentation of this project originated from the Aurignacian grinding stone tool experimentation of Siuren I. The grinding stone yielded several *Typha* sp. starches which led to designing an experimental protocol and executing this with dried cattail rhizomes aiming to extract the starch in the form of flour (Longo et al., 2021). Another interesting and region related study synthesised the presence of medicinal plants and diseases during the Upper Palaeolithic in Western Georgia (Martkoplishvili & Kvavadze, 2015). A variety of *Artemisia* species as well as *Achillea*, *Centaurea* and *Urtica* were detected. These plants were most likely also present in Crimea at that time and *Artemisia* has been identified in the pollen records at more than one site. Although no direct pathologies were

identified, environmental reconstruction of the occupation sites suggest that malaria would not have been uncommon and given the current understanding of artemisinin being used in malaria treatments(Shi et al., 2022), this is a great avenue for further exploration of the medicinal importance of plant exploitation. Though, as investigation of literature showed, no pilot studies for potential medicinal or nutritional avenues have yet been explored on the Crimean Peninsula during the UP when it comes to herbaceous plants.

Other experimental studies around the Black Sea region were mainly executed in northern parts of Turkey, Bulgaria and the Hungarian Plain (Tonkov et al., 2007). Palaeolithic investigations into plant diet, or use, are very few if any at all, and most of the prehistoric palaeoethnobotanical research concentrates around Neolithic and younger periods (Hajnalová & Dreslerova, 2010; Yanushevich & Judelson, 2014). Although still very interesting and relevant for certain wood, berry and nut species, very little research can be found on use of abundant wild plants identified both through palynological and plant macrofossil investigations as well as by looking at extant species in the region.

3.2 Stone tool-plant experimentation: Tools, plant material and protocol

The core of this thesis project is the experimental use of stone tools for processing several plants that would have likely been used by LPG occupants of the Crimea. This project was designed to elucidate the processing steps needed to extract the edible tissues of the plants, and to determine which residues would be preserved on the tools after processing and after environmental exposure. I recorded both the experiences of processing in order to understand the steps or processes used (the lived experience) and the distribution, number and types of starch grains preserved on the stone tools. In this section, I present starch granules and phytoliths and how they are useful for reconstruction of ancient plant use, describe the tools and plant species that I chose to use in these experiments, and outline the design of the protocol.

3.2.1 Starches, phytoliths and taphonomy

Starch is a carbohydrate that is used by plants to store energy and for transportation and is made up of primarily the polysaccharides amylose and amylopectin. There are two general types of starches, transitory and reserve starch. Transitory starches have a short lifespan and can be formed in the general body of the plant where they revert back to simple sugars during photosynthesis. Reserve starches are made and stored in the storage tissue of the plants such as USOs, (unripe) fruits, rhizomes and sometimes young shoots, meant to be used at a later stage or over long periods of time(Henry, 2015; Shannon et al., 2009). When developing, reserve starches obtain diagnostic morphological characteristics per plant taxon, like a visible central point (hilum) around which the polysaccharides grow as rings (lamellae). Different processing actions leave specific marks on starch granules and these attributes in starch make it a desirable research topic within archaeology because it can provide key insights into the presence and preservation of particular plants, their processing and also potential human-plant relationships of the past (Henry, 2015). Additionally, different modification of starches can

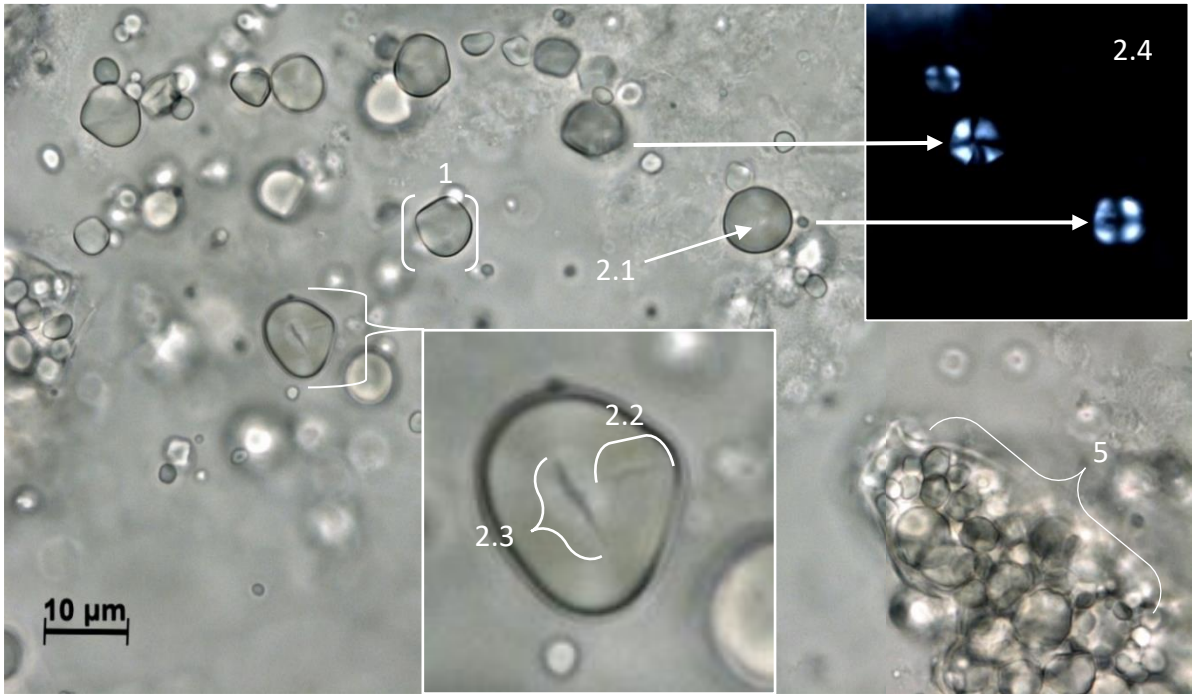


Figure 13 Starch Feature Example. Typha latifolia *fresh starch from the pith used as reference material, 400x magnification in brightfield transmitted and cross polarised (2.4) light. (Image by D.A. Derzhavets)*

reveal intentionality of processing and help understand dietary patterns, manufacture of tools, environmental reconstruction and the influence of taphonomic processes on starches (Henry, 2015; Messner et al., 2008).

The basic starch morphology comes down to understanding the differences within the following sections according to the International Code for Starch Nomenclature (ICSN), parts of which are illustrated in Figure 13:

1. Shape: the general shape of the starch granule, which can be identified in figure 13 as spherical, plano convex and/or ovoid due to its oval shape but flat sides on some of the other starches.
2. Features: distinct features that show or don't show themselves in a starch granule such as the hilum(2.1) around which the lamellea(2.2), grow and a fissure (2.3) caused by growth of starch in the cell. Additionally, cross-polarised starches can have differences in the extinction cross morphology (2.4). The cross helps with identification despite variation in granule shape due to formation in the cell or after processing.
3. Surface description: a general discriptions of features on the surface like texture or patterned shapes.
4. Modification: distinct changes in the starch granule like fragmentation, swelling, pitting, denting, gelatinisation, etc., that indicate damage and can help identify the intention behind the modification, such as cooking or grinding.
5. Definition of starch assemblages: is understanding the features of large groups of starches, whether they are all the same or have distinct sizes and shapes throughout.
6. Nature of the starch grain: what type of starch is it and what function does it serve, depending on the features that have been observed. Making a distinction between storage or reserve starch and a transitory for example.

Following the ICSN for this project has made it possible to identify the starches in their native, unaltered, form as well as determine the modifications to the starches during the processing. When examining the starches I have primarily focused on the following types of damages,

including some personal supplementation in brackets because the reference was unclear or insufficient. Examples of damages identified during this project can be found in Chapter 4:

- **Burst**: Starch in which the inner material has expanded beyond the granule margins (the starch still recognisable and 'together', with a depression in the middle)
- **Corroded**: One or more of the lamellae removed from the surface of a starch granule by a digestive process.
- **Crack**: A fissure in the grain as a result of processing.
- **Dented**: The presence of depressions in the surface of the grain.
- **Disjoining**: Separation of a compound starch.
- **Exudate**: The inner starch matter breaks through the margins of the starch granule (a singular or multifaceted break where the margin of the starch is intact and the inside is clearly oozing out).
- **Fractured**: A complete dividing fissure due to which parts of granule are removed.
- **Fragmented**: A part of an entire granule.
- **Hilum Opening**: An increased opening of the hilum due to loss of water.
- **Pitting**: Deep excavated areas on the surface of the starch due to action of enzymes.
- **Shrinkage**: Reduction in size on one or more axes due to dehydration.
- **Truncated**: Breaking of parts of starches as a result of milling.

Next to starches, some of the attention was directed at counting phytoliths in the samples as an additional proxy. Phytoliths are silica deposits within a plant and provide structural support and protect the plant by being naturally nutrient poor. At the lack of macro remains, pollen and starches, phytoliths can be a useful tool at determining the presence of plants, sometimes down to a plant taxon, because they are a more stable insoluble particle. In archaeology phytolith research has particularly been gaining popularity in agricultural evolution and fire related studies focused on fuel and tinder plant material (Albert et al., 2012; Elbaum et al., 2003). Grasses contain a large amount of phytoliths (Fig. 14) and they can also

withstand relatively high levels of heat, developing distinct features of heat treatment. The reason for including phytoliths in this project is because of their preservation and their abundant presence in plants. As mentioned above, the Crimean Peninsula at the time of the LPG underwent many environmental fluctuations, though a consistent steppe environment has been presented through the data. In such steppe environments grasses thrive and thus I have

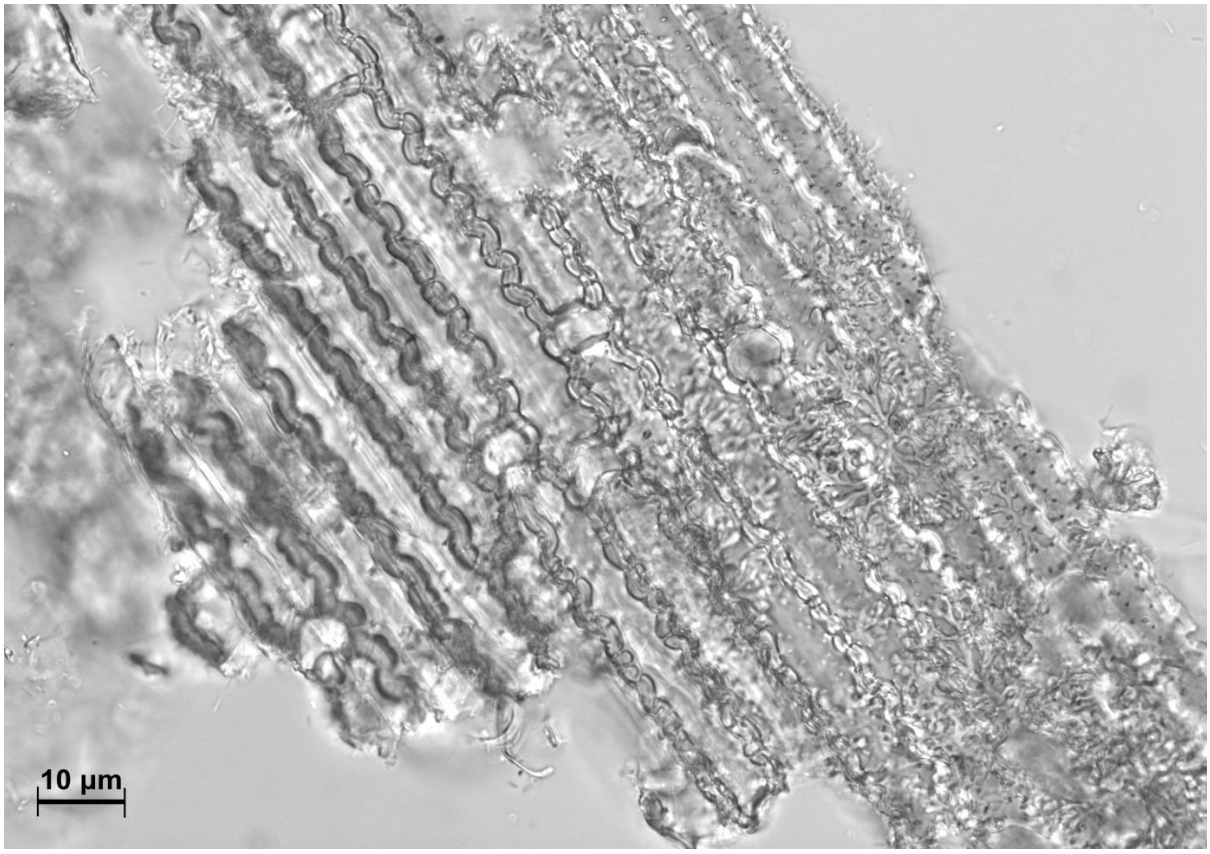


Figure 14 Phytolith Cluster. A cluster of phytoliths from sample F-20-I in brightfield light, with dendrate (teethlike) edges, a common characteristic for the Poaceae (grass) plant family. (Image by D.A. Derzhavets)

decided to include one plant that is of the grass family, *Phragmites australis,* or the common reed. Further justification for use of *P. australis* can be found in paragraph 3.2.2. In order to understand what to look for, we must first understand how a (micro) remain got to a certain stage and location, by looking at the life history and taphonomy of a remain. Starch life histories are made based on ethnographic and experimental research which document and describe the development of the starch in the plant, the first human interaction, the discard and burial of the starch and the excavation and laboratory processing (Henry, 2015). Taphonomy is the

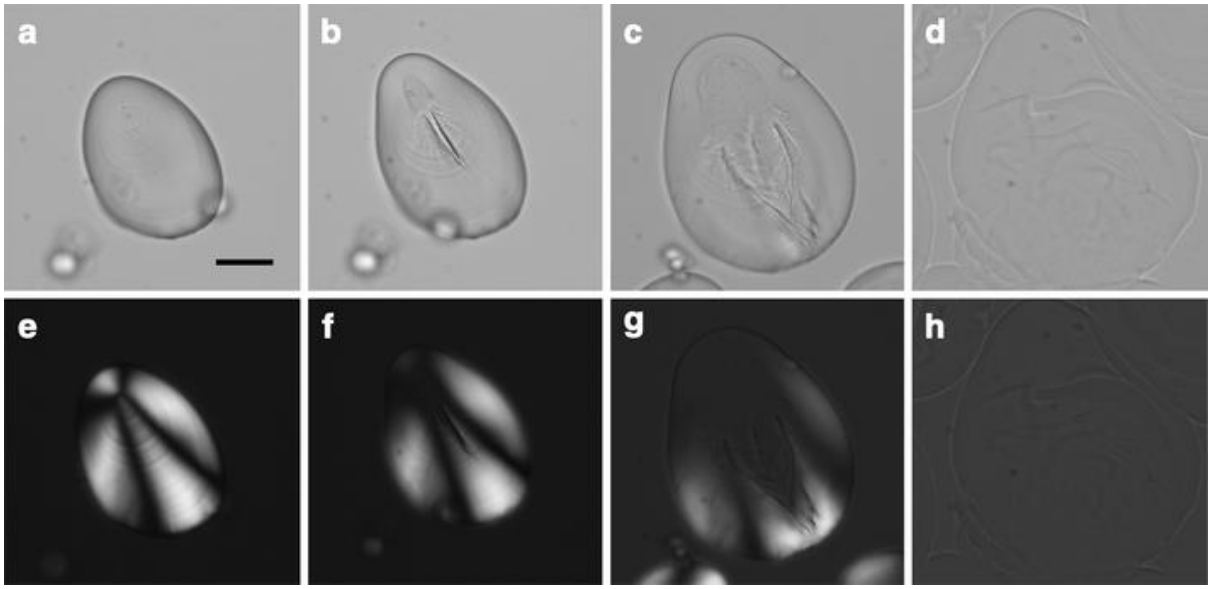


*Figure 15 Modern Potato (*Solanum tuberosum*) Starch Granule. Starch gelatinisation, showing progressive swelling, morphological deformation and loss of birefringence. Photographs taken in brightfield transmitted* ***a–d*** *plane- and* ***e–h*** *cross-polarised light.* Scale bar *equals 20 μm. (Crowther, 2012).*

process of how organic matter passes from the biosphere into the lithosphere and understanding taphonomic processes in this project is one of the core objectives. Taphonomic processes are of mechanical, biological and chemical nature and range from wind dispersal, to burrowing of animals that disturb the soil, bacterial and fungal digestion, chemical weathering through mineral interaction or washing out of micro remains further into the crevasses of the ground. Starches and phytoliths are influenced by these processes and this becomes evident in their morphology through distinct types of damages, which makes understanding taphonomic processes crucial to the study of ancient remains (Haslam, 2004). When heating starches in a medium like water, they swell, gelatinise and lose their structure (Fig. 15), often times forming amorphous masses. All four modifications to the native starch can be used to say that this plant (part) was boiled or cooked somehow (Crowther, 2012). However, other factors like presence of salt which can speed up gelatinisation or native starch survival rate need be taken into consideration (Haslam, 2004). Corrosion and pitting are damages which have been linked to enzymatic activity of the soil, digesting the starch while leaving pit like scars and rugged surfaces (Haslam, 2006). This type of damage is subjected to a multiple taphonomic processes

like transportation of the starch or the digestors to the starch, the biological degradation of the starch by the organism and the mineral composition of the soil that influences the preservation of the starch, like high salinity or pH.

The life history of the starch is the execution of the experimentation. The taphonomic processes that the starch undergoes during and after the experimentation include moving the starches in their plant form and processing them mechanically, climatic fluctuations both in- and outside, oxidation and biochemical degradation, biological activity of moving and consuming the starches by organisms (Hutschenreuther et al., 2017). As mentioned before, no taphonomic analysis for phytoliths were included.

3.2.2 Tools

Flint

We selected flint tools for this project because these were found at the site and most likely were used in a variety of processing, potentially including plant processing. No site or research on the Crimean peninsula for the LGP investigated the potential use of flint tools for the processing of plant material and so I wanted to include this type of tool to investigate the necessity and ease of processing plants with flint tools as well as understanding the plant residues on flint tools, like the damage, morphology, quality and quantity of the micro-remains. The flint material was selected with guidance of dr. Demidenko, dr. Gravina and dr. Roussel. This project required the use of fine grained flint, which is the most common type in Crimea, and was gathered from southwest France due to easy procurement. The technocomplex for this period and location is identified as Epi-Grevettian with signature elongated backed pieces. All but a few more coarse grained flakes were made by me using fine grained flint from Dordogne. I produced simple unbacked flakes because flakes could perform the actions just as easily without me having to spend extra time on learning how to make blades or perfecting the backing, and the aim of the project was not to look at the use-wear, but collect the residues left on the tool. That being said, each action is best executed with a specific shape of a tool, so I still selected flakes with varying shapes, reminiscent of the backed tools, by experimenting with

different actions and flake shapes prior to the experimentation. For my hand specifically, I found that elongated and relatively thin flakes were best suited for shaving and splitting, but also for sawing thick but brittle plant material like cattail or other thick stalked herbaceous plants. Elongated and rather thick flakes were better to cut in general, sawing was best for fibrous and rather thick materials. Convex thick tools that are reminiscent of a scraper are great for splitting and shaving as well. Therefore, in the flint tool collection many shapes of flakes are represented (Fig. 16), even though there was no standard type indicating a specific technocomplex. I did not haft the tools nor did I wrap the lithics in plant or animal material, the rubber gloves provided the grip and the safety.

Figure 16 Assortment of Flint Flakes. Flint flakes after decontamination ready to be used for the experimentations. (Photo By D. A. Derzhavets).

Grinding stone tools

The grinding stones for this experimental project are based on the limestone slab recovered from Siuren I (Demidenko et al., 2012). Getting limestone from Crimea itself was not possible so a local stone dealer in the Netherlands was approached that provided me with French silicious limestone slabs of a similar type of hardness and comparable composition, though with an unknown geological formation period. Three slabs were provided and eventually two were used, leaving one for emergency use. The slabs were prepared by pecking multiple surfaces and the irregularities of the slabs created natural divisions where material could be processed. I chose to process two plants per limestone slab, using both sides. In total, eight areas of processing were created on the two slabs (Fig. 17).

Grinding stones in Crimea are difficult to identify because they are often naturally rounded or shaped ready for use, which makes recognising alterations that much more difficult(Longo et al., 2021). They are more likely to be overlooked during surveying due to an absence bias, despite more grinding stone being documented starting the Gravettian period (Aranguren et al., 2007). The main stone types used for grinding in this region are limestone, quartzite and (quarzitic) sandstone (Stepanova, 2020a).

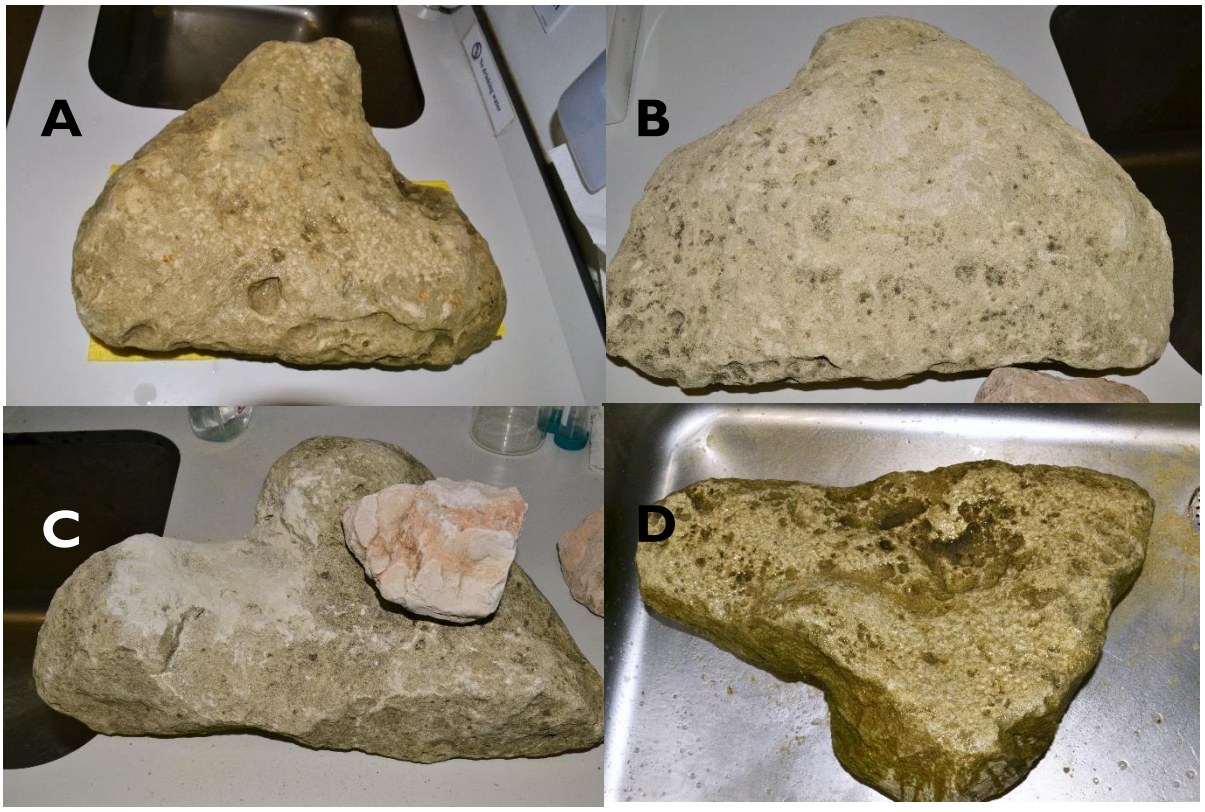


Figure 17 Grinding Stone Slabs. A: GS1 on the left processing side of Typha. B: processing side of Daucus. C: GS2 processing side of Anthriscus. D: processing side of Phragmites. (Photos by D.A. Derzhavets).

Rounded cobbles or runners are easily found on the seashores, alongside river streams and around lake deposits of the peninsula. Runners are the stones that move over the stone slab under them, so they are the flexible part of the grinding process. For this experimentation I decided to use rounded cobbles that were the easiest to procure, namely quartzite cobbles used for decorative purposes in the Netherlands. All cobbles were quartzite with the exception of 4, which were identified as red porphyritic granite and an andesite with some faint striations, of unknown provenance. They were naturally rounded, some having slightly elongated and

irregular shapes, size ranging between 10 to 20 cm in length/width. When selecting the cobbles, I consulted colleagues in the Material Culture Laboratory of Leiden University as well as looking at advice from different experimental papers. A nice fit for my hand allowed me to move the cobble ergonomically and with a good grip, which is important for long-term grinding tasks (Key et al., 2020; Marzke, 2013; Williams-Hatala et al., 2016). A selection of 10 was made and 8 were used in total, each shape was chosen at the beginning of each new grinding round depending on the angle of the slab and the behaviour of the plant material.

All of the tools were washed with a brush, soapy water, boiled and put in an ultrasonic bath to remove contaminants (Fig. 18).

Figure 18 Cleaning Experimental Tools. on the left, grinding stone and flint in a sonication bath. On the right, runners drying after cleaning with visible algal residue on them. (Photos by D.A. Derzhavets)

3.2.2 Plant material

The experimentation revolved around the collection and examination of starches on the stone tools. The plants were chosen because they represent taxa likely to have been on the Crimean peninsula during the LPG. Plant parts were chosen based on the highest starch content during a colder period, just before dormancy initiates. The shoot or the stem of the

plant is the part that grows above the ground, the young shoot is the same part at a younger stage sometimes submerged under water or still making its way from under the soil, and the root is the part below the soil also often serving as an energy reservoir (Cutler et al., 2008). In order to understand what I was looking for and looking at, I prepared reference slides of the plant material. For each plant part, as mentioned before, a slide was made by cutting the material in half and scraping a small amount of the desired plant section onto a glass slide using a scalpel. The plant material was then mixed with 10 to 20 microliter of a 5% glycerine solution and covered with a cover glass of 20 by 20 mm. The slide was labelled and a Zeiss Axiovision microscope was used for inspection. The material was described at magnification 240x, 400x and 600x for a thorough understanding of the starches and other micro remains.

The plant material was collected from late October to late November 2021. Cattail and reed were collected first at the end of October, at the beginning of November cows parsley was gathered and end of November, wild carrot. This is also the order in which I conducted the experimentation and how it is listed below. With each new batch I performed a check of the starch content which also gave me the opportunity to familiarise myself with the general microscopic structure of the plant anatomy of each selected plant. The understanding of the starch morphology and phytoliths was crucial to the post experimental analysis. During the check of the starch content I was also describing and learning to see and differentiate between the different starches. A starch consists of several parts of which the most distinctive ones are the hilum, lamellae, fissure and extinction cross, besides the size and general shape.

Three locations were used to collect the material: Meijendel Nature Reserve, South Holland (*T. latifolia* and *P. australis*), Cronesteyn Park and Bio Science Park, Leiden (*P. australis* and *D. carota),* Kerkengebied, Ouwerkerk (*Anthriscus).* Using reed and cattail I tested out some of the actions and angles of lithic processing until I knew the material enough to prepare criteria and confidently initiate consistent processing.

Below, the plant material is generally described as well as put into experimental and archaeological context. At the end of each section I elaborate on the morphology and quantity of the micro remains from the reference material during first examinations using microscopy. In the schematic drawings a personal choice of plane views (top, bottom, side) has been identified in combination with the designated areas of the starch according to the ISCN.

Typha latifolia

Typha latifolia, also known as the common cattail, is a perennial herbaceous plant which grows in wet environments, often with their roots and rhizomes submerged in water (Fig. 19). The common cattail is widespread and sometimes considered invasive, although native to all continents except Australia (Mitich, 2000; Stevens, 2000). It prefers shallow fresh or brackish water and is known to have been used for dietary purposes throughout the Upper Palaeolithic to modern times (Aranguren et al., 2007; Liptay, 1988). The roots and rhizomes of the cattail are rich in starch, especially towards the winter, and are relatively easy to extract. Most archaeological experiments focus on the extraction of starches in the form of flour or meal, where the whole of rhizomes are dried and then beaten, after which the fibres are removed (Revedin et al., 2017). This is an easy method that also allows for the production of a secondary product, long fibres. Longo et al. executed such an experimentation in 2020 after finding several starch grains of the *Typha* genus on the Siuren I griding stone (Longo et al., 2021). *Typha* is a versatile and relatively readily available waterside plant that can also be used for fire making and weaving. It is

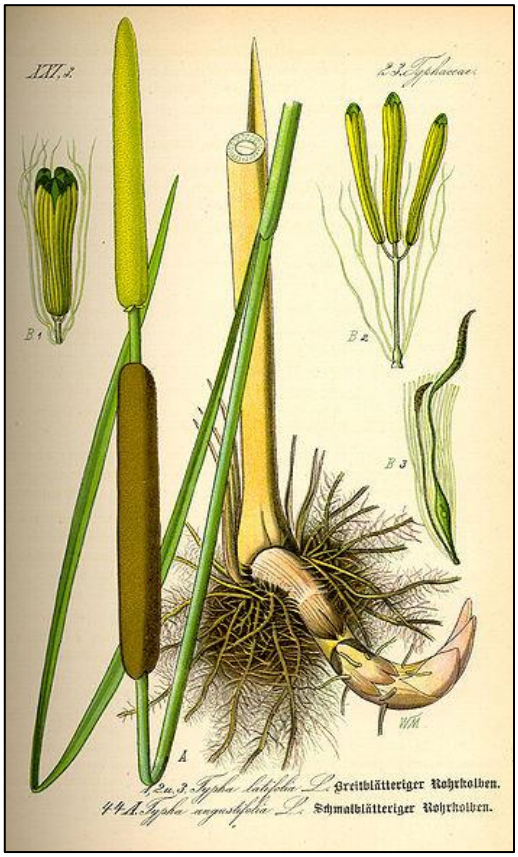


Figure 19 Typha latifolia. *Botanical illustration. O. W. Thomé.*

therefore not surprising that it has been at the centre of many experimental archaeological (Aranguren et al., 2007; Fullagar et al., 2021; Liu et al., 2017) and ethnobotanical(Stevens, 2000) projects.

Towards the colder periods the cattail accumulates lots of starches specifically in its base and rhizomes, storing it to use it as energy during spring month for new growths. Different parts were examined for their starch, of which the base and the pith had the most starch content. The cortex also yielded a significant amount of starches, but in comparison it was half the count.

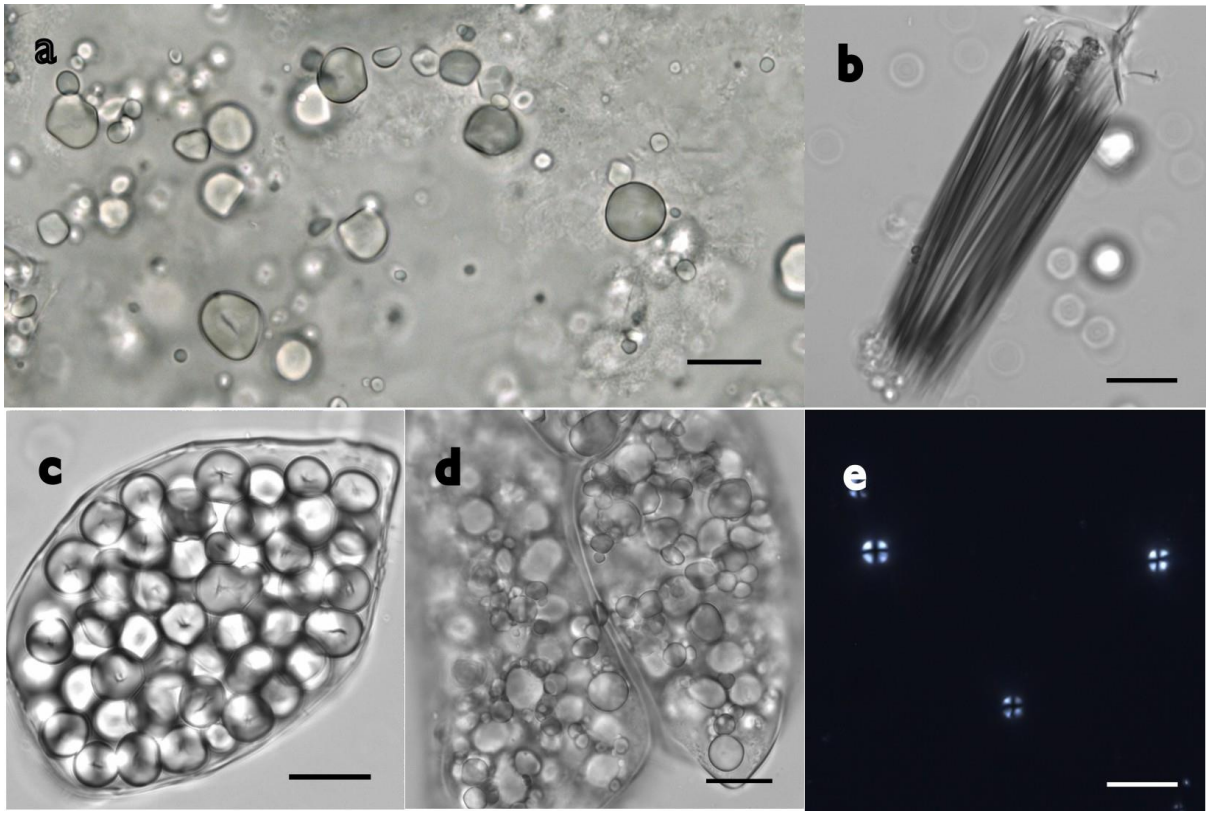


Figure 20 T. latifolia *Micro Remains. a: free starches; b: raphides cluster; c: starch cell with homogenous sized starches; d: starch cell with heterogenous sized starches; e: starches under cross polarised light. Images a-d are taken under brightfield transmitted light. Scalebar equals 10 μm (Images by D.A. Derzhavets).*

During the analysis of the reference material for *T. latifolia,* the identified native starches were primarily simple, forming singularly, within and outside of the cells (Fig. 20). Compound starches were also observed, often consisting of 2 to 4 individual starches. The presence of the compound starches differed strongly, but per each slide of 10 μl that was analysed, there would be between 0 and 4% compound starches. The starches in the rhizomes

of T. latifolia are storage or reserve starches, concentrating primarily in the pith. Their shape is generally isomorphic, but can seem heteromorphic due to the wide range in sizes (from 1 µm to 15 µm) and their compression within the cells. The shape is combination of ovoid/spherical, hemispherical and convex-concave appearances from the side and sometimes can even look like a kidney (Fig. 20a). The hilum is ovoid with a distinct centric, spherical, refractive from the top and mesial from the side. From the bottom the native starch shows a longitudinal fissure that sometimes branches out into a total of 3 or 4 parts, depending on the size and position in the cell. The visibility of the fissure is depends on the view of the starch, the best range being side-bottom. The extinction cross, from the top view, is distinct, centric, symmetrical, sharply defined with relatively short and thin arms. The lamellae are fine, uniform, completely and centric to the hilum but are faintly defined when viewed from the top.

Phragmites australis

Phragmites australis (Fig. 21), or the common reed, was the only plant that wasn't used for roots or rhizomes. I thought it would be interesting to take something that tends to grow together with *Typha* species, both being waterside plants with high tolerability of environmental stresses. P. australis propagates through rhizome networks, storing more starch in submerged areas with cooler temperatures (Wersal et al., 2013). Although uncommon and often not considered in prehistoric nutritional use, the young shoots of reed contain a high number of starches as well as sugars, new shoots being stored under water during autumn and winter (Dinka & Szeglet, 1999). The shoots are easy to harvest by cutting or breaking them off but sometimes would have to be cleaned from the

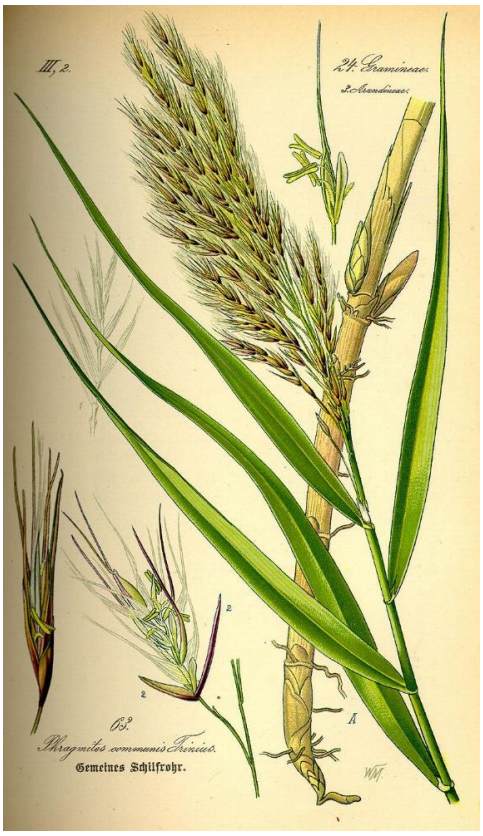


Figure 21 Phragmites australis . *Botanical illustration , by E. G. von Steudel.*

rotting layers due to the underwater storage. Cooking them out for sweetness and starches into a stew has been used in the Balkans as famine food during cold climates and food disparity, just like *T. latifolia* (Dénes et al., 2012). The local availability, connection to the cattail and the fact that nutritional exploitation of this plant remains scarce, was the main reason for choosing this plant. Additionally, including one contrasting plant material that was not fully an USO containing mostly starches, but rather phytoliths, provides a different proxy angle in this project.

P. australis starches are simple starches that very rarely produce compound starches of 2 granules. They are potentially trimodial, meaning having distinct size ranges, with a large (6-8μm) middle(5-4μm) and small(1-2μm) size of starches (Fig. 23b). Most starches in the reference material are very small (between 1,5 and 5 μm) and do not have any diagnostic features (Fig. 23b). Larger starches (between 5 μm <) have diagnostic features of semicircular and trapezoidal shape combinations, almost like a robust wedge with a rounded back (Fig. 22). I find the starches to be heteromorphic in the material I used, but this can be due to the size differences that obscure more detail and some of the starch being transitional rather than storage starch. The hilum is centric, mesial , refractive and slightly elongated parallel to the

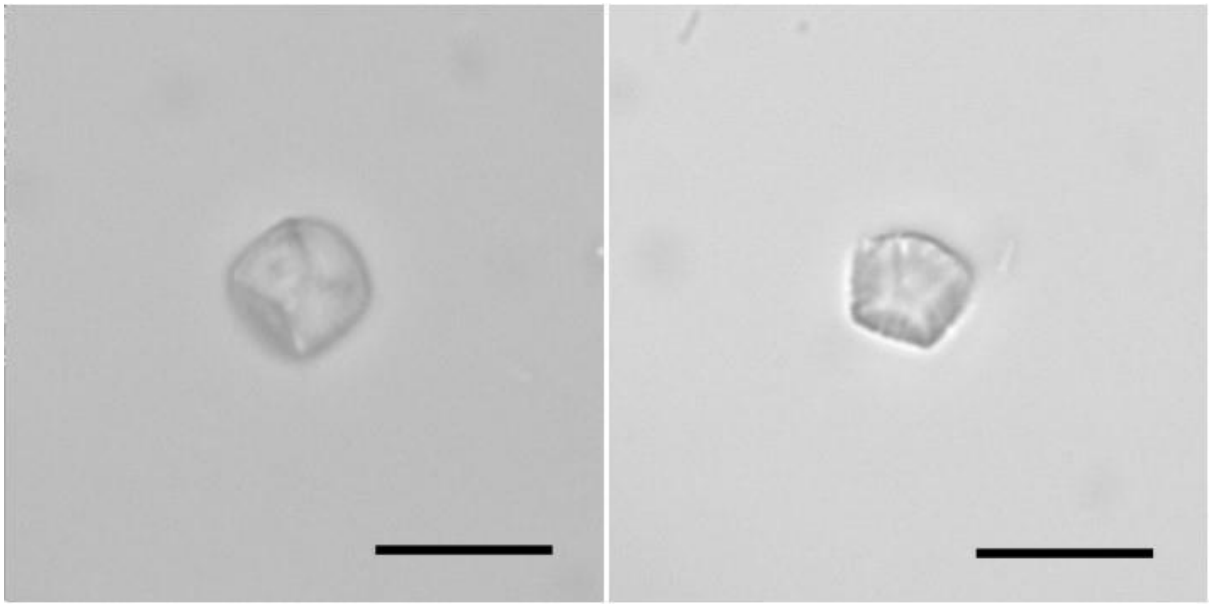


Figure 22 Diagnostic Starch Example. P. australis *starch viewed in brightfield transmitted light with diagnostic ridges. Scalebar equals 10 μm. (Image by D.A. Derzhavets).*

long axis of the gran, though not always clearly visible. The four planes from the bottom, which form the characteristic 'envelope' outline (Fig. 22), can obscure the hilum and the faintly

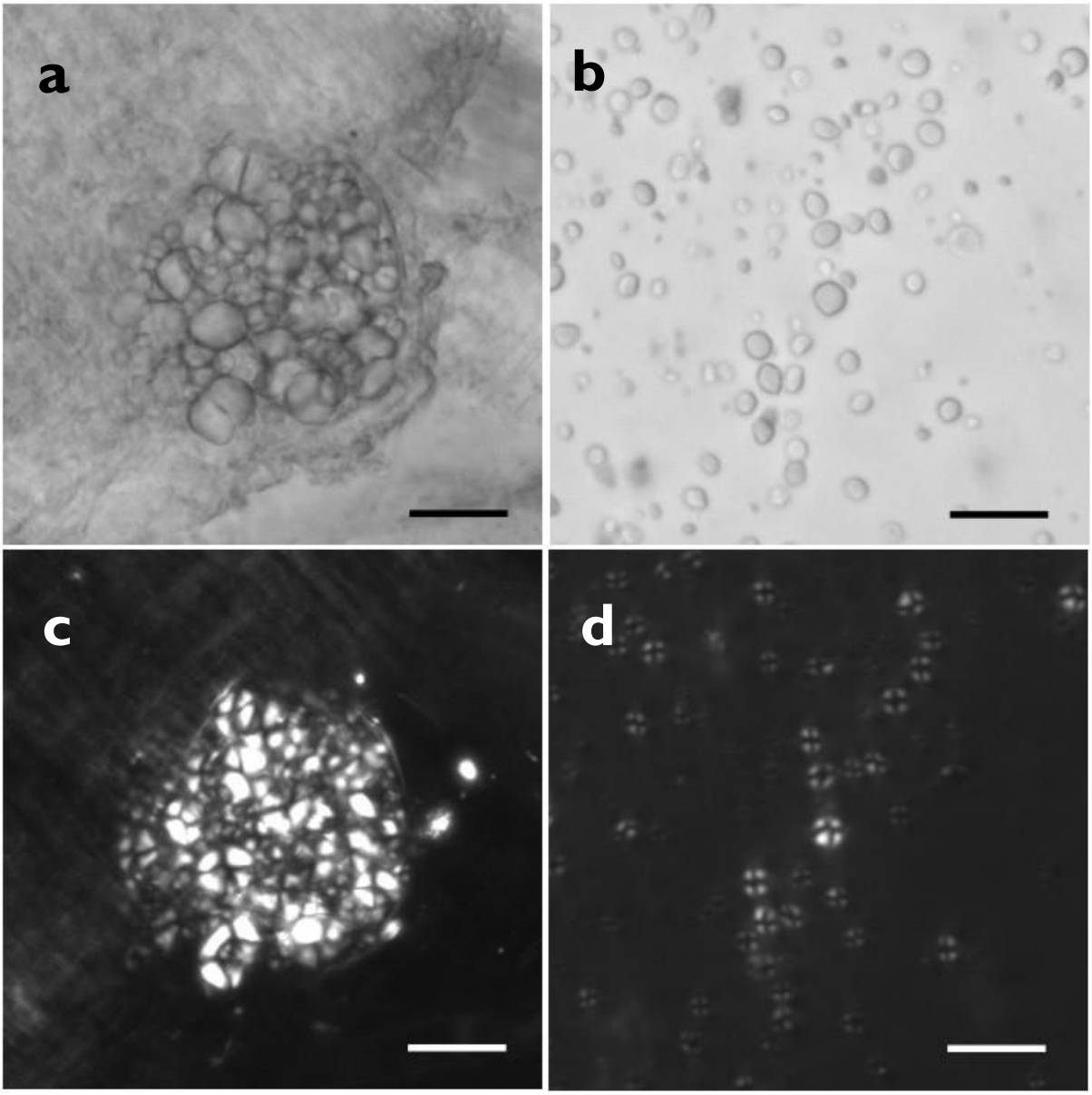


Figure 23 P. australis *Starches. a, c: a cluster of starches; b,d: free starches. a,b are viewed in brightfield transmitted- and c,d in cross polarised light. Scalebar equals 10 μm (Image by D.A. Derzhavets).*

visible, fine and uniform lamellae. The extinction cross under polarised light is centric to slightly off centre and distinct from the top view (Fig. 23d), with short, sharply defined arms and asymmetric composure, which becomes evident when rolling the starch around. The fissure is parallel to the hilum and has a delicate, smooth appearance.

Anthriscus sp.

Anthriscus sp., also known as wild chervil or cows parsley (Fig. 24), is part of the Apiaceae family of biannual and perennial plants. Although I am relatively certain that this is Anthriscus sylvestris, the Apiaceae family grows together and they tend to mix. Therefore I will be using the family name when referring to this plant in the remainder of the study. These species have a wide dispersal and can be found in most of the northern hemisphere in moderate climates. They thrive well on disturbed soil and make up a large cover of understory plants in loamy, clayey soil, being able to withstand moisture and rotting well. The inclusion of this plant was an easy choice due to its wide availability in the Netherlands and it is known to grow in abundance in Crimea. This plant is not often considered in prehistoric cuisine or for other uses except for environmental reconstruction, and thus lacks substantial refence material (Heidgen et al., 2020). In the environmental reconstructions of the Crimean sites, a peak of Apiaceae pollen has been identified(Gerasimenko, 2011). Ethnobotanically, this plant has been used all around the Black Sea region and beyond, especially as a medicine for various ailments used as an anti-inflammatory remedy when made into a brew (aqueous extract) and thus would have been relatively easily

Figure 25 Anthriscus sylvestris. *Botanical illustration, by C.A.M. Lindman.*

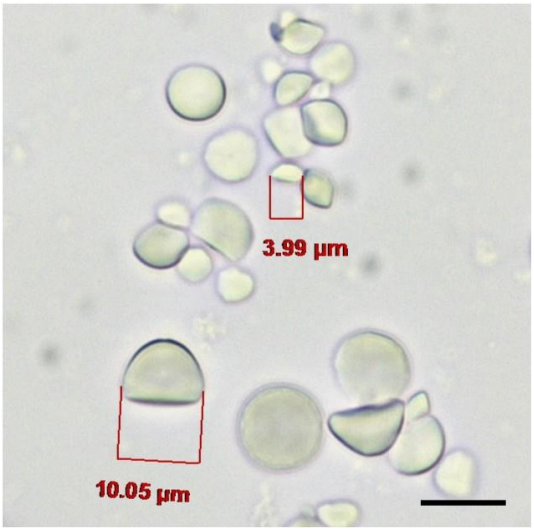


Figure 24 Anthriscus *Starch. Starch granules viewed in brightfield transmitted light. Scalebar equals 10 µm (Image by D.A. Derzhavets)*

accessible in such a way by all who know how to wield boiling water (Bussmann et al., 2020). Nutritionally it is an interesting root containing a high number of starches and vitamin C (Heidgen et al., 2020), specifically deposited in large numbers in the side roots after flowers in preparation of winter (Kuehbauch et al., 1976).

Anthriscus sp. starches are simple, storage starch grain with an occasional compound formed by 2, and even more rarely, by 3 starches (Fig. 26c). Its size ranges between 1,8 and 13 µm. The starches are isomorphic with some variation in shape due to the growth within cells. The shape is hemispherical to convex-concave, but flatter than the *T. latifolia* one generally. There are some distinct endings, each pole on the longitudinal side, going into a little conical

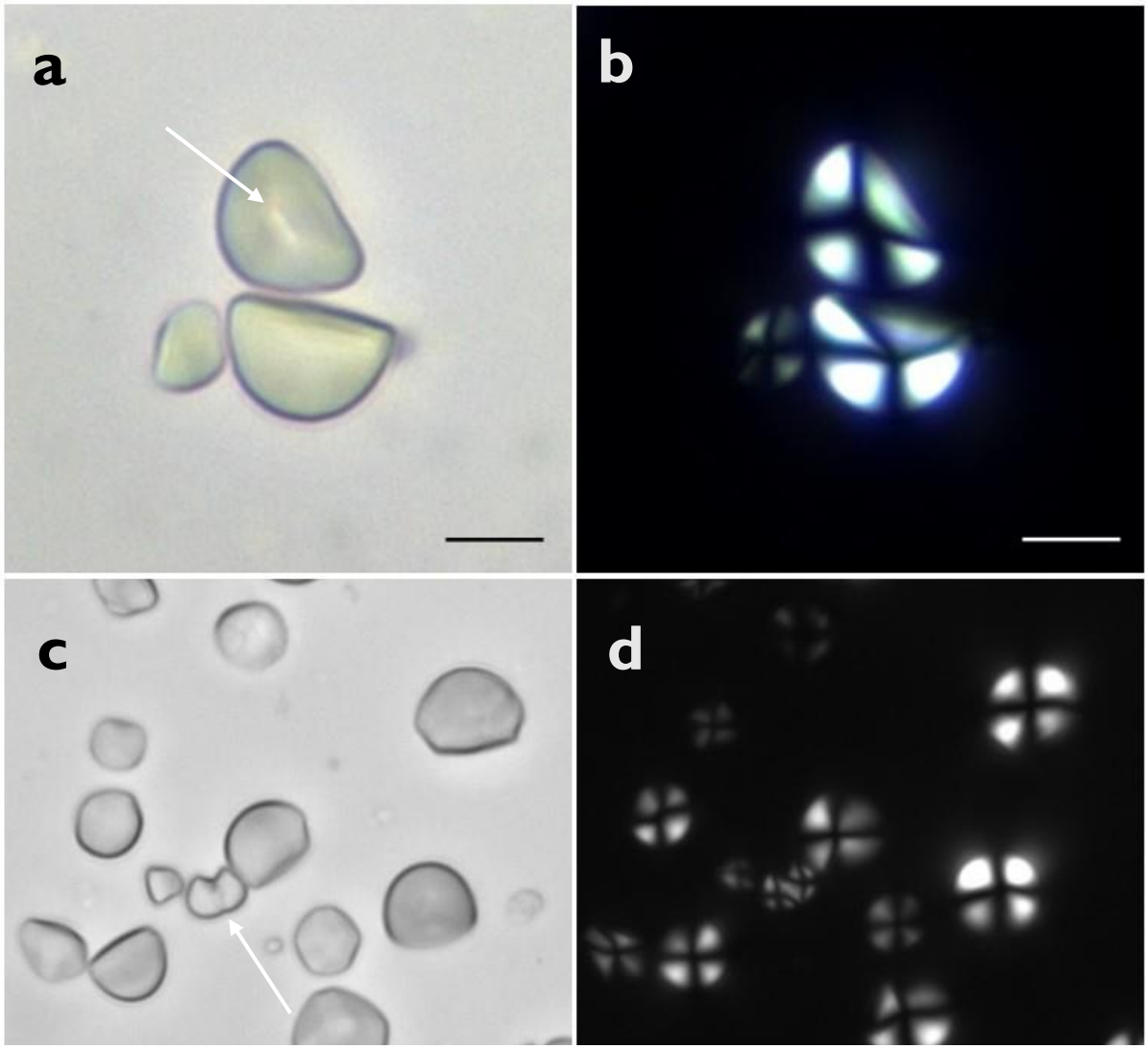


Figure 26 Anthriscus *Starch. Examples of distinct morphology, a,c are in brightfield transmitted and b,d in cross polarised light. In (a) the hilum is indicated with an arrow, in (c) a compound starch is indicated with an arrow. Scalebar equals 10 µ m. (Images by D.A. Derzhavets)*

shape or a bud. It has a centric hilum that is refractive. A centric, distinct cross, which is symmetric and arms that are thin and straight, with a slight curvature towards the margins. High level of polarisation and the arms are equal lengths. The starch appears to be not fissured or difficult to discern whether it is. The lamellae are concentric and continuous, faintly visible but not in all starch granules. Best way to see this is from the side of the grain where it looks like a long hemisphere. Narrow lines and uniform to the shape. These starches have a smooth surface, there is a projection of the curvature that goes inward (Fig. 26a).

Daucus carota

Daucus carota, or the wild common carrot, is a widespread perennial plant that is often mentioned in palaeolithic or early Holocene food research of western Europe, but has not been fully understood yet in the eastern regions (Diaz-Villaquiran, 2019; Pino, 2005). With a large coverage of norther and southern hemispheres, the wild carrot has been a staple for many peoples, not only due to its easy cultivation and nutritional values of complex carbohydrates, but also the presence of antioxidants and anti-inflammatory properties have been well-researched in the wild carrot (Surbhi et al., 2018). This plant is also widely available in the Netherlands and easy to recognize with the curling up of the inflorescence when the seeds are formed, dry out and are ready to disperse. Due to the spike in herbaceous plants and specifically the Apiaceae family, I thought it would be interesting to compare two family members, both in their processing and the amount of residues that are gathered on the tools. Their availability, sufficient research and possible medicinal avenues were the main reasons for choosing this plant.

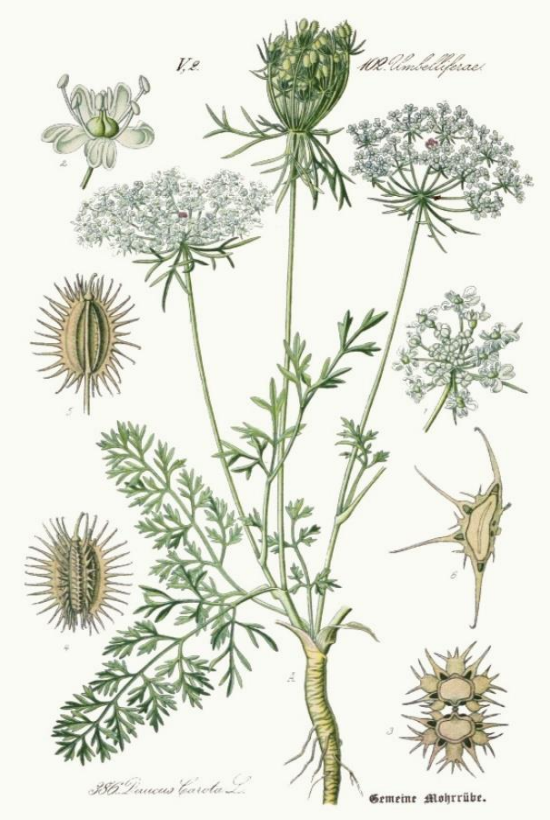


Figure 27 Daucus carota. *Botanical illustration, by O.W. Thomé.*

D. carota starches are simple, singular storage starches (Fig. 28). An individual half-compound starch has been seen. The sizes of these starches lie between 1,3 and 15 μm .These starches are characteristic, potentially diagnostic, and appear heteromorphic due to dents being related to the way that the starch is placed in the cell. Can be mistaken for the *Anthriscus* starch sometimes, one that has a more ovate shape and is more rounded. The shape is that of a polygon, between 5 and 8 sides, one convex or concave plane on top of which more polygons are placed, showing sharp edges. The starch also looks a compressed at times, but this depends on what size you are looking at.

The hilum is centric, distinct, spherical and refractive whilst the cross, is centric, distinct, asymmetric, with thin arms and slightly curved lines, somewhat distorted, short arms that can be

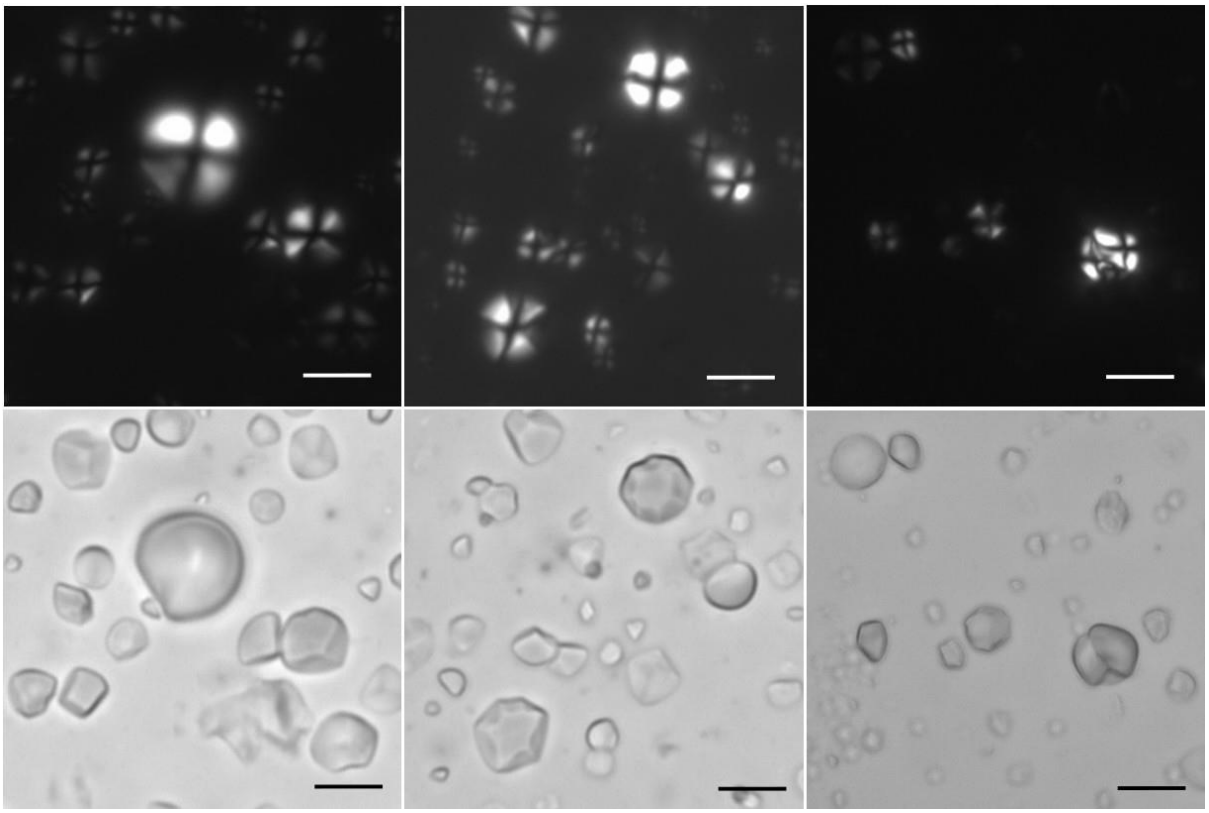


Figure 28 Daucus carota Starch. Examples of various shapes and sizes of D. carota. In (c,f) a compound starch is visible. In (e) diagnostic multifaceted starches are visible. Images a-c are viewed in cross polarised light, images d-f are viewed in brightfield transmitted light. Scalebar equals 10 μm. (Images by D.A. Derzhavets).

observed well under polarised light. The fissure is delicate and parallel, sometimes you can see it branching in bigger starches. The lamellae are centric, complete and distinct, with fine lines

that are uniform in composition. The surface is smooth with no other characteristic but the planes sometimes looking like pressured or dented facets, even though it is a characteristic part of the morphology.

3.2.3 Processing protocol: Actions and processing of plants

All of the experimentation was done in a separate small room, under a fume hood, at the Material Culture Laboratory at Leiden University, between October 2021 and February 2022. With every experimentation, a dish of water was placed inside the fume hood to collect the dispersing microparticles. These were later checked for any outside contaminants like domesticated crop starches. The actions used to process plant foods are quite varied, and depend on the plant type and desired end product. Preliminary investigation into how to use flint tools best on some of the plant material helped met familiarise myself with basic movements. Though, when examining the literature for flint processing actions preformed on plants, not much could be found except an occasional wood working practice that would focus on the felling of trees or gathering of crops with flint sickles. Considering my plant material was relatively soft and ¾ of it an USO, I decided to draw inspiration from butchering and leatherworking actions and activities. Next to that, studies focusing on use-wear were also consulted. Additionally, the paper by Shea (Shea, 2015) solidified my own observations in the preliminary processing, specifically that of the unidirectional motion to keep the edge sharp. I selected a restricted set of actions to help navigate and retain the reliability of each processing sequence.

Slicing

Slicing in this context is an action that emulates the use of a knife. It requires a flake to go from one end of the material to the other in one quick gesture. This would indicate that the plant material is something relatively small in diameter or width and easy to separate through this action. Depending on the width and the material, this motion can leave traces and residue not only on the slicing edge but also the medial part of the flint, because of prolonged contact.

With thin plant material that is elongated, only the edge is expected to have traces of use and residue. Goal of the action is quick separation of material in two or multiple parts.

Shaving

Shaving was defined as a motion with an elongated or semi-elongated flake or tool, with the aim to take off the top layer of the material while sliding the tool perpendicularly over the surface. An experimental study focusing on the complexity of use of flint tools through use wear was also experimented on some Apiaceae species with this action, calling it peeling rather than shaving. Although their results focused on the polish on the tools, it was interesting to see that the processing idea and use of a certain action were of a similar nature (Groman-Yaroslavski et al., 2021). Depending on what the angle and the plant is, the tool will then also be exposed to more of the plant material over its surfaces and traces will be left on much of the tool. Slight convexity on the ventral surface would is ideal in terms of prehension and performance of the action. The action is performed over the whole of the stem of one shoot or root. The goal of the action is to remove outer shoot or root surfaces for further processing or direct consumption.

Splitting

The action is performed over the whole of the shoot of the plant and is done two times per one plant part, thus splitting it in 4 pieces longitudinally. Splitting is often done in order to refine or reduce the material that is needed for a finer fibre and can even leave a specific use wear trace depending on the plant (Sobkowiak-Tabaka & Kufel-Diakowska, 2019). In order to maximize the transfer of residues, I choose to use each tool to split a number of plant parts, like root, shoot and young shoot. Splitting is a motion that is done easiest with a semi-convex edge flake which takes the flake through the length of the stem, in turn letting the plant part go through the width of the flake, leaving traces accordingly. The goal is to separate the rhizome or root longitudinally to allow further processing or easier consumption.

Sawing

Sawing is used for plant parts that are too thick to be cut with a single slicing motion. A sawing motion needs to be applied in order to get through the material, such as separating the roots form the shoots or shortening the shoots. This also means that more of the tool is touching the material with a back-and-forth motion (Shea, 2015). Sawing can be done unidirectionally or bi-directionally, both of which leave their own types of traces on the tool. The amount of residue and how it spreads throughout the tool when moving the tool back and forth, depends on the type of plant and this is taken into consideration when collecting residues. The decision was made to time the bi-directional motion while counting and filming, instead of deciding how many cuts each material will receive. This was a preliminary try out and though bi-directional sawing was something almost automatic, I found myself using uni-directional sawing in some instances, specifically with thick pieces. I believe that this personal 'instinct' allowed me to move with the material and showcase a more representative way of processing plant materials, be it with a bias after using modern tools. Additionally extensive documentation allows me to generate an average time per plant when the action is applied, as well as account for solutions like breaking the material off at the last bit and slicing through the last parts.

Pounding and grinding

Grinding and pounding are both done with semi- to fully rounded quartzite cobbles. These two movements are similar, but grinding is confined to movement in a single direction across a flat surface, with the plant between the base and the handheld tool, while pounding uses a movement orthogonal to the flat surface (Shea, 2015), and is used to soften up the plant tissue and bring the scattered material from grinding back together into a neat patty if it the material is fresh. Pounding can make the plant use easier without excessive effort as it requires only a short impact that can be achieved by gravity using a large stone. Such tasks involve breaking open the seeds, pounding stems or roots to make chewing easier and thus allowing for better absorption of the needed compounds (Heidgen et al., 2020).

Both pounding and grinding were used interchangeably with notes on where either would be used more or preferred. To divide these tasks strictly is to remove the reality from the action. For the root part both pounding and grinding need to be involved when trying to homogenise it seeing how the first part is to break up the root into smaller pieces and then grind it. Young shoots, roots and rhizomes were used for grinding and pounding.

3.2.4 Documentation and control environment

Initially, I designed an identification system for each experimental tool with abbreviations of the plants and actions during the experimentation (Table 1 & 2)

Table 1 Initial documentation method. (Table by D.A. Derzhavets).

Material/tool		Action		Plant species		Plant part		Nr.
Flint	F	Cutting *	C	*Anthriscus* sp	A	Root	R	
Grinding stone	GS	Shaving	S	*Daucus carota*	Dc	Shoot	S	
		Sawing	Sw	*Phragmites australis*	Pa	Young Shoot	Ys	
		Splitting	Sp	*Typha latifolia*	Tl			
		Pounding/Grinding	P/Gr					

Table 2 Abbreviation of the documentation method. (Table by D.A. Derzhavets).

Material/tool	Action	Plant species	Plant part	Number
Flint	Splitting	*Daucus carota*	Root	2
F	Sp	Dc	R	2
F_Sp_Dc_R_2				
GS_P/Gr_Tl_R_1**				

* Cutting in the manuscript has been changed to slicing

** Because there were only 4 runners in total per plant, the first two were used for fresh plant material, and the last two for dry, which was documented with the grinding stone slabs and the timing of the processing.

The slabs were used as a single tool with multiple processing spots, therefore the slabs were named GS1 and GS2. The samples of the slabs were identified according to the slab, plant, plant state and the situation of sampling (which is explained later in section 3.3).

Example: GS1 – *Daucus* – Fresh – Outside > GS1_DFO

Ultimately, the flint and runner names were changed into F+Nr. and GS+Nr., whilst the slab notation remained the same. The genus names are used in all graphs and tables because of the documentation ease and recognisability of the name when processing material faster.

Control of the experimental environment was ensured by placing a dish of water into the fume hood to collect any dispersing starches and other micro-remains. The expectation was that there might be some starches and micro-remains from agricultural context like potato, wheat or other plant that is common in modern consumption. The water in the dish was centrifuged and excess water removed to create a more concentrated residue. A total of 4 *Triticum, Aegilops, Secale* and *Hordeum*, also known as 'TASH', starches were observed. These starches belong to the most commonly cultivated grains like wheat, oat, rye, etc., and are most likely to come from clothing of the people working in the same environment, as well as my own garments.

3.2.5 Plant processing and processing experience

This section elaborates on the processing of the plants using the previously defined actions and procedures. Availability of the plants dictated the amount of the material, so there is no standardisation in this criteria. In the tables 1 and 2 the tool names and the plant part that has been processed accompanied with the action are indicated . The plants were processed while fresh with flint tools, and were ground in both fresh and dry states. The fresh material was kept cool in a wet cloth and has a 100% hydration state, whilst the dry material was dehydrated at 35 degrees Celsius over a period of 24-72 hours and has a hydration state of 0%. For each plant part and action I used three flint flakes and two runners. During the experimentation I realised that processing the shoot of *P. australis* was a miscalculation, so I proceeded only with the experimentation of the young shoot, but still included the shoot flints in the overall assemblage. All experiments were filmed, and the tools were photographed both before and after the processing, and again after the residues were extracted. In Appendix A the division of tools, their plant part and hydration state at the time of processing can be found.

Typha latifolia

The cattail and reed were collected first and during the preliminary experimentation I established that it would be best to clean and then cut the material. Because of the availability of the cattail and it being at the centre of many experimental studies within the palaeolithic record (Aranguren et al., 2007; Longo et al., 2021; Revedin et al., 2010), I made the decision to not only focus on the rhizomes of the plant but include young shoots as well, see the division of tools in Table 1. Starch content is high around the base of the plant as well as young shoots also containing sugars when going towards the dormant state, like these cattails that were collected in late October from the Meijendel Nature Reserve. The shaving was necessary to get to the cleaner part of the cortex and the pith, which contains the most starches and the slicing was used as a preparation step for the grinding (Fig. 29). The grinding of the fresh material was smooth due to the smaller chunks, which had to be pressed open first before any grinding could be done. After some grinding the material had to be collected back to the centre of the

Figure 29 T. latifolia Flint Processing. Top from left to right shows the progression from fresh plant to cleaned plant using shaving/scraping actions. Bottom from left to right shows sawing being applied. Arrows indicate the starch rich pith material. (Photos by D.A. Derzhavets)

slab to continue pulverising it (Fig. 30). This was similar for the dry material, but the dry material was more difficult to begin with due to the smaller chunks jumping away on impact.

Figure 30 T. latifolia Grinding. Top three images from left to right show the process of grinding the fresh material, collecting it in a patty to dry after the process. Bottom three images show the sequence of dry processing of the plant, resulting in a flour and fibre mixture. (Photos by D.A. Derzhavets)

This made the processes a bit more difficult and took longer than the fresh material.

Phragmites australis

Reed I chose to process differently, taking the young shoots. It was also one of the first plants to be ground and practiced with. Reed contains a sufficient amount of starches but has generally more phytoliths. This was a bold choice, mainly for the grinding part of the project, and especially the dry grinding of the reed, because it moves everywhere. Fresh young shoots were gathered but due to them being submerged under water, they needed to be cleaned from the outer layers, to reach the sweet core, therefore I chose shaving.

Figure 31 P. australis Flint Processing. From top left to right, shaving the material. Bottom left to right, sawing the material. (Photos by D.A. Derzhavets).

Based on the length and thus also the exposure the flint tool would have on the material, I chose to go for between 70 and 80 cm length, which accounted for approximately between 10 and 15 minutes of constant use. The residue collected during the shaving was clearly visible and lots of fibrous material was sticking to the surface of the tools (Fig. 31). Subsequently, the cleaned material was then sawn into pieces of 1 to 2 cm in length with bidirectional motion

Figure 32 P. australis Grinding. Processing of the dry plant material with top image showing the grinding stone before processing, and the bottom images showing the processing. (Photos by D.A. Derzhavets)

(Fig. 31). The grinding was very unstable in the dry material and not much was ground even after 10 minutes. The fresh material tore up faster but stuck to the surface of the tool too much and had to be continuously scraped back to the centre. Dry material also tended to jump everywhere because of the impact and the rigidity of the material (Fig. 32). It was not easy to grind this plant in the way that I did it.

Anthriscus sp.

Anthriscus was one of the most interesting and easiest pieces to process. First the plant material was divided in batches of the same size, mainly looking at the diameter and length to estimate

Figure 33 Anthriscus Flint Processing. Top left to right shows raw material that is being cleaned with the shaving motion. Bottom left to right shows clean material that is being sliced into smaller discs. (Photos by D.A. Derzhavets)

the surface that would be cleaned, around 50 cm of length was used spread over 4 to 5 pieces with a diameter between 1.5 and 2.5 cm.

The root was separated from the shoot and two actions were used on this plant: shaving and slicing (Fig. 33). The *Anthriscus* root has many expanding parts and is often easier to clean when separating these parts, so the slicing tool was used for that as well as separating the shoot from the root. I recorded the time it took to separate the shoot, and included it within the total used for "slicing". Once I prepared the root to ease the processing, the shaving of the root began. Contrary to *D. carota*, *Anthriscus* has a dark unpleasant skin that is not appealing and contains a lot of gritty debris. However, due to the root having a more sponge like constitution in the cortex part of the root, the skin is relatively easy to take off both with shaving and peeling. Often a combination of both was used, as this was the most natural way to move around the material with a flint tool. Nevertheless, residue was clearly seen on the surfaces of the tools when done.

Slicing the *Anthriscus* root was extremely easy and quick, and the tool quickly collected a lot of plant matter, mainly on the hafting edge, as the material would slide further up when slicing. The roots were all sliced in pieces of 5mm thick. Part of the material was then immediately used on the grinding stone and part was dried in the dehydrator.

Figure 34 Anthriscus Grinding. From left to right, dry plant material being ground up into a course flour. (Photos by D.A. Derzhavets)

The grinding of the material was easy and quick and it was done on 60 g in total, 30 g for each runner. Fresh material formed itself into a patty and fibres were still visible, though

they were not as visible due to the slicing. The dry material was approximately 11 g per runner and was tougher to grind on a smaller surface, but the abundance of starches and fibres being relatively small, made the dry material crumble relatively fast (Fig. 34). Separating fine powder from the fibre was more difficult with the fibre being sliced into pieces.

Daucus carota

In the months of October and November the wild carrot was slightly difficult to acquire due to most of the shoots being mowed away. After finding a good patch, it also became evident that the roots would not be longer than 15 cm and wider than 2 cm, in short, material was scarce. Therefore, the decision was made to use the splitting and slicing action on the *D. carota*, seeing how the cortex of the carrot is clean. The collection then was aimed at getting the longest roots to ensure no lack of material would present itself, for longer shoots make up for longer exposure to the plant, and slicing can be done even on thinner roots, just more frequently, like chopping herbs.

Approximately 70 cm of length was used for each splitting tool, where the root was split in several elongated pieces and subsequently sliced, the slicing being timed and lasting between 1 and 2 minutes (Fig. 35). Clear residue traces were visible on the tools, though the material was not as sticky as the cattail or the chervil, and thus fell off quicker.

Whilst preparing the grinding, 60 g in total was used for the fresh ground parts and 10 g for the dry material. The fresh grinding immediately revealed a lot of moisture coming out of the roots as well as the signature beta carotene orange oxidation that happened about 2 minutes into the grinding process (Fig. 36). Since the material had both long and short fibrous structures it became relatively quickly homogenised and formed a patty despite being mainly wet and having less of a sticky nature. The dry material was difficult to grind on a small surface but the elongated fibres could be easily removed whilst the grinding of the cut pieces was much harder and tougher in general. Overall, the plant was much harder to grind than other root in this project, both fresh and dry.

Figure 35 D. carota Flint Processing. Top images are raw material being prepared for processing. Below the action of splitting on the left and the processed material result on the right. Bottom images show slicing being applied with the final result on the bottom right (Photos by D.A. Derzhavets).

Figure 36 D. carota Grinding. Top two images show the grinding stone after processing fresh material, on the right the plant material oxidised. Bottom three images show the dry material pre, during and post grinding. (Photos by D.A. Derzhavets).

3.3 POST EXPERIMENTAL PROCEDURE

The main focus post experimentally was the handling of tools in different controlled conditions and the collection of residues. Tools were divided into three groups, one of which was placed outside for weathering to track a taphonomic signal. The tools were sampled and after sampling, the goal was to identify and compare the presence of starch, but also other micro-remains such as phytoliths were examined to train this type of microscopic analysis and ensure a more complete approach of interpretation to this project.

3.3.1 Organisation of the tools post processing

After the processing of the plant material, the lithics and the grinding stones were divided into groups in order to be placed outside and stored inside. Prior to sampling all tools were stored, drying out the residues. Because I chose to do three flint tools per plant and action, a sampling division of 'Before', 'Inside' & 'Outside' was proposed by dr. A. Henry. This meant that the grinding stones with varying numbers per action per plant would have to fit that model. This division can be seen in tables 3, 4 and 5.

The 'Before' category indicated the sampling before some of the tools would be left outside to face the elements. 'Inside' was reserved for the set of tools that were left in the laboratory in a box with holes, enough for air circulation to happen but not to be contaminated. 'Outside' was the group of tools that was placed outside from the 10th of March 2022 until the 29th of May, flipping the tools on the 21st of April so both sides are exposed to different types of weathering.

Table 3 Flint Tools. Division of tools per sampling condition. (Table by D.A. Derzhavets).

Flint flaked tool				
	Before	**Inside**	**Outside**	Total
Anthriscus	F-25/26	F-27/28	F-23/24	6
Daucus	F-29/30	F-31/32	F-33/34	6
Phragmites	F-17/18	F-19/20	F-21/22	10
		F-15/16	F-13/14	
Typha	F-01/02	F-03/04	F-05/06	12
	F-07/08	F-09/10	F-11/12	
Total samples	10	12	12	34

Table 4 Runners. Division of tools per sampling condition. (Table by D.A. Derzhavets).

Runners				
	Before	**Inside**	**Outside**	Total
Anthriscus	All	GS-10 | GS-12	GS-09 | GS-11	8
Daucus	All	GS-06 | GS-07	GS-05 | GS-08	8
Phragmites	All	GS-13 | GS-15	GS-14 | GS-16	8
Typha	All	GS-01 | GS-03	GS-02 | GS-04	8
Total samples	16	8	8	32

The slabs were all sampled as 'Before' and 'Outside' seeing how there were only 2 of them in total and both were placed outside. A total of 16 samples were collected from the slabs as can be seen in table 3.

Table 5 Grinding Slabs. Division of tools per sampling condition.(Table by D.A. Derzhavets).

GS Slabs	**Before/Inside**		**Outside**		**Total**
Plant/condition	Dry	Fresh	Dry	Fresh	
Anthriscus	GS2-ADB	GS2-AFB	GS2-ADO	GS2-AFO	4
Daucus	GS1-DDB	GS1-DFB	GS1-DDO	GS1-DFO	4
Phragmites	GS2-PDB	GS2-PFB	GS2-PDO	GS2-PFO	4
Typha	GS1-TDB	GS1-TFB	GS1-TDO	GS1-TFO	4
Total	4	4	4	4	16

Placing the part of the tools outside would allow for microbial growth, fungal interaction and other elemental weathering and disruption of the starches that have been collected on the surfaces of these tools. After this 79 day period the stones were collected, sampled and the samples compared to the samples taken from the 'before' and 'inside' tools.

Outside conditions and placement

The tools were placed outside between 12th of March and 29th of May, for a total of 79 days of exposure. During that time the weather was relatively dry with a small number of heavy rain days, less than 5. The wind was weak, which is less common for the Netherlands during this time, and this caused for a relatively hot and dry exposure for the tools. Plenty of

burrowing, arthropod and slug activity was observed, especially on the flat and the contact surfaces of the grinding slabs.

There was no particular intention behind the placement of the stones (Fig. 37). The idea was to randomly place the artefacts with enough space in between them, mimicking a realistic but controlled 'abandonment' of tools at an open site. The space between each next tool approximated between 10 and 20 cm, the radii differed in shape. A schematic representation of the tool placement can be seen in figure 38. One consistency was that the runners were all placed with their contact surface up, leaving the residues primarily exposed to the sun and wind. The weather is considered to be a predictable condition – to a degree – and the activity of animals is an unpredictable condition.

Figure 37 Tools Outside. All of the tools that were placed outside. On the left, 12th of March, on the right, flipping them on 20th of april (Photo by D.A. Derzhavets).

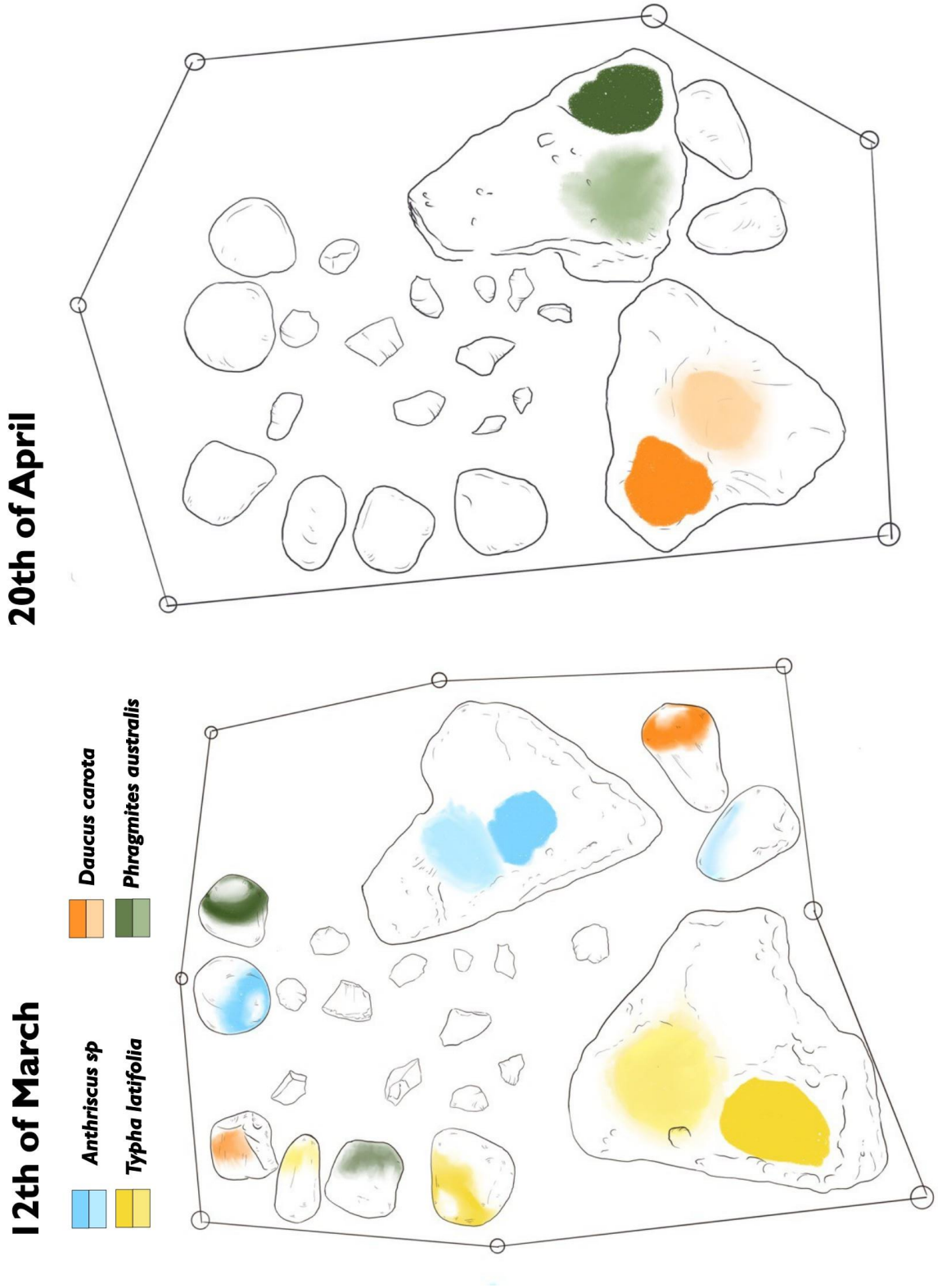


Figure 38 Tools Placed Outside. Schematic representation of the tools with residue indication for the grinding stones. The dark colour of the set is the fresh processing, the light colour is dry processing. (Illustration by D.A. Derzhavets).

3.3.2 Tool sampling procedures

Flint

The flint tools were stored in aluminium foil containers. The aluminium foil is starch free and when completely new should be as sterile as possible. The container can be made easily on the spot and this gives and extra contamination prevention when doing experimentations that easily spread starches with every move. Upon the completion of each action on each plant, the aluminium containers were stored in a sterilised box, each plant was assigned one box. The flint was then divided into the 'Before', 'Inside' and 'Outside' groups randomly and the 'Before' group was sampled first.

Figure 39 Flint Sampling Set-up. Initial sampling set up of the flint sampling that was later changed. (Photo by D.A. Derzhavets).

During the set-up of the sampling, of the 'Before' batch, which was sampled 1cm submersion of the cutting edge (Fig. 38), I decided to change the procedure for the 'Inside' and 'Outside' batches. The main reasons to fully submerge the latter batches was because I wanted to get a better gauge at what was on the tool in total and when comparing it to the

Figure 40 Flint Sampling. Sampling that was done for the 'Inside' and 'Outside' batches of flint. (Photo by D.A. Derzhavets).

grinding stone, reverse calculating a similar area would be easier and more reliable (Fig. 39). Elaboration on the calculation can be found in paragraph 3.3.3.

For full submersion, flint tools were put in glass beakers for sonication and placed next to each other in the ultrasonic bath tray. Sonication of the flint tools, and other materials used as tools, is a common and a well-researched practice amongst experimental researchers and thus perfect for removing all the possible residues from the tools (Cnuts & Rots, 2018; Rots et al., 2016). There was enough water to just cover the top of the tool in the beaker (Fig. 39), so as little water removal as possible would be needed. The tools were sonicated for 10 minutes each, then placed on a sterilised paper towel and moved back into the aluminium containers with the paper towel, seeing how contamination was no longer an issue. The residues were centrifuged, excessive water was extracted using a pipette, the amount of that residue in medium was noted down and the residue was moved to 2ml Eppendorf tubes waiting to be analysed. A single drop of pure glycerine was added to each tube for preservation. When not

Figure 41 Stored Flint Tools: A selection of lithic tools that were stored post sampling. (Photo by D.A. Derzhavets).

used, the flint tools remained in distinct groups of the sampling strategy, 'Before', 'Inside' and 'Outside', in labelled plastic containers (Fig. 40).

Grinding stones

For the grinding stones, slabs and runners, spot sampling was used. Spot sampling is a technique used to sample a specific location and surface area. Spot sampling is used in a variety of archaeological micro-fossil research and has been elaborately used in starch residue research (Messner et al., 2008). The area is secured and the surface is completely cleaned off with water, that water being collected, centrifuged and excess water is removed leaving a residue (see more detailed protocol below). Performing this type of sampling on grinding stones is best when the surface is flat, to prevent the water travelling anywhere but the designated spot.

The stones in this experimentation were used for grinding and pounding, with an expectation of the plant material slightly spreading outside of the runner-grinding stone contact surface. The gauge of the spread is determined by worked surface, plant material and the force within the action applied. This can also be seen in an experiment that focuses on the determination of spatial distribution of residues on grinding stone. Grinding residues can, but do not necessarily have to, spread further from the centre of the worked surface (Cristiani & Zupancich, 2021), though this is dependent on the hydrations state of the material. For this experimentation however, one slab was used for multiple grinding surfaces with a diameter ranging between 7 and 14 cm in diameter. Multiple grinding surfaces are not uncommon in experimental studies (Hayes et al., 2017), but the size can limit processing ability. Taking these studies into consideration and examining the stones immediately after they have been worked to see where the material accumulated most, my decision was to sample the runners just outside of the centre of the surface contact. The slabs, having many cavities and thus also places for starch to accumulate, were sampled also just outside of the centre of surface contact with the runner. Large visible accumulations were avoided in the 'Before' sampling to avoid overrepresentation and oversaturation of the material. The standard sampling area was a circle of 1 cm in diameter, being roughly 0,78 cm2 (Fig. 41). This circle was prepared using a pipette tip with 1cm gauge

and clear nail polish. The nail polish brush was cleaned in between the application of circles with acetone, 5% potassium hydroxide solution and demineralised water.

Figure 42 GS1 Sampling. Nail polish circles being marked on the grinding stone surface so the spot can be sampled. (Photos by D.A. Derzhavets).

The slabs each had 4 grinding locations, making it a total of 8. Each location was sampled twice, 'before' and 'outside', making it a total of 16 samples, and a total of 48 samples for the grinding stone. For a complete sampling documentation, see Appendix B.

Within the ring of nail polish spot sampling with a pipette was performed. 50 μl of water was pipetted onto the surface, left there for up to 2 minutes to soak up and loosen the plant material. Then the water was collected and pipetted on and off. When the water in the pipette became opaque or murky, it was deposited into a test-tube. Another 50 l was then pipetted on and off in the same fashion and this continued until the water in the pipet was clear, indicating no more residues could be extracted by surface washing this spot. For each 50 μl a new pipette tip was used. Once this was done on several grinding stones, the test-tubes were placed in a benchtop centrifuge and put on for 5 minutes at 3000rmp. The water used for the surface wash varied per sampling due to the composition of the stone, quartzite is not as

porous as silicious limestone, and thus required a bit less water. Once the centrifuging was done, the test-tubes contained a specific amount of residue at the bottom. The excess water was taken out with a pipette while the pipette was held just above the pallet of the residue. This way the residue was not disturbed and a very concentrated sample was left in the tube. This sample was then transferred to a smaller Eppendorf tube of 2 ml, and whilst doing so the approximate volume was calculated. This was determined by pipetting all of the residue into a 1ml pipette tip and slowly lowering the volume until there is no air at the bottom of the tip of the pipette.

3.3.3 Residue analysis

All 'Before' residues were collected on the 10th and 11th of March 2022, of which the first analysis was executed on the 1st and 25th of April 2022. This means that there was 3 to 7 weeks between sampling and analysis for the 'Before' batch. Between 13th and 24th of May control samples were analysed. The sampling of the 'Outside' and 'Inside' batches was done on the 3rd and 10th of June 2022.

The residues of the stone tools that were placed outside contained a large amount of dirt and sand that needed to be removed first, before mounting the slides. Sand settling velocity is about 1m/s whilst that of a starch is between 0,007 and 0,112 cm/min, significantly slower. Based on this difference, it is possible to separate sand from starch by vigorously mixing the samples and pouring off the supernatant after a fixed time has elapsed. Originally, 15ml tubes were used when surface washing the 'Inside' and 'Outside' tools. The tubes with the residues were filled back up again with water until 10ml, shaken and then after 3 seconds the water was poured off in a different tube leaving the sand and silt mostly behind. This was repeated 3 times per sample to make sure no starches were dragged down by the sand.

After all the preparation of the samples for mounting, residues were pipetted on slides with the ratio of 10 μl of residue and 10 μl of 20% glycerol solution, covered by a 20 x 20 mm cover glass. In some cases, when big chunks were at the middle of the slide or the sample was expected to dry out quicker, more glycerol solution was added. The samples were visualized at 400x

magnification using a Zeiss AxioVision transmitted light microscope with two polarizers, that allowed me to examine the sample under cross-polarized light.

In order to collect data representing the entirety of the sample without having to examine the entire cover glass, I used a random coordinate generator that was designed to provide 10 locations (or fields of view), one each within the 10 concentric squares that define the surface of the cover glass. When very little residue was available, the whole slide was skimmed through after completing the loci provided by the random generator. Starches were counted per view, and documented in the database. Phytoliths were also counted and examined as a secondary objective, though not as extensive as the starches. These micro-remains were primarily included as an additional analysis, where the general assumption is that *P. australis* leaves a phytolith signal rather than a starch one which then can be compared amongst the plants and the conditions they were left in overtime. Besides starches, all that was of importance was photographed and noted. This included things like diatoms, fungal spores, fungal hyphae, yeast, algae, plant matter, plant cells, other cells, minerals and bacteria. The count of the starch cells was then calculated back to the amount present in the sample based on the volume that was mounted, the volume that was originally left after centrifuging and the total area on the tool that was sampled.

To equate the tool samples to each other, some reverse engineering needed to be done with the flint tools. The 'Before' batch was sampled only 1 cm of the cutting edge, meaning from the most distal part to 1 cm submerged border, which differed for all flint tools. This was corrected by making an approximation based on the surface area and the concentrations of residues present when examining photos of the tools directly after use, with this formula:

(Total starch sample : Sampled surface) x 100.

The 'Before' batch was first equated to the other fully submerged flint tools, the correction of which is the following formula *(starch count slide : percentage tool sampled) x 100 = total starch count slide.* The surface area percentage estimation was made using Adobe Illustrator. Then all the tools were examined and an estimation was made for 1 cm diameter circular surface

area which is 0,785398 cm. The following calculation was then applied: *(starch count : surface area whole tool measured in cm) x 0,785398.*

The slide is 22x22 mm, one view is 1x1, the slide therefore has 484 possible views. The calculation goes as follows:

(number of starches in slide x 484) x (volume µl : mounted sample µl) = starch count of the sample. An example is: (389 x 484) x(49 µl : 10 µl) = 922552,4 starches in the whole sample. All of the numbers have been rounded up. The residues were entered in a database with elaborate descriptions of morphology, damage, clusters, contamination and the presence of other micro remains and other observations. Relevant additional data, like the initial stach and phytolith count per slide and 10 µl of sample, can be found in Appendix C.

3.3.4 Expectations from residue analysis

Having processed all of the plants, examined the tools post processing and analysed the potential damages related to processing and taphonomy, the following hypotheses on the amount of micro remains, their morphology and distribution were developed.

Quantity

The number of starches is dependent on the production of starch in the plant, the tool, action and the sampling method. *P. australis* has the least amount and the smallest starch, while *Anthriscus*, *D. carota* and *T. latifolia* are abundant in starches with relatively bigger starches. Therefore I do not expect *P. australis* to exceed the other plants in starch count. On contrary, I expect to see very little to no starch in all *P. australis* sample and conditions. Flint tools can accumulate many residues in their scars (fissures on the surface of the tool from production impact) and the tool gets fully covered in material while handling. However, the rest of the smooth surface of the tool leaves the residues more vulnerable to taphonomic processes. The grinding stones have a more coarse and larger surface which traps residues better and is more in contact with the starch rich material by volume, than flint, which aims at cleaning and preparing the material. The slabs have a more pitted surface in which starch can get trapped better. Therefore my hypothesis is that in terms of quantity I will see relatively similar spikes

amongst tools per plant in the 'Before' batch, a decline in the 'Inside batch' and grinding stones dominating the 'Outside' batch, specifically the slabs.

Quality

The quality of the starches is dependent on the life history of the starch and the taphonomic processes that it has undergone. Per plant type there should be differences in damage based on the quantity and size of the starch granules, as well as the hydration state. The shrinkage and hilum opening are damages that I primarily expect in the dry material due to the link with dehydration, but this does not have to be the case since air humidity can significantly affect the moisture levels in the starch. Mid and large sized starches, between 5 and 15 μ m, are most likely to be damaged and in a larger concentration of starches from USOs it is more likely to see more and different types of damages.

Mechanical damage caused by tools differs in impact. The most intense flint actions are sawing and shaving/scraping, which should show the most damage percentage and types, in flint tools. There is no consistent or elaborate literature on the starch damage types from flint processing because starches are primarily associated with grinding activities. However, I do expect to see some fracturing, cracking, fragmenting and disjoining. The damages involved in grinding come from the impact and the friction of the motions on a rough surface, which compresses, tears and crushes the material. Damage associated with this type of processing, includes cracking, denting, disjoining, fracturing, fragmenting and truncation (Babot, 2003). All of the tools are likely to have some microorganisms on them from the environment, especially the tools that were left outside. This biochemical interaction leaves corrosive and pitting damage on the starches. This type of damage I specifically expect to see in the 'Before' and 'Inside' batch of flint tools because they processed the outside of the plants, where most microorganisms from the soil are present. All of the 'Inside' and 'Outside' batches have more time for the microorganisms to develop and potentially digest starches, therefore I expect to see this biochemical damage also in these batches of grinding stones. Bursting and exudating are related to mechanical processing, moisture content and temperature. This damage can

therefore be present in all batches and all tools, though I cannot say with certainty to what extent.

Distribution

Fresh plants tend to stick more to a surface, depending on the plant, due to water' adhesive properties. Mucilage or pectin can also influence the adhesion of the residue as it is being processed and is assumed to ensure a better cohesion to a surface. This does not say anything about survival or preservation of micro remains. Dry and highly starchy plants are naturally brittle because of the lack of hydrogen (water) bonding that occurs on a cellular level.

Additionally, any changes and occurrences in the experimental environment are likely to cause contamination from contaminants from my own clothing, the environment and whatever bacterial and fungal growth happens between the grinding and the mounting of slides. The material that is not placed outside is expected to have the majority of starches, damage increasing with time and exposure to the outside environment.

4. ANALYSIS AND RESULTS OF THE EXPERIMENTATIONS

The analysis of the grinding stone experimentation was done by looking at the residues that were collected from the stone tools, differentiating between samples taken right after experimentation from all tools and after an 79 day period of tools staying inside and outside. The focus was on starch residues with a brief consideration of phytoliths and other remains. First, I present the raw data per tool type, focusing on starch damage across plants, tools and hydration state of the plant. Secondly I compare this data amongst each sampling condition (Before, Inside, Outside) across plants, flint processing actions, hydration state of plant and starch count of tools per individual plant Thirdly, I present a section on phytoliths and other micro-remains in light of their presence, preservation and possible interaction with starches. All images are taken in brightfield transmitted light unless stated otherwise.

4.1 STARCH COUNT ACROSS THE TOOLS

In this section I present the number of starches divided per plant and action for the flint tools, number of starches per plant and hydration state for the grinding stone tools, and for each tool type there is an indication of native, damaged and a percentage of damaged starches. This data aims to answer the research questions regarding the amount and quality of residues that are collected on the tools. The most relevant additional data can be found in the appendices as supplementation, for all the other data, please contact the author. In graphs and tables there is an indication of each plant in colour and in letter, taking the first letter of the plant genus. Blue is *Anthriscus* sp., orange *D. carota,* green *P. australis,* yellow *T. latifolia.* Do keep in mind that the numbers are an estimate of the whole sample, calculated with the formula provided in chapter 3.3.3.

4.1.1 Flint flaked tools

Flint 'Before'

Flint flaked tools were used in this project to gauge whether any residues would be left on the tools, if so, how much and across which actions and which plants. The 'Before' batch

shows *T. latifolia* and *Anthriscus* dominating the numbers. Tools processing *T. latifolia* rhizomes show a high number of full starch cells. *T. latifolia* shows a relatively consistent accumulation except one. This tool was used to process the bulbous part connected to the shoot, which is mainly pith material.

Table 6 Flint Before. Flint tool starch count and damage profile. (Table by D.A. Derzhavets).

Tool ID	Plant	Action	Total starch count	Native starches	Damaged starches	Damage %
F-25-B	*Anthriscus*	Shaving/ scraping	8712353	5736130	2976223	34,2
F-26-B	*Anthriscus*	Slicing	2216772	703737	1513035	68,2
F-29-B	*Daucus*	Splitting	1799878	1156038	643836	35,8
F-30-B	*Daucus*	Slicing	6199836	4277089	1922747	31,0
F-17-B	*Phragmites*	Shaving/ scraping	856738	645073	211664	24,7
F-18-B	*Phragmites*	Sawing	1180515	320330	860185	72,9
F-01-B	*Typha*	Shaving/ scraping	1502908	918244	584663	38,9
F-02-B	*Typha*	Sawing	1591108	707769	883339	55,5
F-07-B	*Typha*	Shaving/ scraping	1767162	1353437	413724	23,4
F-08-B	*Typha*	Sawing	6004328	3042552	2961776	49,3

As can be seen in table 6, the damage rate differs strongly per tool and plant, but accounts for at least 23% per action type and per plant type. By action there are three outliers

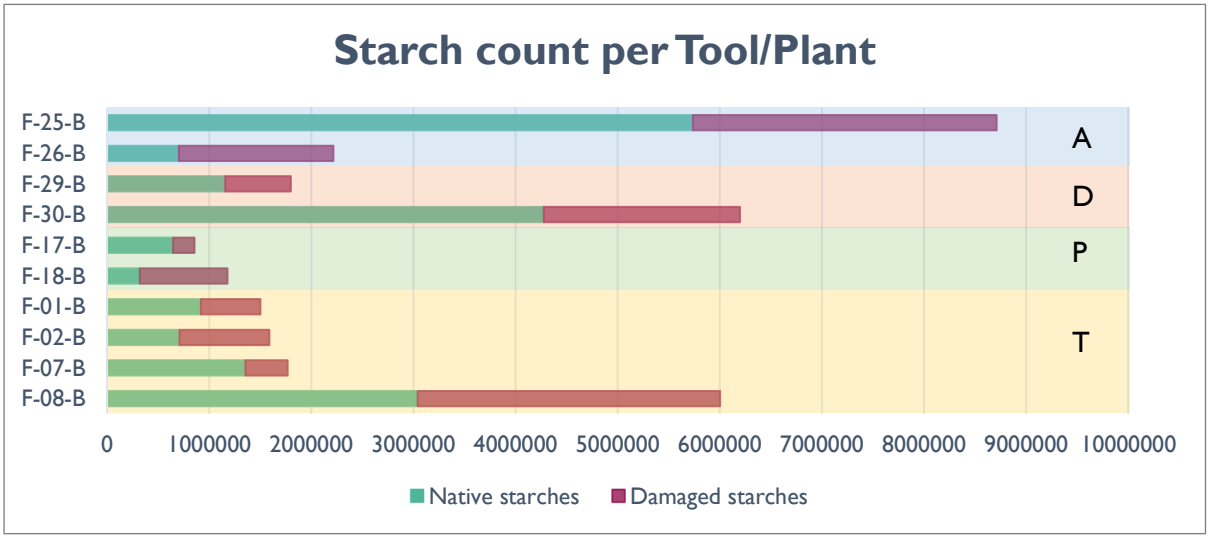


Figure 43 Starch Count per Tool/Plant. The amount of starches accumulated on the 'Before' flint tools organised per plant. (Graph by D.A. Derzhavets).

from all different plants within otherwise a relatively consistent accumulation of starches. No specific patterns for the number of starches per tools can be observed in this batch. On average,

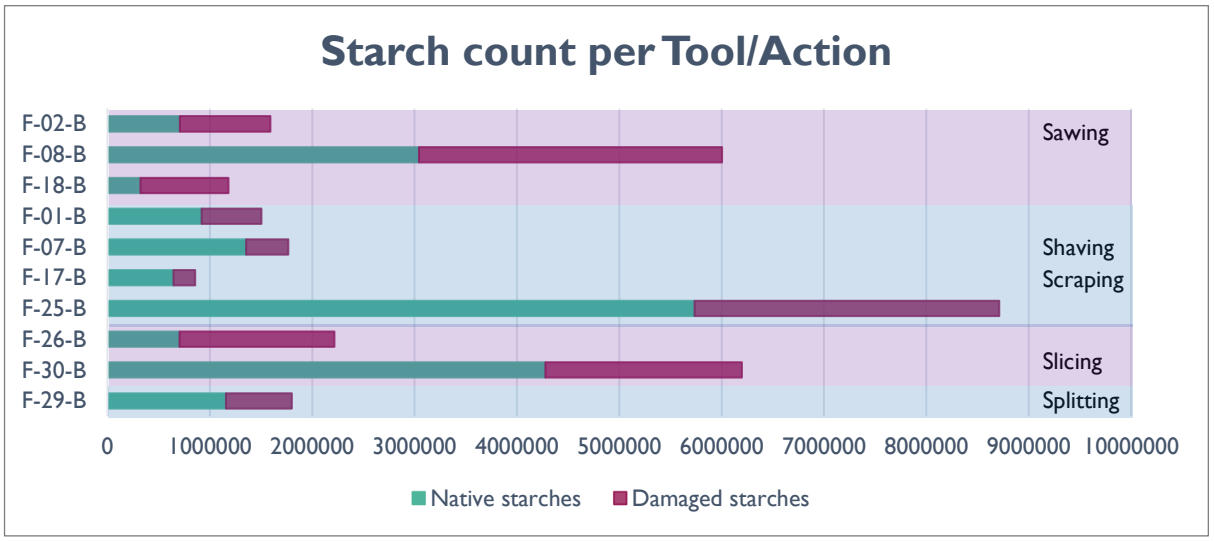


Figure 44 Starch Count per Tool/Action; The amount of starches accumulated on the 'Before' flint tools organised per processing action. (Graph by D.A. Derzhavets).

shaving/scraping shows a consistent low damage percentage.

The primary damage of this batch is denting, cracking, fragmenting and pitting (see table 7 and Fig. 44). A clear concentration of damage is shown in denting and cracking, regardless of the plant or action. *D. carota* does not show fragmentation and generally very little fracturing with a low variety of damage. Fracturing, fragmenting, cracking and denting can be seen on one starch simultaneously in varying combinations. Pitting is present in all samples in varying degrees, but most in *Anthriscus* and *T. latifolia*. The sizes of the starches are consistent with the reference material, no dehydration visible. *T. latifolia* shows full cells of intact starches with varying sizes in one and a consistent size in a different cell (Fig. 45). *Anthriscus* and *D. carota* have singular cases of mostly empty starch cells. Across all plants, per starch there is one or two types of damages, larger starches can show more. The main and most diverse damage occurs in the midrange size starches between 4 and 8 μ m. Smaller starches are either completely burst or only have a slight indentation or cracking, while larger starches show more fracturing, fragmentation, bursting and enzymatic damage. There are no particular patterns of clusters and very few compound starches are visible, mainly found in *Anthriscus*

and *T. latifolia*, which are or do not appear to be disjoined. All samples contained enough diagnostic starches to determine the plant species despite the damages. A singular *Anthriscus* native starch was found in F-18 sample.

Table 7 Damage per plant and action Flint 'Before': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage. (Table by D.A. Derzhavets)

	Plants				Actions			
	n=2	n=2	n=2	n=4	n=3	n=4	n=2	n=1
Damage	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Sawing	Shaving/ scraping	Slicing	Splitting
Burst	1	2	1	1	2	0	2	1
Corroded	0	0	0	0	0	0	0	0
Crack	2	2	2	3	3	3	2	1
Dented	2	2	2	4	3	4	2	1
Disjoining	0	0	0	0	0	0	0	0
Exudate	1	0	1	2	1	3	0	0
Fractured	2	1	2	3	2	4	0	0
Fragmented	1	0	1	2	0	4	1	0
Hilum opening	2	0	2	1	1	3	1	0
Pitting	1	1	1	1	2	0	2	0
Truncated	0	0	0	0	0	0	0	0

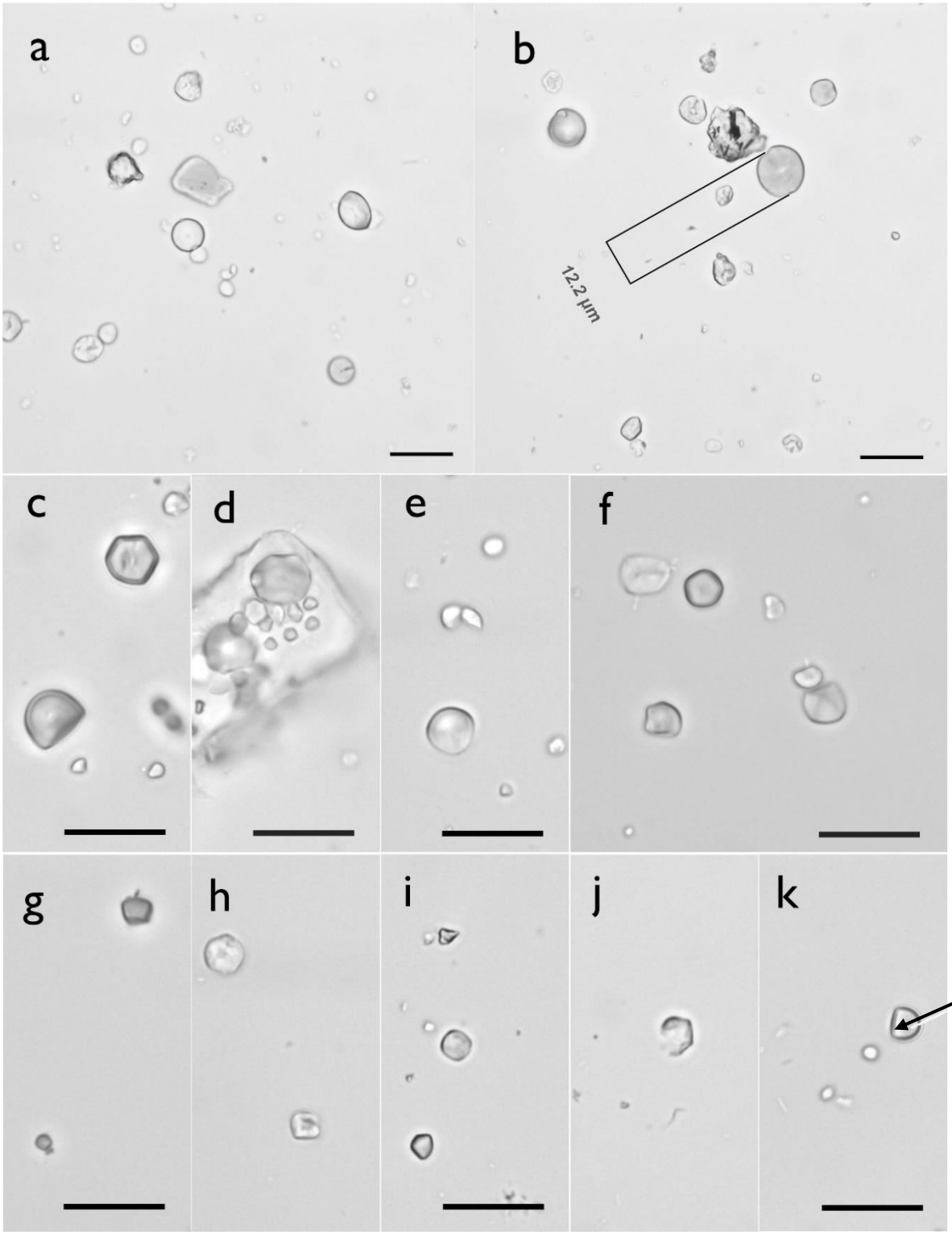


Figure 45 Starches Flint 'Before'. Anthriscus*: a) pitting, denting and cracking, b) pitting and denting.* D. carota*: c) typical* D. carota *starch that is dented and a hemispherical morphotype. d)* D. carota *starches in a cell, dented. e) starch fractured and digested and a whole starch. f) distinct* D. carota *starches with a digested starch in top left.* P. australis*: g) & I) small dented starches. h) & j) starches being digested. k) contamination by* Anthriscus*. Scalebar equals 10 µ m (Images by D.A. Derzhavets).*

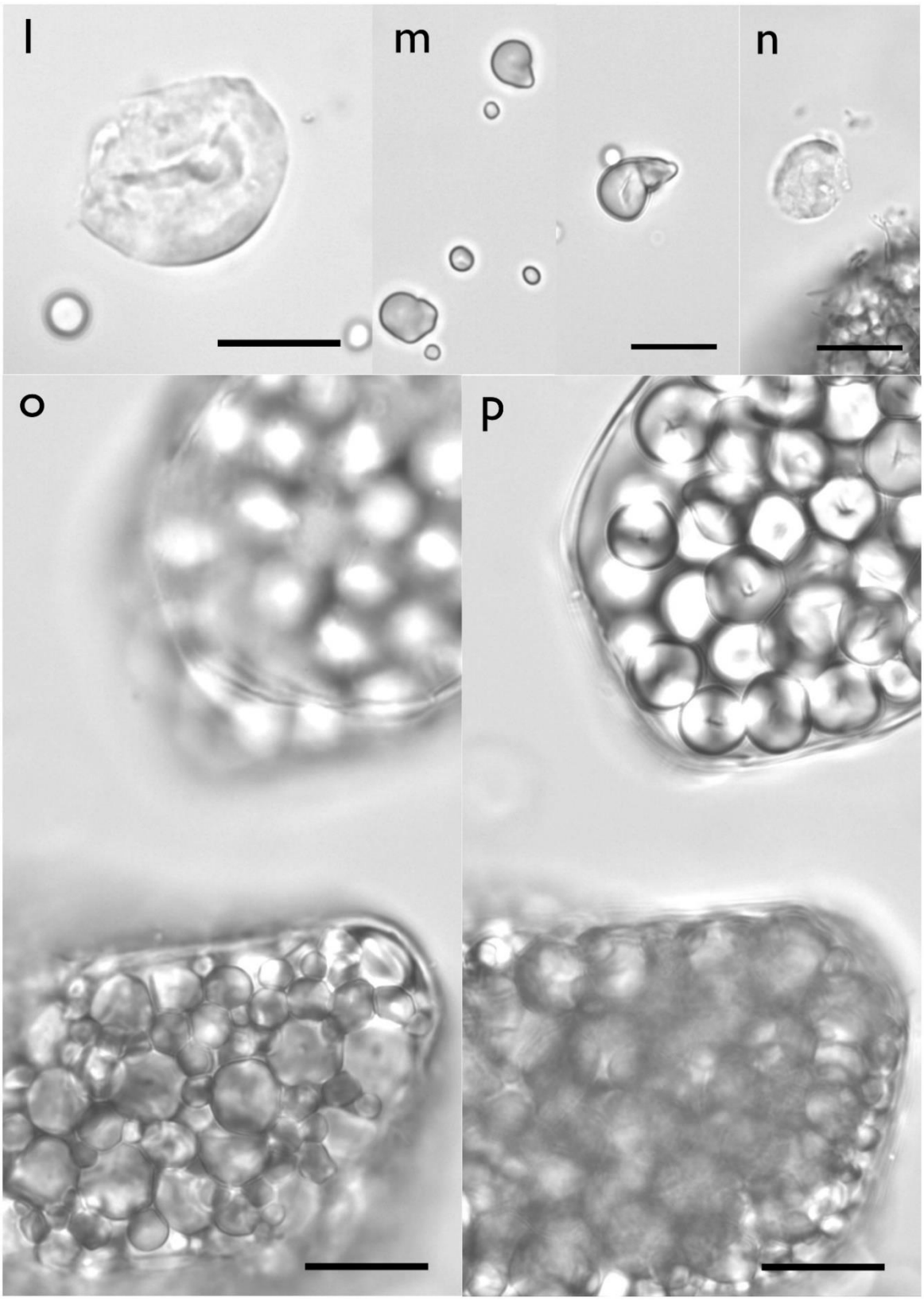


Figure 46 T. latifolia *Starches Flint 'Before'. Starches collected from the tools processing. l) & n) present digestive damage, m shows possible exudation, o) & p) presenting starch cells with different size categories per cell, uniform and heterogeneous. Scalebar equals 10 μ m. (Images by D.A. Derzhavets).*

Flint 'Inside'

Table 8 Flint Inside. Flint tool starch count and damage profile. (Table by D.A. Derzhavets).

Tool ID	Plant	Action	Total starch sample	Native starches	Damaged starches	Total damage %
F-27-I	*Anthriscus*	Shaving/scraping	894604	268070	626535	70,0
F-28-I	*Anthriscus*	Slicing	824098	543857	280241	34,0
F-31-I	*Daucus*	Splitting	2088627	884973	1203654	57,6
F-32-I	*Daucus*	Slicing	167393	95378	72015	43,0
F-15-I	*Phragmites*	Shaving/scraping	78528	36022	42506	54,1
F-16-I	*Phragmites*	Sawing	83084	27344	55740	67,1
F-19-I	*Phragmites*	Shaving/scraping	116902	99328	17574	15,0
F-20-I	*Phragmites*	Sawing	78842	68218	10624	13,5
F-03-I	*Typha*	Shaving/scraping	396800	343669	53131	13,4
F-04-I	*Typha*	Sawing	1017995	68518	332806	32,7
F-09-I	*Typha*	Shaving/scraping	145287	114154	31133	21,4
F-10-I	*Typha*	Sawing	713402	620663	92739	13,0

The flint 'Inside' batch has remained in a controlled environment for 79 days before being sampled. In this batch an additional two *Phragmites* tools were sampled. The most number of starches per plant is seen in *T. latifolia*, followed by *D. carota*, *Anthriscus* and *P. australis* in that order (Table 8 and Fig. 46). The damage in *T. latifolia* is the lowest and *Anthriscus* and *P. australis* show the most consistent starch count. Half filled or almost empty

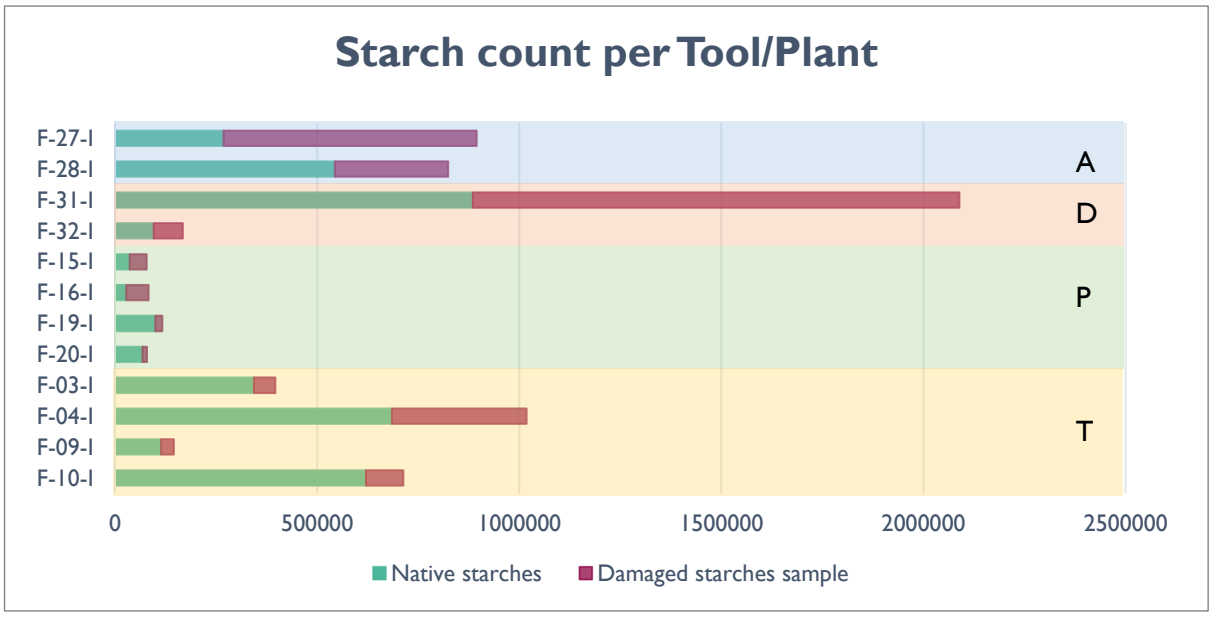


Figure 47 Starch Count per Tool/Plant Inside. The amount of starches accumulated on the 'Inside' flint tools organised per plant. (Graph by D.A. Derzhavets).

starch cells were present in all *Anthriscus*, *D. carota* and *T. latifolia* samples (Fig. 48 and 49). There are no other starch count patterns that can be observed. Per action there are no consistencies in count but there is a somewhat consistent low damage percentage in Shaving/Scraping and Sawing actions (Fig. 47). There is an outlier of the splitting action on *D. carota*, which is related to the size of the tool and recalculation to 0,78cm^2 surface area.

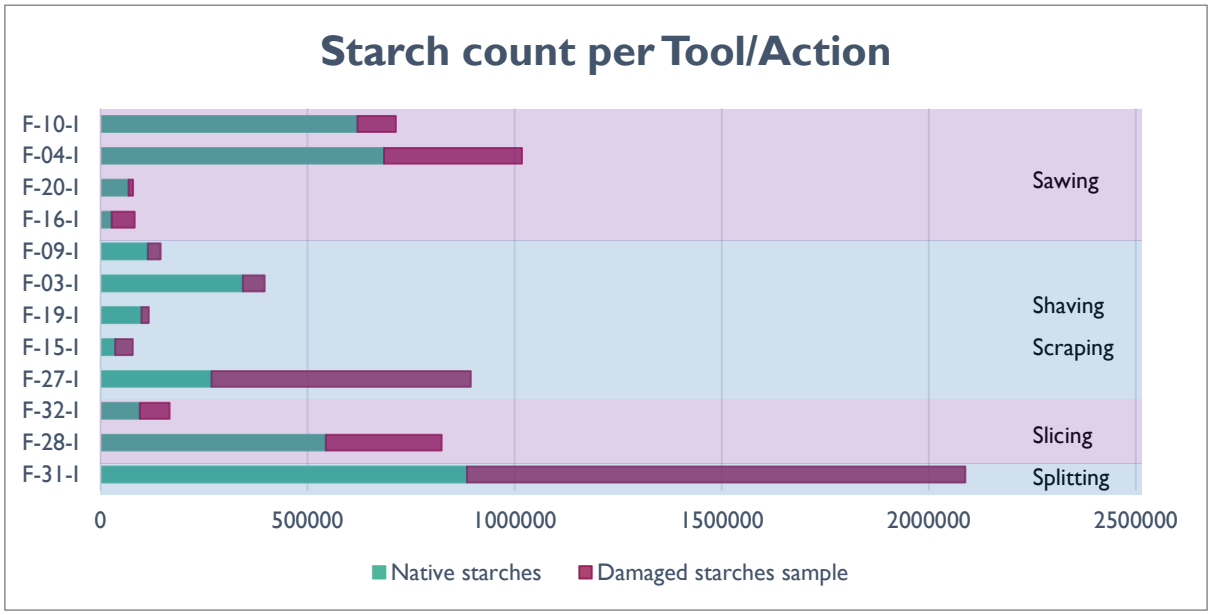


Figure 48 Starch Count per Tool/Action; The amount of starches accumulated on the 'Inside' flint tools organised per processing action. (Graph by D.A. Derzhavets).

The damages are mainly denting, pitting, hilum opening and cracking, with *Anthriscus* and *D. carota* showing the most variety in damages (Table 9). *D. carota* has a relatively high number of hila openings when compared to the other plants (Fig. 48). Clusters of starches being held together by some vegetal matter or broken down starch material are common in all samples. Pitting damage amount in all root processing tool samples and makes up about 25% of all damages. This is not the case for *P. australis*, where it is between 5 and 10%. The sizes differ strongly depending on the amount of starch, the most visible size is 4 – 9 μm. The smaller starches cannot be recognised and are often too fragmented. In numbers they outweigh the largest starches. Clear damage examples are best visible in the 6-14 μm sizes. Across all plants, there is a consistent pattern of at least two types of damages on the free starches, from

denting, cracking and/or pitting. Starches that remain in their cells have a singular dent or a crack but are mostly native, of which there is still a relatively large number, across all plants.

Table 9 Damage per plant and action Flint 'Inside': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage. (Table by D.A. Derzhavets)

	Plants				Actions			
	n=2	n=2	n=4	n=4	n=4	n=5	n=2	n=1
Damage type	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Sawing	Shaving/ scraping	Slicing	Splitting
Burst	1	2	3	0	2	2	1	1
Corroded	0	1	0	1	0	1	0	1
Crack	2	1	2	0	1	2	1	1
Dented	2	2	4	4	4	5	2	1
Disjoining	0	0	0	1	0	1	0	0
Exudate	1	0	0	3	2	1	1	0
Fractured	2	1	1	2	1	3	1	1
Fragmented	2	2	0	0	0	1	2	1
Hilum opening	2	2	0	2	1	2	2	1
Pitting	2	1	1	4	2	4	1	1
Truncated	0	0	0	0	0	0	0	0

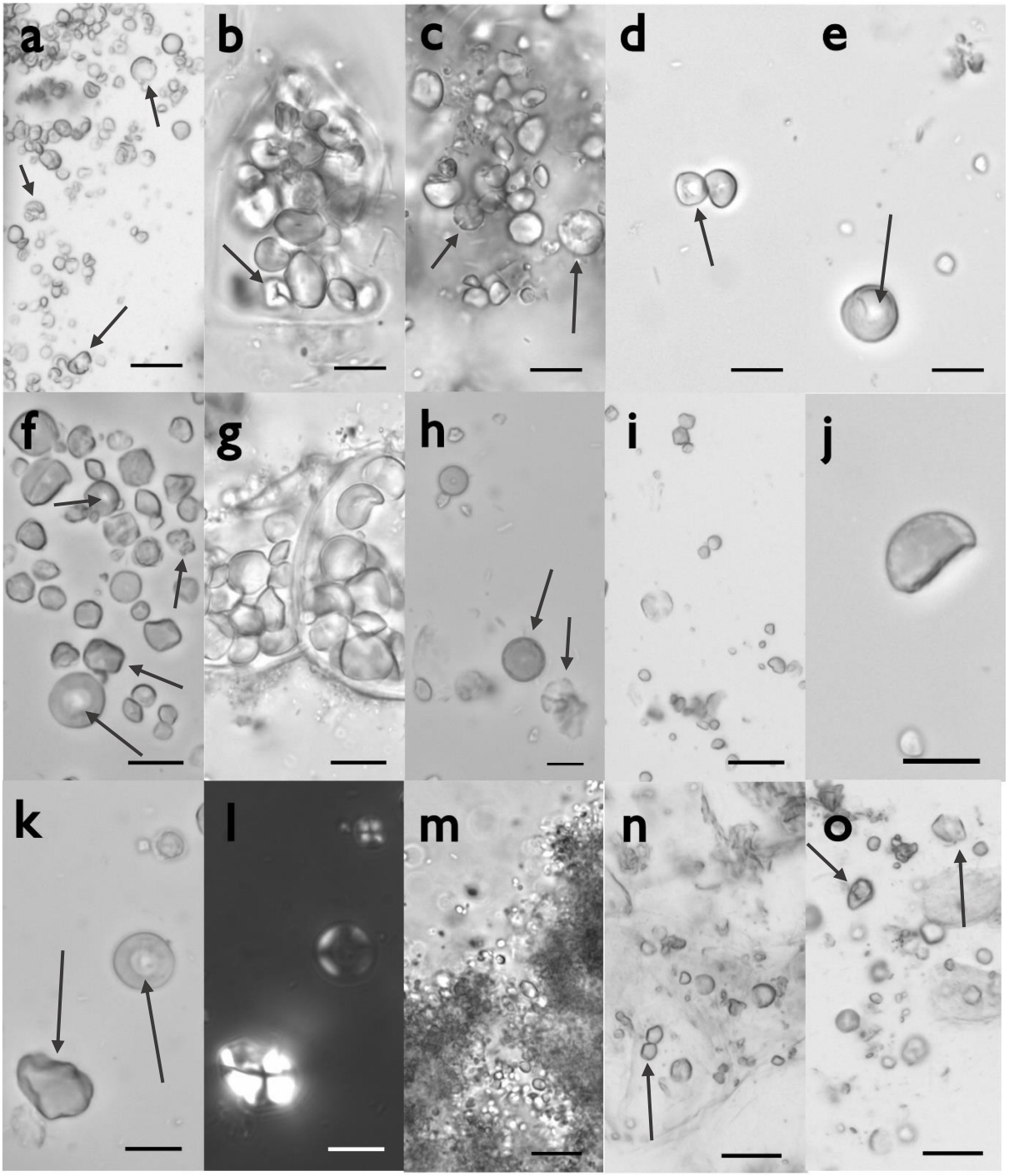


Figure 49 Starches Flint 'Inside'. Anthriscus *: a) cluster of starches with fragmenting and pitting damages; b) Starches in a cell with more pronounced fissures and oval shaped; A cluster of starches in a vegetal mesh with cracking and digestion damages; d-e: enlarged hila, looks like open hila.* D. carota*: f) variation of starches with denting, fracturing and open hila modifications; Starches in cell, elongated shapes, potentially dented; h-j) digestive damages; k) Dented and corroded starch, a starch with an open or enlarged hilum; l) image K under cross polarised light;* P. australis*: m) cluster of non-diagnostic starches; n) 2 diagnostic starches, other starches trapped in vegetal material; o) denting and digestive damage. Scalebar equals 10 μ m .(Images by D.A. Derzhavets).*

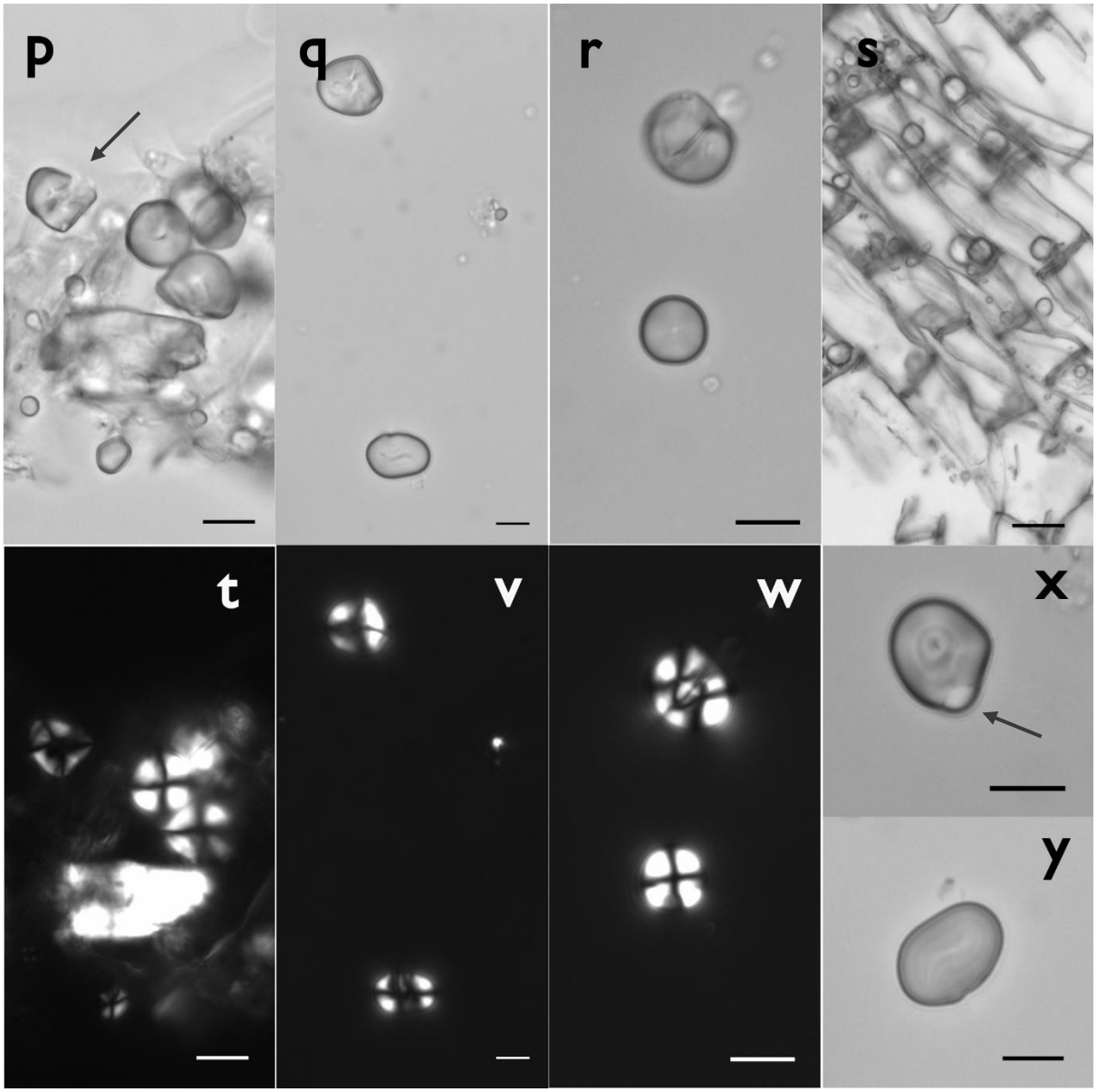


Figure 50 Starches Flint 'Inside'. T. latifolia *starches: p) fractured and dented starch in a cluster with varying sizes; q) Cracked and dented distinct* T. latifolia *starch (top), variation on morphology with elongated fracture and shape (bottom); r) distinct* T. latifolia *a starch (bottom) and compound starch (top); s) starches in and between cells; t-w) cross polarised images of p-r); x) typical* T. latifolia *starch with clear hilum and lamellae, faint cross and possible exudation damage; y) variation of a* T. latifolia *starch, elongated, lamellae growing along what seems like an elongated hilum. Scalebar equals 10 μ m. (Images by D.A. Derzhavets).*

Flint 'Outside'

Table 10 Flint Outside. Flint tool starch count and damage profile. (Table by D.A. Derzhavets).

Tool ID	Plant	Action	Total starch sample	Native starches	Damaged starches	Total damage %
F-23-O	*Anthriscus*	Shaving/scraping	441	0	441	100
F-24-O	*Anthriscus*	Slicing	514	0	514	100
F-33-O	*Daucus*	Splitting	0	0	0	0
F-34-O	*Daucus*	Slicing	467	0	467	100
F-13-O	*Phragmites*	Shaving/scraping	0	0	0	0
F-14-O	*Phragmites*	Sawing	830	0	830	100
F-21-O	*Phragmites*	Shaving/scraping	0	0	0	0
F-22-O	*Phragmites*	Sawing	0	0	0	0
F-05-O	*Typha*	Shaving/scraping	357	0	357	100
F-06-O	*Typha*	Sawing	0	0	0	0
F-11-O	*Typha*	Shaving/scraping	2179	0	2179	100
F-12-O	*Typha*	Sawing	4032	0	4032	100

The amount of starches found on the tools is dominated by *Anthriscus*, *T. latifolia*, *P. australis* and *D. carota*, in that order. *T. latifolia* shows the highest survival rate, which is almost eight times that of *Anthriscus*, even though *Anthriscus* is more consistent (Table 10 and Fig. 50). Across different actions there are no clear patterns in starch count, except for the slicing (Fig. 51).

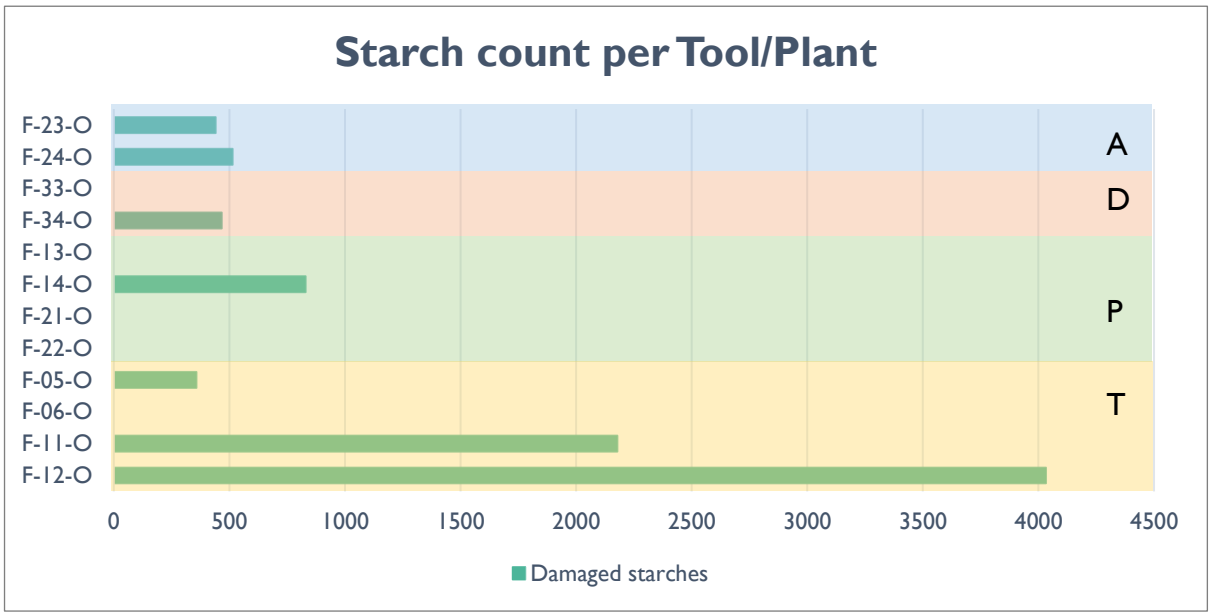


Figure 51 Starch Count per Tool/Plant Outside. The amount of starches accumulated on the 'Outside' flint tools organised per plant. (Graph by D.A. Derzhavets).

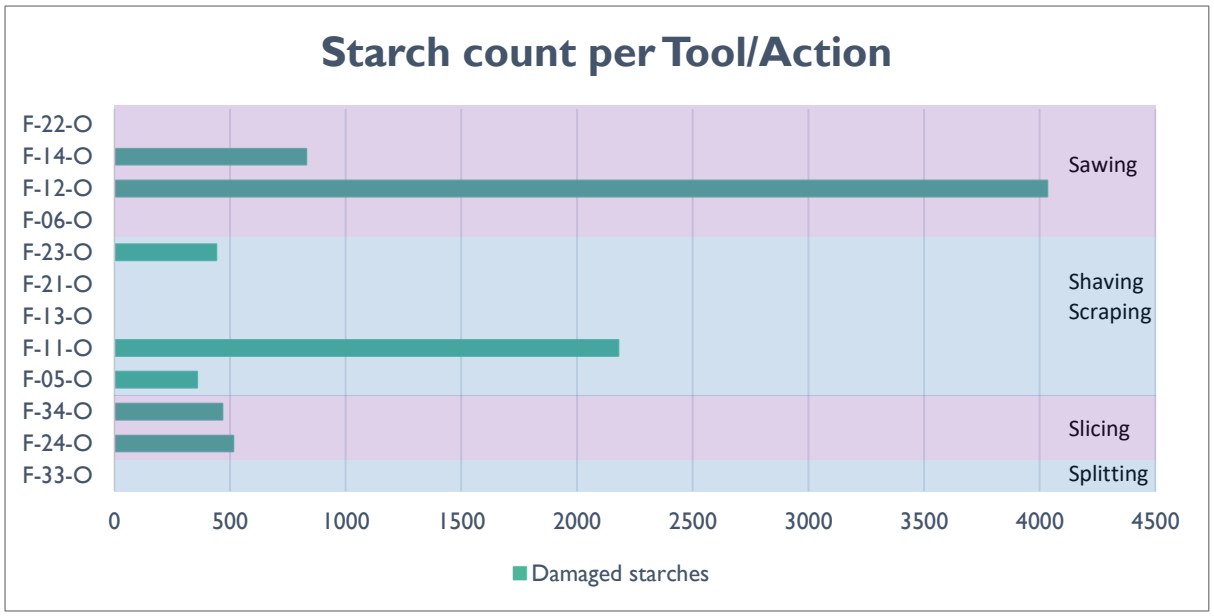


Figure 52 Starch Count per Tool/Action; The amount of starches accumulated on the 'Outside' flint tools organised per processing action. (Graph by D.A. Derzhavets).

Not many damage types were identified due to a relatively low starch count per sample analysis. *T. latifolia* that has the largest damage profile while others vary in damage type (Table 11). Starches between 4- 7 μ m preserved the best, whilst bigger and smaller starches were not visible or not recognisable. The starches in this size range suffered mostly fracturing, denting and digestive damages. Only some *T. latifolia* starches retained the proper characteristics (Fig. 52), *Anthriscus* and *D. carota* were confused amongst each other though starch cells with some starches in the F-23 sample were useful for further investigation and identification. *P. australis* had no distinctive features other than the cross under cross-polarised light. Starches that survived best were in or near some type of vegetal material or algal cells.

Table 11 Damage per plant and action Flint 'Outside': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage. (Table by D.A. Derzhavets).

	Plants				Actions			
	n=2	n=2	n=4	n=4	n=4	n=5	n=2	n=1
Plant	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Sawing	Shaving/ scraping	Slicing	Splitting
Burst	0	0	0	0	0	0	0	0
Corroded	0	0	0	0	0	0	0	0
Crack	0	0	0	2	1	1	0	0
Dented	0	1	1	3	2	3	1	0
Disjoining	0	0	0	0	0	0	0	0
Exudate	0	0	0	0	0	0	0	0
Fractured	2	0	0	1	0	3	0	0
Fragmented	1	1	0	0	0	0	2	0
Hilum opening	0	0	1	1	2	0	0	0
Pitting	1	0	1	3	1	3	1	1
Truncated	0	0	0	0	0	0	0	0

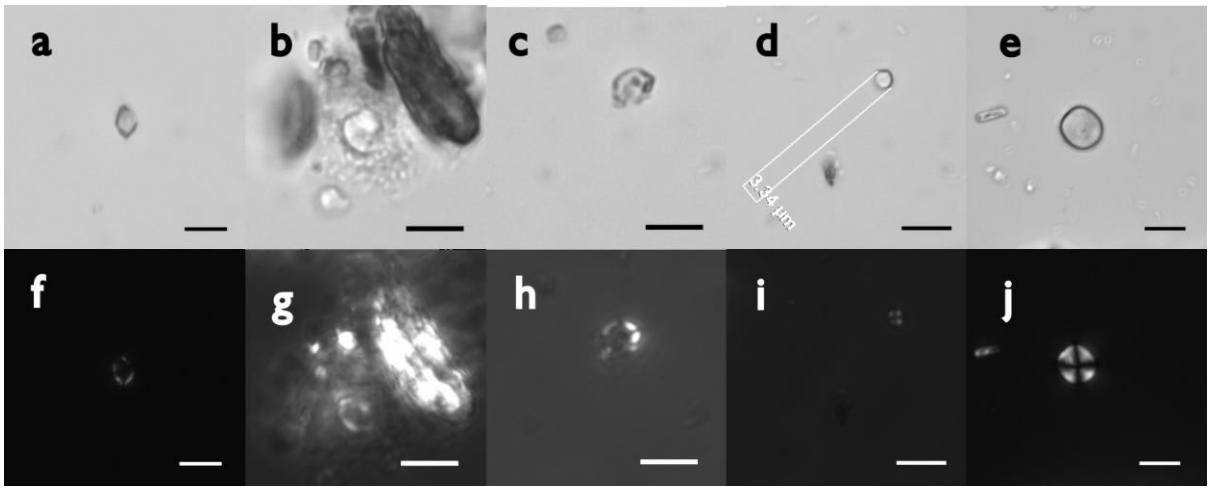


Figure 53 Starches Flint 'Outside'. f-j cross polarised light. F-14: partly digested elongated and somewhat faceted starch (a,f); F-05: dented and digested starch (b,g;c,h); F-11: a small dented speherical starch (d,i); whole distinct T. latifolia *starch with clear hilum and faintly visible lamellae (e,j). Scalebar equals 10 μ m. (Images by D. A. Derzhavets).*

4.1.2 Ground stone tools

Runners Before

Table 12 Runners Before. Tool starch count and damage profile for runners.(Table by D.A. Derzhavets).

Tool ID	Plant	Hydration State	Total starch sample	Native starches	Damaged starches	Total damage %
GS-09-B	*Anthriscus*	Dry	1250172	125356	1124816	89,9
GS-10-B	*Anthriscus*	Dry	473110	78166	394944	83,4
GS-11-B	*Anthriscus*	Fresh	11135775	1437190	9698586	87,1
GS-12-B	*Anthriscus*	Fresh	8353066	2419032	5934034	71,0
GS-05-B	*Daucus*	Dry	1729913	808183	921730	53,3
GS-06-B	*Daucus*	Dry	4084960	786016	3298944	80,7
GS-07-B	*Daucus*	Fresh	1074480	381876	692604	64,5
GS-08-B	*Daucus*	Fresh	1086096	304920	781176	71,9
GS-13-B	*Phragmites*	Dry	124533	12003	112530	90,3
GS-14-B	*Phragmites*	Dry	5518	0	5518	100
GS-15-B	*Phragmites*	Fresh	26426	0	26426	100
GS-16-B	*Phragmites*	Fresh	142296	0	142296	100
GS-01-B	*Typha*	Dry	2786920	573879	2213042	79,4
GS-02-B	*Typha*	Dry	1712295	151782	1560513	91,1
GS-03-B	*Typha*	Fresh	718740	344995	373745	52
GS-04-B	*Typha*	Fresh	3138256	1078352	2059904	65,6

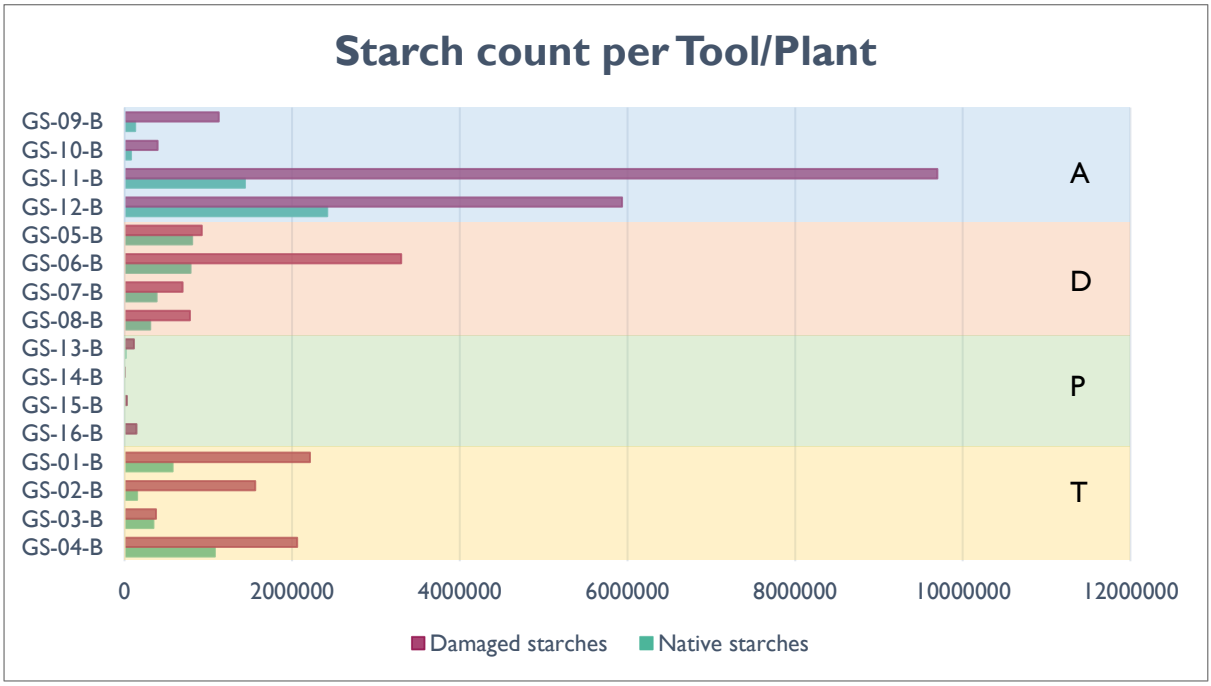


Figure 54 Starch Count per Tool/Plant Before. The amount of starches accumulated on the 'Before' runners organised per plant. (Graph by D.A. Derzhavets).

The runners show a pattern of starch numbers across plants, with *Anthriscus* the highest, followed by *T. latifolia*, *D. carota* and *P. australis* in that order (Table 12 and Fig. 53). For *D. carota* and *T. latifolia*, dry material seems to be leaving more residues than fresh, which is the opposite for *Anthriscus*. *P. australis* has very little difference of accumulation between hydration state (Fig. 54). There are several clusters in the samples of *Anthriscus*, *D. carota* and *T. latifolia*. *D. carota* and *Anthriscus* show filled and semi-filled starch cells, *T. latifolia* exhibits either full or empty starch cells. The starches in the filled and semi-filled starch cells do not appear to have been damaged and filled starch cells occur in fresh material whilst empty and semi-empty cells in dry material across the above mentioned plants. Dry processed material shows up more on the tool in terms of total starch numbers for the USOs. *P. australis* is inconclusive in that regard, showing an almost equal spread for both hydration states. All starches were recognised to the taxon and retained most of their distinct features in one sample or more.

The main damage is denting, cracking, fracturing and pitting, with *Anthriscus* and *T. latifolia* having the most diverse type of damage (see table 13 and Fig. 55). Corrosion is

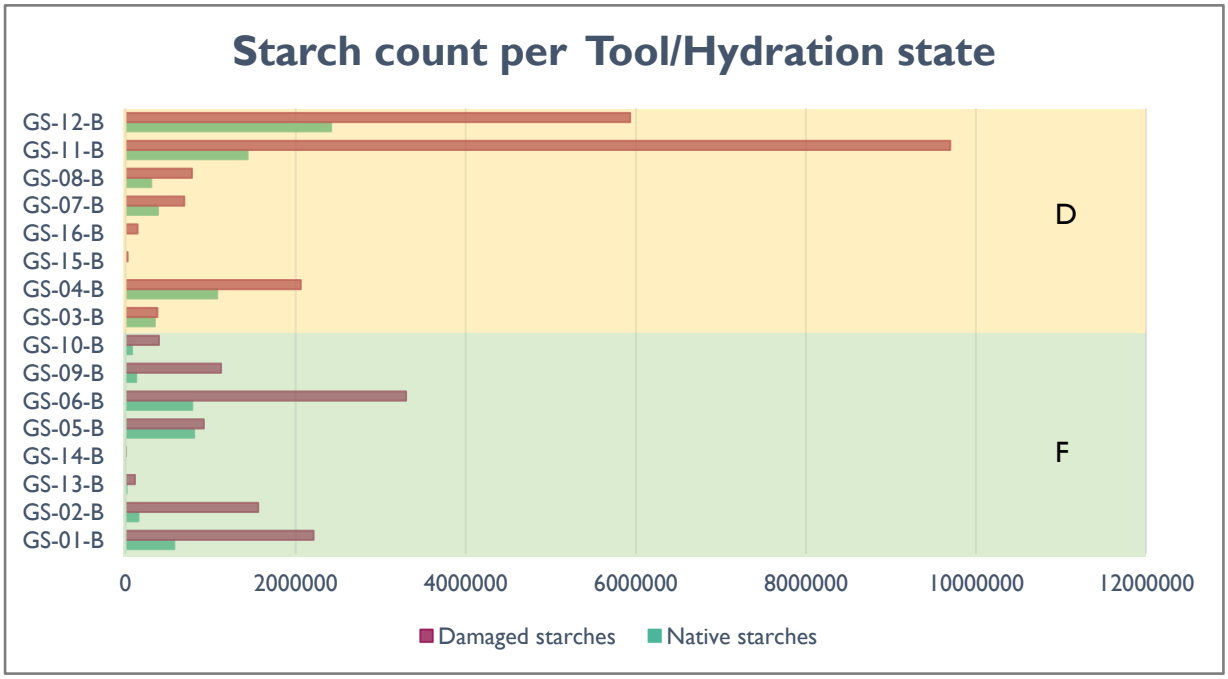


Figure 55 Starch Count Hydration State. The amount of starches accumulated in 'Before' runners when processing either Dry or Fresh material. (Graph by D.A. Derzhavets).

visible in USOs but very limited, whilst enzymatic action is present in varying degrees, leaving traces on starches between 5-10 μm, *T. latifolia* suffering most digestive damage followed by *Anthriscus* and *D. carota*. Starches below 5 μm mainly crack or fracture, whilst starches between 8-13 μm suffer multiple damages and are still recognisable. There are a number of compound starches found in samples of *Anthriscus*, *D. carota* and *T. latifolia*, but that number is very low.

Table 13 Damage per plant and hydration state Runners 'Before': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage in colour. (By D.A. Derzhavets).

	Plants				Hydration State	
	n=4	n=4	n=4	n=4	n=8	n=8
Damage type	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Dry	Fresh
Burst	2	4	1	3	6	4
Corroded	1	1	0	0	2	0
Crack	3	2	4	4	7	6
Dented	4	3	4	4	7	8
Disjoining	0	0	0	0	0	0
Exudate	1	1	0	0	0	2
Fractured	3	4	2	2	5	6
Fragmented	3	2	0	2	3	4
Hilum opening	2	0	0	2	2	2
Pitting	4	3	2	4	5	8
Truncated		0	0	0	0	0

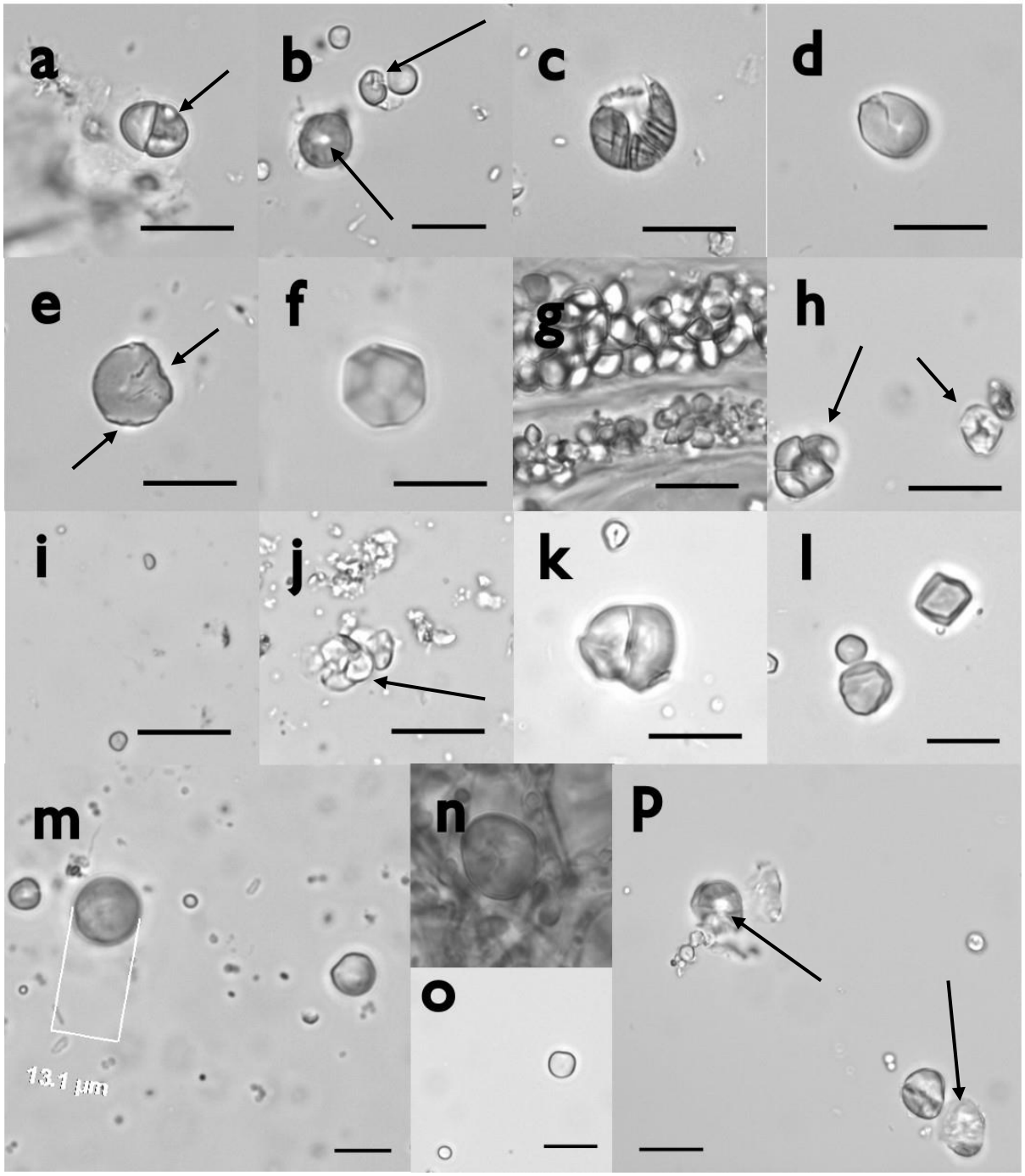


Figure 56 Starches Runners 'Before'. Anthriscus*: a) compound starch with corrosive damage; b) denting, fracturing and exaggerated hilum; c) fragmented starch with unidentified marks; d) starch with a clear crack along one side.* D. carota*: e) digestive damage, potentially corrosion; f) native* D. carota *starch; Starches in semi-filled cells; h) compound starch and cracked starch.* P. australis*: i) small native starches; j) a cluster of starches, potentially a compound starch disjoining.* T. latifolia*: k) compound starch with some dents; l) very dented starches from GS-04 potentially desiccated; m) large typical* Typha *starch; n) large* Typha *starch in fungal hyphae; o) native starches; p) Fractured starch with a hilum opening and dented, cracked and digested starch on the right. Scalebar equals 10 µm (Images by D.A. Derzhavets).*

Runners Inside

Table 14 Runners Inside. Tool starch count and damage profile for runners. (Table by D.A. Derzhavets).

Tool ID	Plant	Total starch sample	Native starches	Damaged starches	Total damage %	Hydration state
GS-12-I	*Anthriscus*	7625129	2419033	6751606	88,5	Dry
GS-10-I	*Anthriscus*	4485954	78167	3304027	73,6	Fresh
GS-07-I	*Daucus*	470351,2	381876	295530	62,8	Dry
GS-06-I	*Daucus*	313535,2	786016	170658	54,4	Fresh
GS-15-I	*Phragmites*	72648,4	7647,2	65001	89,4	Dry
GS-13-I	*Phragmites*	240451,2	53433,6	187018	77,8	Fresh
GS-03-I	*Typha*	1831843,2	344995	1451129	79,2	Dry
GS-01-I	*Typha*	23464320	573879	2213041,6	79,4	Fresh

The runners that remained inside were placed in plastic containers with enough airflow so mould wouldn't develop but other materials wouldn't get in. Additionally, sterile paper towels were put in the boxes to absorb moisture. All tools exceed the 50% damage percentage with *P. australis* and *Anthriscus* showing the most damage in numbers (Table 14). Also here the runners exhibit a pattern across plants, with *T. latifolia* accumulating most starches, followed by *Anthriscus*, then *D. carota* and *P. australis* (Fig. 56). Although the

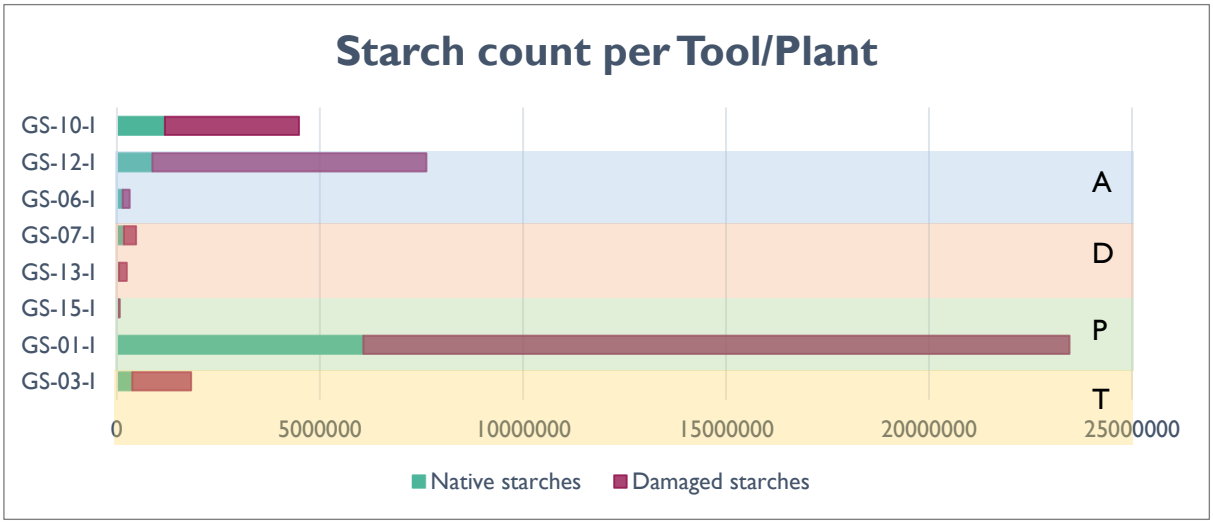


Figure 57 Starch Count per Plant Type. The amount of starches accumulated in 'Inside' runners when processing either the different plant material. (Graph by D.A. Derzhavets).

numbers of *D. carota* are always on the lower end, in this batch they are very low compared to the other plants and especially compared to *Anthriscus*. The results of hydration states are inconsistent, *T. latifolia* accumulating a lot more while being processed fresh and *Anthriscus* more when dry (Fig. 57). *Anthriscus* shows a survival of starches between 4 and 8 μm that have the particular shape of a cap, or convex concave shape, in compounds of 2 starches. The larger starches seem to be in lower counts and most of the material is clustered around algae

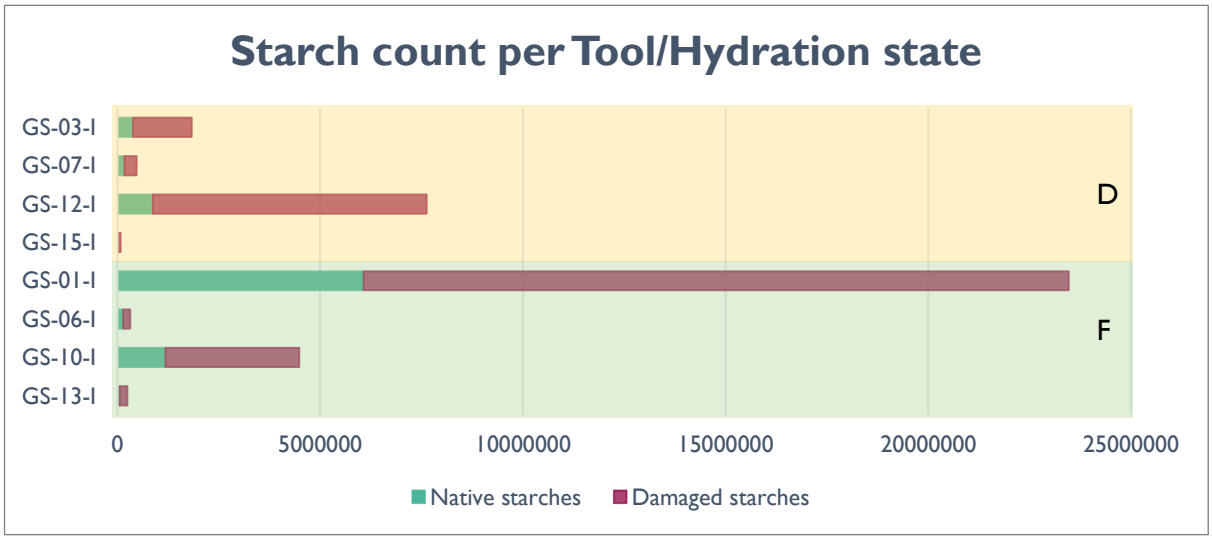


Figure 58 Starch Count Hydration State. The amount of starches accumulated in 'Inside' runners when processing either Dry or Fresh material. (Graph by D.A. Derzhavets).

and vegetal material, being digested by some bacteria and yeasts.

Full and semi-full starch cells are present in *D. carota*, Anthriscus and *T. latifolia* (Fig. 58). There is an increase in digestion damage and some corrosion is exhibited by *T. latifolia* starches. The main damages concentrate around denting, cracking, fracturing and fragmenting (Table 15 and Fig.58). There are also many cases of burst starches but they often go in combination with another modification such as cracking and fracturing. Except for *T. latifolia*, there are not many starches over the size of 8 μm. All samples display diagnostic starches and it was relatively easy to identify each taxon. With *D. carota* having almost no starches it was interesting to find diagnostic starches nearly every time, even though they had endured a lot of damage. This was also the case for *P. australis*, starches that bear specific morphology survived but there are no other remnants or smaller specimen.

Table 15 Damage per plant and hydration state Runners 'Inside': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage in colour. (Table by D.A. Derzhavets)

	Plants				Hydration state	
	n=2	n=2	n=2	n=2	n=4	n=4
Damage type	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Dry	Fresh
Burst	2	2	2	0	3	3
Corroded	0	0	0	1	0	1
Crack	1	1	2	0	2	2
Dented	2	2	1	2	3	3
Disjoining	0	0	0	0	0	0
Exudate	0	0	0	1	1	1
Fractured	2	2	1	1	3	3
Fragmented	0	1	0	0	0	1
Hilum opening	1	1	0	0	1	1
Pitting	2	1	2	2	4	1
Truncated	0	0	0	0	0	0

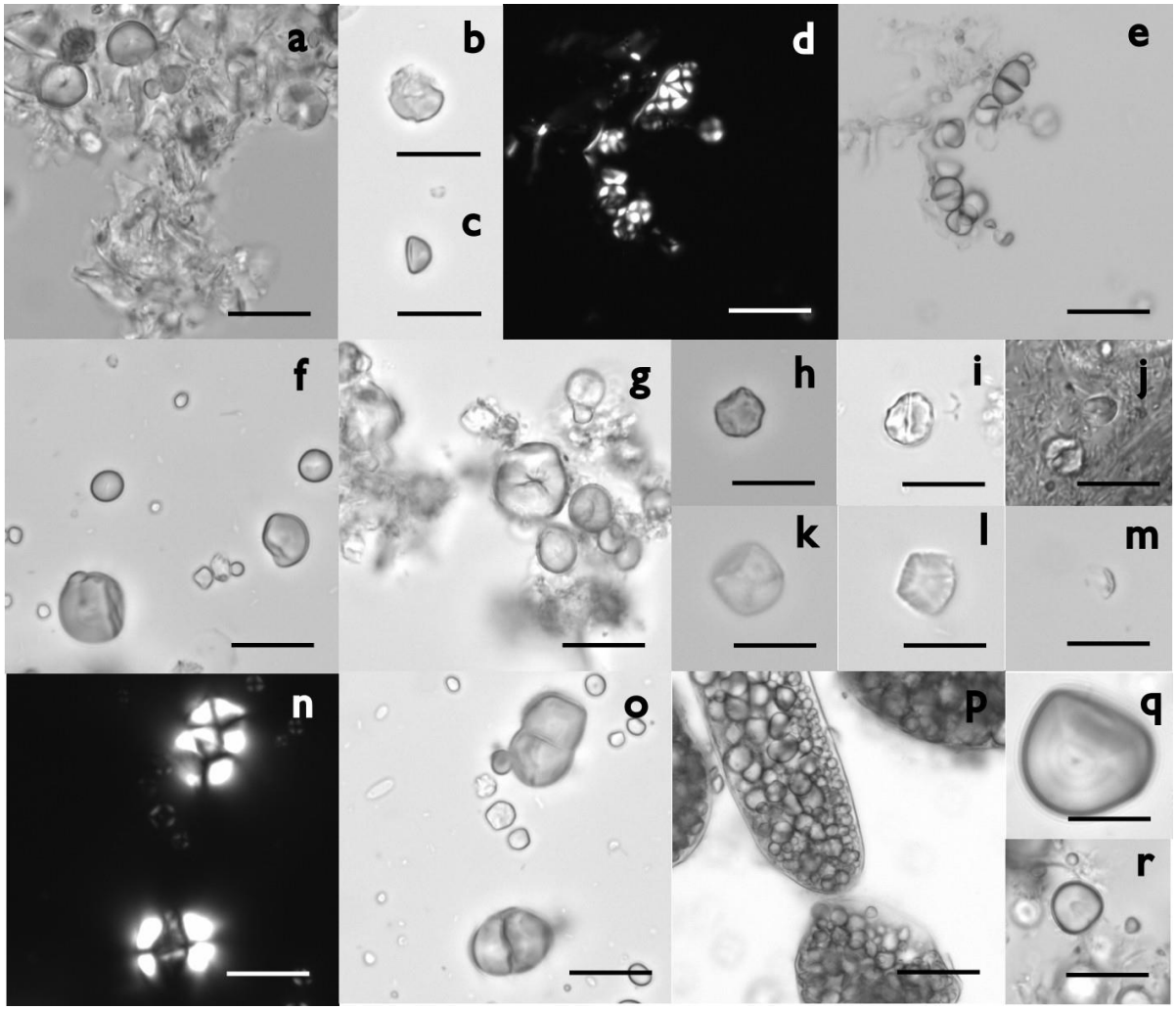


Figure 59 Starches Runners 'Inside'. Anthriscus: *a) a mesh of damaged starches entangled in vegetal material. They are dented, fractured and cracked, with some pronounced hila; b) dented and fractured starch with diagnostic features like the hilum and the shape; c) Convex concave* Anthriscus *starch 'hat' type, native; d-e) a cluster of starches, primarily compound starches; f-g) typical* Anthriscus *starches, specifically f), dented, fractured and with a slightly enlarged fissure in g);* D. carota*: h-j) characteristic starches with many indentations and j) fractured;* P. australis*: k-m) affected by digestive processes and some cracking. k) and l) bear a distinct morphology of* P. australis*;* T. latifolia*: n-r, diverse set of starches, some only slightly dented. n-o) compound starches under cross polarised and brightfield transmitted light. q) an exemplary* T. latifolia *starch with clear hilum, lamellae, slightly ovoid/kidney shape and relatively large. The elongated fissure can be seen in r). Scalebar equals 10 µm (Images by D.A. Derzhavets).*

Runners Outside

Table 16 Starch Count Runners Outside. Tool starch count and damage profile for runners. (Table by D.A. Derzhavets).

Tool ID	Plant	Total starch sample	Native starches	Damaged starches	Total dam-age %	Material condition
GS-09-O	*Anthriscus*	34848	0	34848	100	Fresh
GS-11-O	*Anthriscus*	31944	0	31944	100	Dry
GS-05-O	*Daucus*	9680	0	9680	100	Fresh
GS-08-O	*Daucus*	26136	0	26136	100	Dry
GS-14-O	*Phragmites*	0	0	0	0	Fresh
GS-16-O	*Phragmites*	0	0	0	0	Dry
GS-02-O	*Typha*	3194,4	0	3194,4	100	Fresh
GS-04-O	*Typha*	16214	6485,6	9728,4	60	Dry

The runners that were placed outside did not come in contact with the soil in the first half of the designated environmental exposure time, see chapter 3.3. This means that the grinding surfaces got to experience the weather conditions and potential small animal consumption first after which they were flipped and came in contact with the soil. There is no survival of starches for *P. australis* though *Anthriscus* once again shows that a consistent dominance on count (Table 16 and Fig. 59). The starches found in *Anthriscus* samples were compound and clusters, and *T. latifolia* starches also were tangled in vegetal material and phytoliths (Fig. 61). *D. carota* exhibited some compound starches, but some of them were difficult to differentiate due to the fusion of the starches and poor visibility due to debris. There

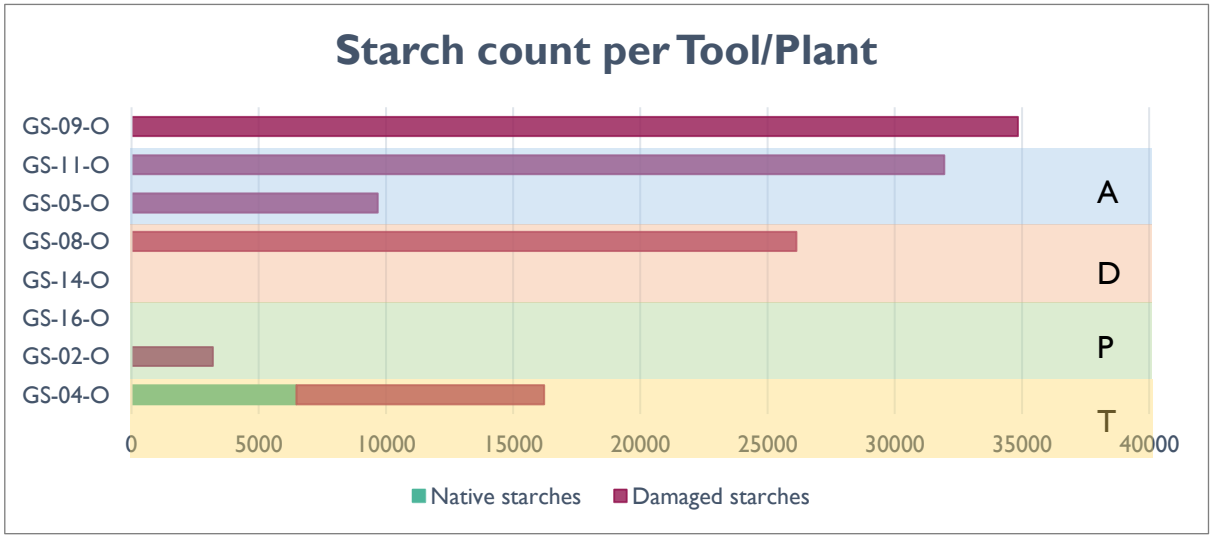


Figure 60 Starch Count per Plant Type. The amount of starches accumulated on 'Outside' runners when processing the different plant material. (Graph by D.A. Derzhavets).

is a slightly different plant pattern in this batch which is shown very clearly in figure 60, where dry and fresh material is compared. Next to all plants having preference for dry processing in terms of the signal that they leave, the patterns has shifted to *T. latifolia* being at the bottom, *D. carota* moving in second and *Anthriscus* still dominating the starch count. However, native starch count is something observed only in *T. latifolia*.

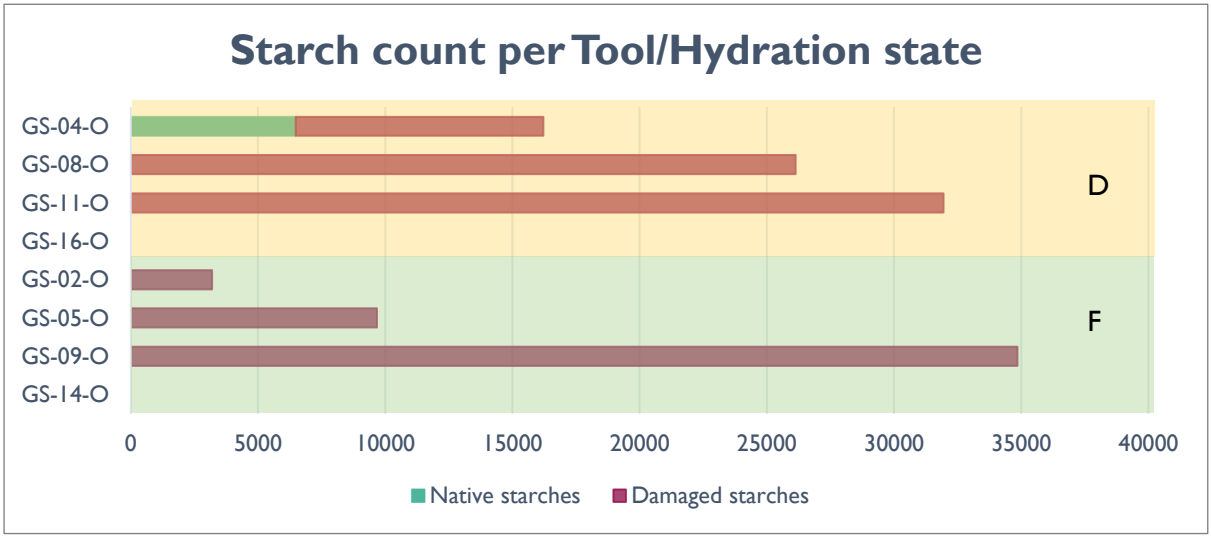


Figure 61 Starch Count Hydration State. The amount of starches accumulated in 'Outside' runners when processing either Dry or Fresh material. (Graph by D.A. Derzhavets).

The damages consist mainly of denting but cracking, fracturing and pitting are also present (Table 17). The mechanical damage is clear in this batch but the amount of other material made it extra challenging to identify proper damage types or starches. *T. latifolia* left several diagnostic starches that can be seen in figure 61. *Anthriscus* was also immediately identified though I had trouble distinguishing *D. carota*. *Anthriscus* also exhibits starches being stuck to vegetal material, more often than them being completely free. Except for a few starches in *T. latifolia*, all of the other plants showed a decrease in size that was visible and recognisable. This size is approximately between 3 and 5 μm.

Table 17 Damage per plant and hydration state Runners 'Outside': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage in colour. (Table by D.A. Derzhavets).

	Plants				Hydration state	
	n=2	n=2	n=2	n=2	n=4	n=4
Plant	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Dry	Fresh
Burst	0	0	0	0	0	0
Corroded	0	0	0	0	0	0
Crack	2	1	0	2	3	2
Dented	1	2	0	2	3	2
Disjoining	0	0	0	0	0	0
Exudate	1	0	0	0	1	0
Fractured	1	1	0	0	1	1
Fragmented	0	0	0	0	0	0
Hilum Projections	0	0	0	0	0	0
Pitting	1	1	0	0	0	2
Truncated	0	0	0	0	0	0

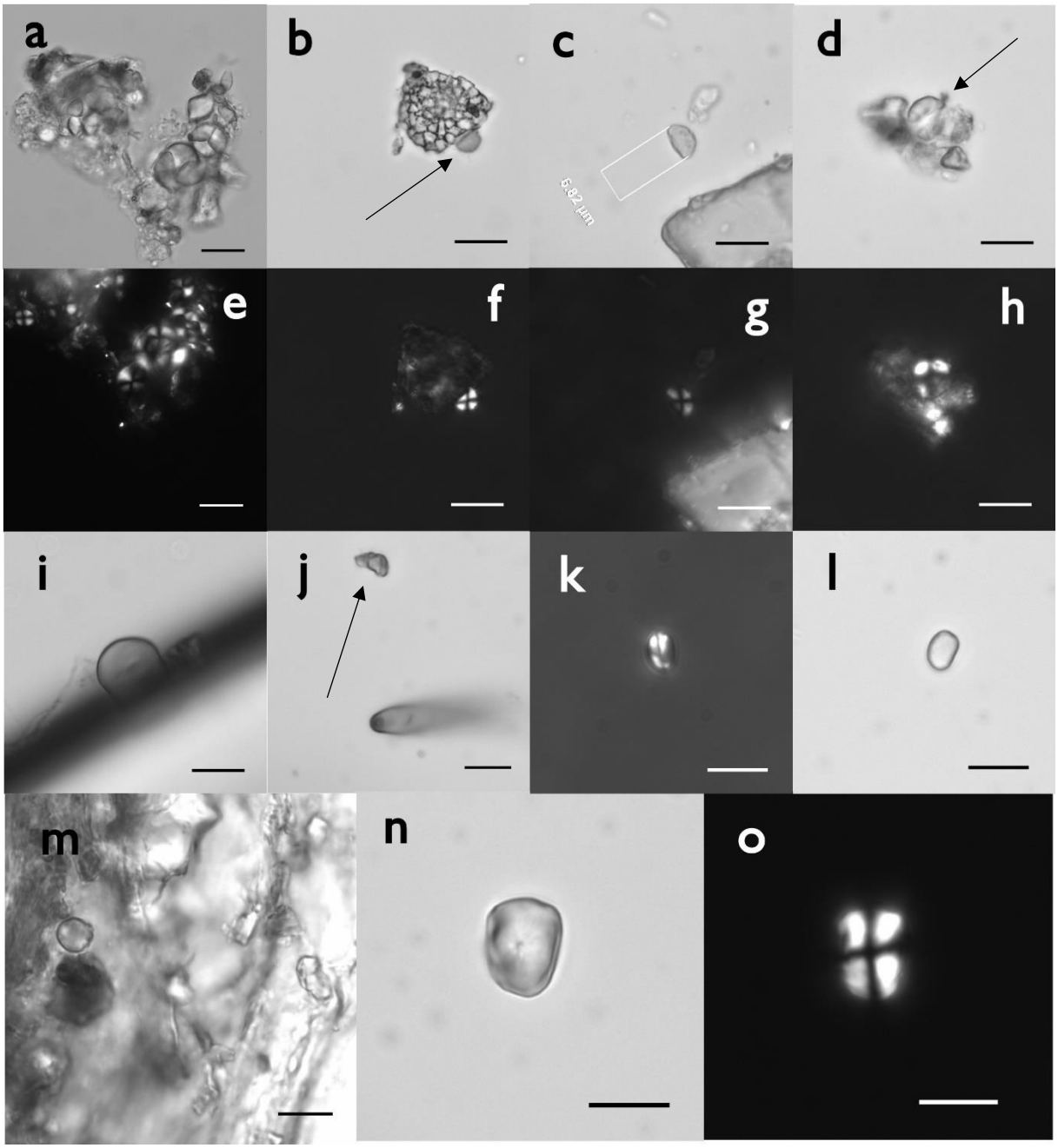


Figure 62 Starch Runners 'Outside'. Anthriscus *a-h: a) a cluster of* Anthriscus *starches having the distinct hemispherical to elliptical shape. They are also compound starches of 3 if not more. b) starch stuck on some kind of a vegetal material; c)hemispherical slightly flat, corroded and cracked. Fractured starch stuck in a mesh of material.* D. carota *i-j: i) a starch that is potentially compound but difficult to see, otherwise it looks unharmed. j) top a small but unrecognisable starch.* T. latifolia *k-o: k-l elongated, potential* T. latifolia *starch; m) starches stuck in a mesh of spirals and vegetal material; n) morphologically distinct starch for* T. latifolia*. e-h, k, o, were taken under cross polarised light. Scalebar equals 10 µ m (Images by D.A. Derzhavets)*

Slabs Before

Table 18 Starch Count Slabs Before. Starch count and damage for slabs.(Table by D.A. Derzhavets).

Tool ID	Plant	Total starch sample	Native Starches	Damaged Starches	Total damage %	Hydration state
GS2-ADB	*Anthriscus*	48393030	8693027	39700003	82	Dry
GS2-AFB	*Anthriscus*	3333792	394944	2938848	88	Fresh
GS1-DDB	*Daucus*	1910203	132858	1777345	93	Dry
GS1-DFB	*Daucus*	1184832	575137	609695	51	Fresh
GS2-PDB	*Phragmites*	218961	20134	198827	90	Dry
GS2-PFB	*Phragmites*	233675	78989	154686	66	Fresh
GS1-TDB	*Typha*	12051600	1083192	10968408	91	Dry
GS1-TFB	*Typha*	9987243	2936525	7050718	70	Fresh

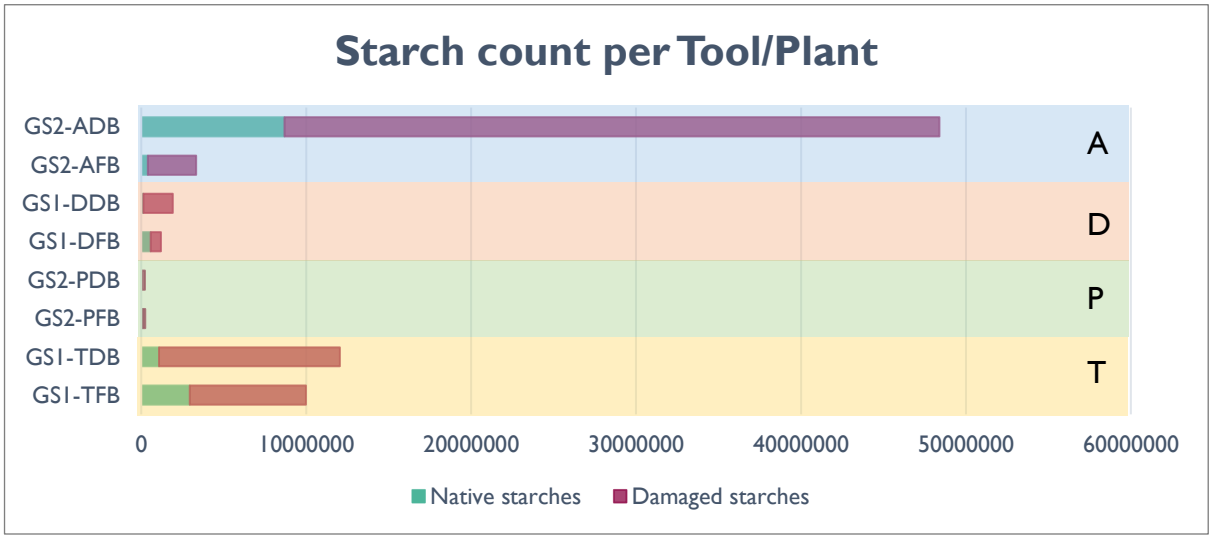


Figure 63 Starch Count per Plant Type. The amount of starches accumulated on 'Before' grinding slabs when processing the different plant material. (Graph by D.A. Derzhavets).

The starches from the slabs in the 'Before' batch resembled some of the already seen patterns. The plant pattern continues with *Anthriscus* and *T. latifolia* leaving the most on the tools, followed by *D. carota* (Table 18 and Fig. 62). In all the samples except a few *P. australis* samples, the starches were easily recognised by their morphological features and starch specific features that were observed earlier when examining the raw material. The starches varied strongly in size but the most damage was dealt to starches between 6-10 μm. The hydration state is specifically interesting to *Anthriscus* because of the huge difference in the

amount of starches (Fig. 63). The other plants also tend to be more visible when processed dry but the differences are minimal.

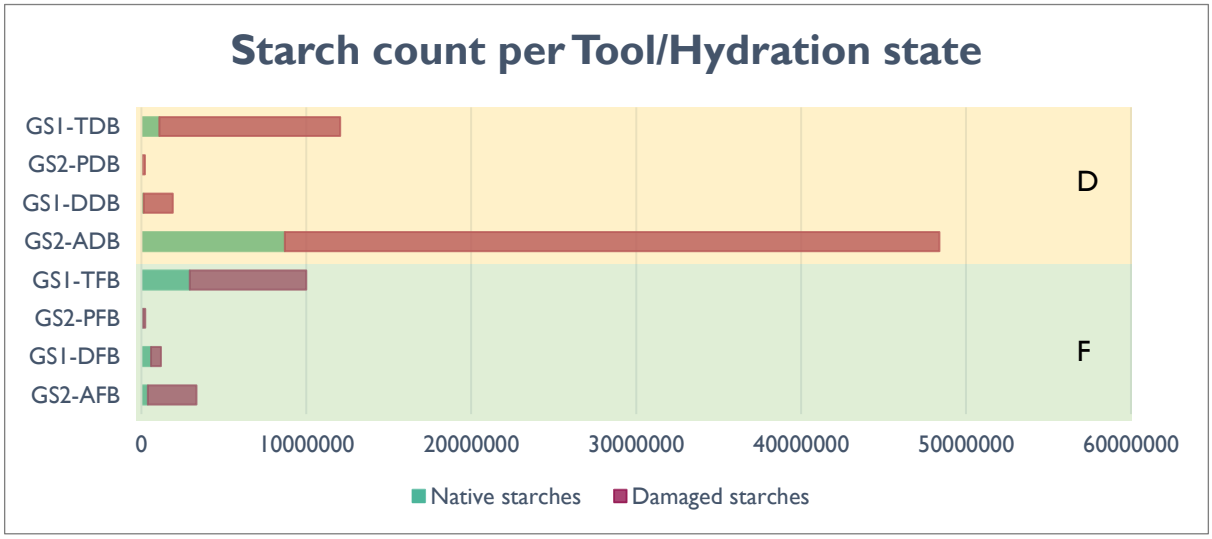


Figure 64 Starch Count per Hydration State. The amount of starches accumulated on 'Before' grinding slabs when processing the plant material dry or fresh. (Graph by D.A. Derzhavets).

The damages are mainly denting and cracking with some fragmenting, which is not surprising for a grinding stone process. The dry material is receiving more damage, also from bursting, but P. australis seems to endure the least amount of damage. The damage profile seems to follow a plant specific pattern where the damage is primarily mechanically related, seen through cracking, denting, fragmenting and fracturing. Though there is not much difference between Dry and Fresh processing damage (Table 19).

Table 19 Damage per plant and hydration state Slabs 'Before': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage in colour. (Table by D.A. Derzhavets).

	Plants				Hydration state	
	n=2	n=2	n=2	n=2	n=4	n=4
Plant	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Dry	Fresh
Burst	2	1	0	2	3	2
Corroded	0	0	0	0	0	0
Crack	2	2	2	2	4	4
Dented	2	2	2	2	4	4
Disjoining	0	0	0	0	0	0
Exudate	0	1	0	0	0	1
Fractured	2	2	1	2	4	3
Fragmented	1	1	1	2	2	3
Hilum openings	2	1	1	1	3	2
Pitting	1	0	1	1	1	2
Truncated	0	0	0	0	0	0

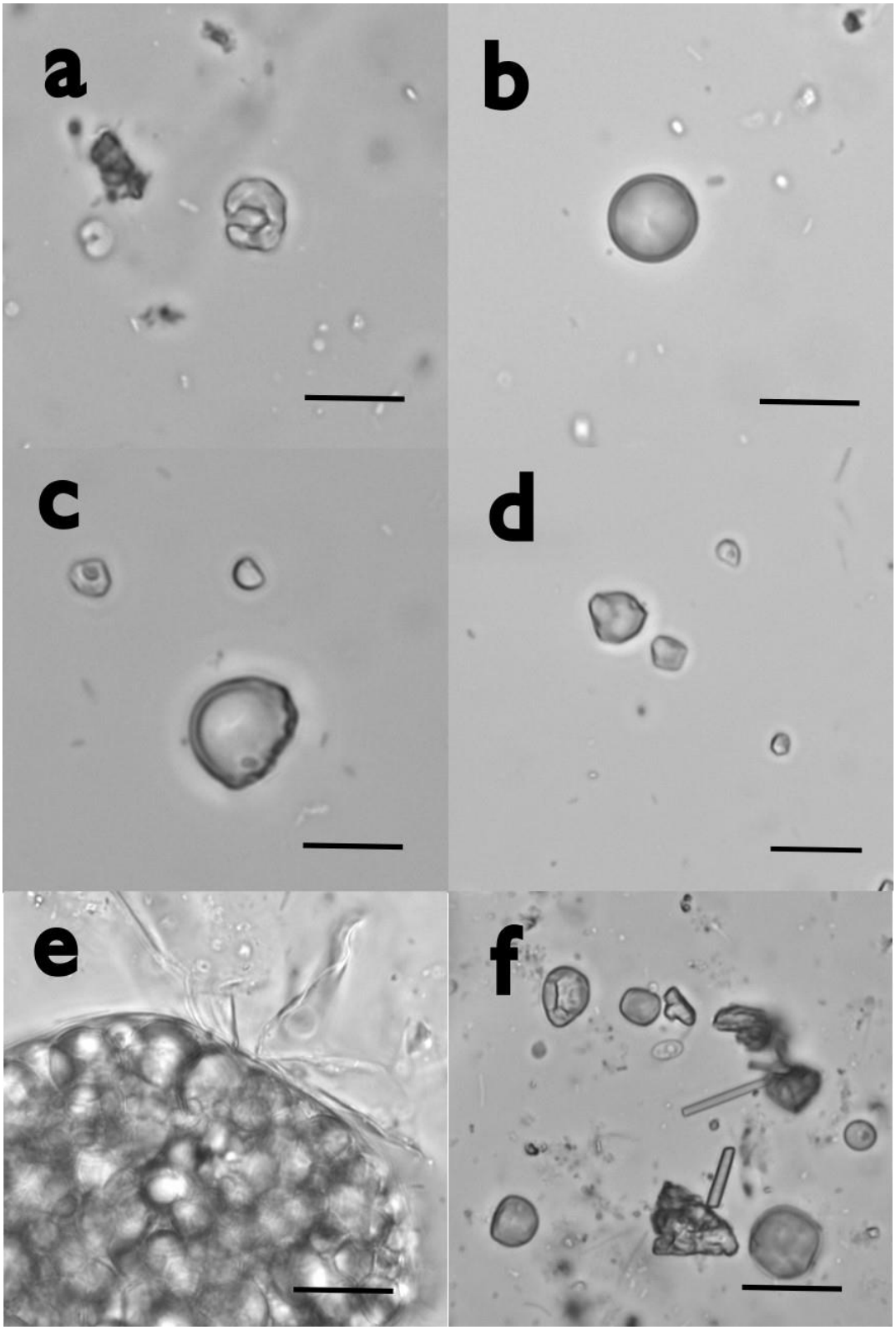


Figure 65 Starches Slabs 'Before'. Anthriscus *a-b: fractured and potentially eaten starch on the left and an intact starch on the right;* D. carota *c-d: pitted and dented starches on the left, dented small starches on the right;* T. latifolia *e-f: Starches varying in size in one starch cell on the left, on the right, a collection of starches with damages from fracturing and cracking but also potential digestive damage. Elongated shafts could be sponge spicules. Scalebar equals 10 μ m. (Images by D. A. Derzhavets).*

Slabs Outside

Table 20 Starch Count Slabs Outside. Tool starch count and damage profile for grinding slabs. (Table by D.A. Derzhavets).

Tool ID	Plant	Total starch sample	Native starches	Damaged starches	Total damage %	Hydration state
GS2-ADO	*Anthriscus*	104544	3872	100672	96,3	Dry
GS2-AFO	*Anthriscus*	24442	0	24442	100	Fresh
GS1-DDO	*Daucus*	31363,2	0	31363,2	100	Dry
GS1-DFO	*Daucus*	4017,2	0	0	0	Fresh
GS2-PDO	*Phragmites*	0	0	0	0	Dry
GS2-PFO	*Phragmites*	0	0	0	0	Fresh
GS1-TDO	*Typha*	10164	0	10164	100	Dry
GS1-TFO	*Typha*	75020	2420	72600	96,8	Fresh

Slabs were places face down with two surface areas that processes *D. carota* and *P. australis*. The *T. latifolia* and *Anthriscus* were face up. The plants that accumulated most starches are listed in Table 20 and showing figure 65. Both Anthriscus and *T. latifolia* exhibit native starches. The plants still keep the same formation in terms of accumulation of starches,

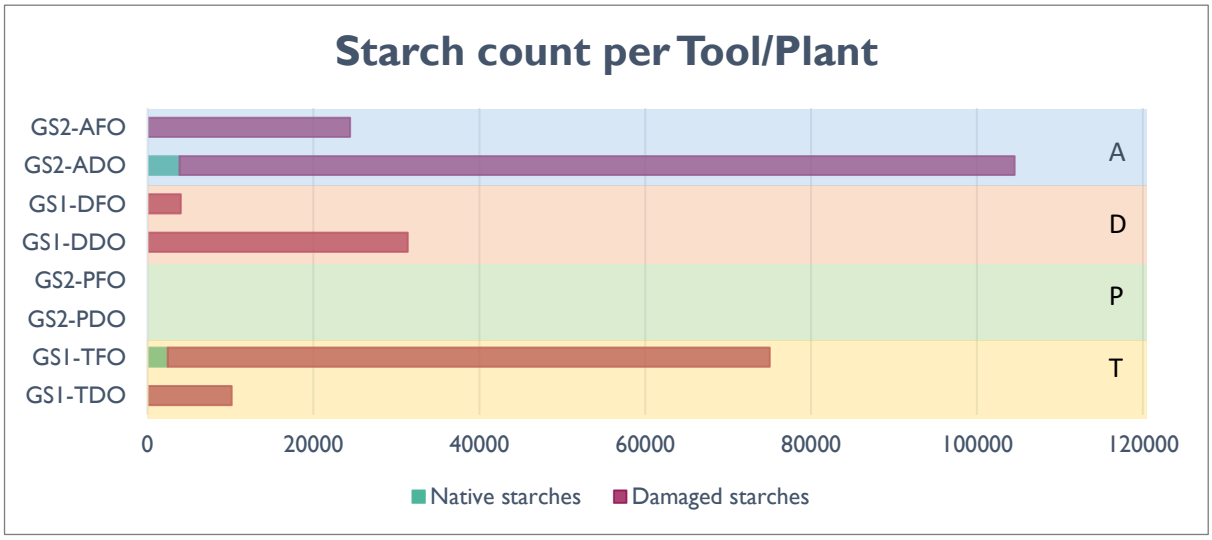


Figure 66 Starch Count per Plant Type. The amount of starches accumulated on 'Outside' grinding slabs when processing the different plant material. (Graph by D.A. Derzhavets).

with *Anthriscus* and *T. latifolia* scoring the highest. No starches were identified in *P. australis* samples . The sample contained a lot of other micro remains and no distinct starches or starch parts were observed. *D. carota* is also low in well preserved material, often not retaining its features. The sizes of all starches decreased in comparison to the reference

material. In figure 65 the plants can be also compared according to their hydration state, indicated with an F (fresh) or D (dry) in the tool ID. Both Apiaceae plants preserved better when being processed dry, there is a rapid decline in their freshly processed counterparts. Only *T. latifolia* seemed to signal better when processed fresh.

The most visible damage is cracking and denting, both *T. latifolia* and *Anthriscus* have a similar damage profile. Examples and elaboration of the damages are shown in figure 67.

Table 21 Damage per plant and hydration state Slabs 'Before': Damage is indicated as present (1) or not present (0) per analysed tool with an indication of concentration of damage in colour. (Table by D.A. Derzhavets).

	Plants				Hydration state	
	n=2	n=2	n=2	n=2	n=4	n=4
Damage type	*Anthriscus*	*Daucus*	*Phragmites*	*Typha*	Dry	Fresh
Burst	1	0	0	2	2	1
Corroded	0	0	0	0	0	0
Crack	2	2	0	1	2	3
Dented	2	2	0	2	3	3
Disjoining	0	0	0	0	0	0
Exudate	0	0	0	0	0	0
Fractured	2	1	0	1	1	3
Fragmented	0	1	0	0	1	0
Hilum openings	1	0	0	0	0	1
Pitting	1	0	0	2	2	1
Truncated	0	0	0	0	0	0

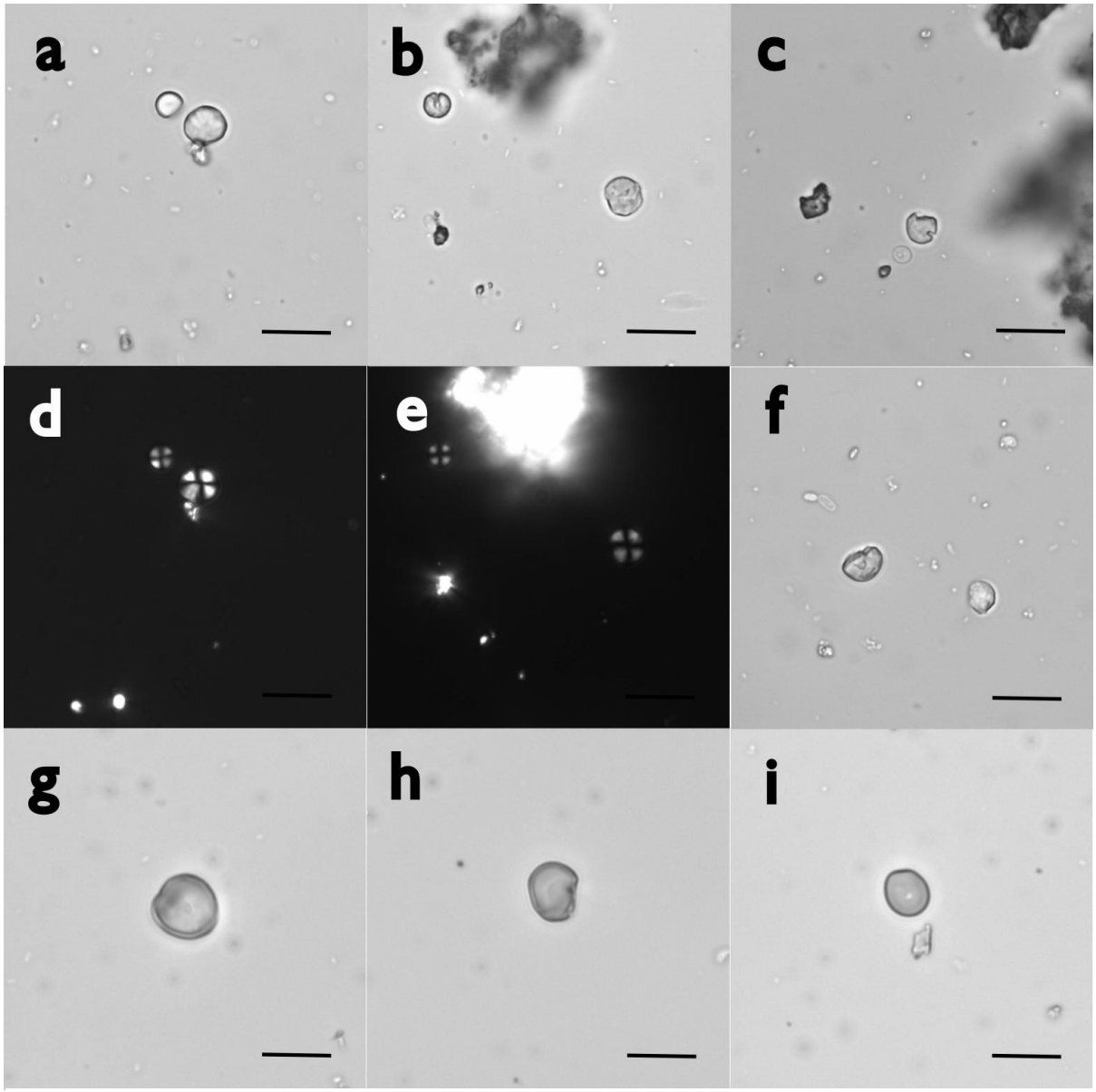
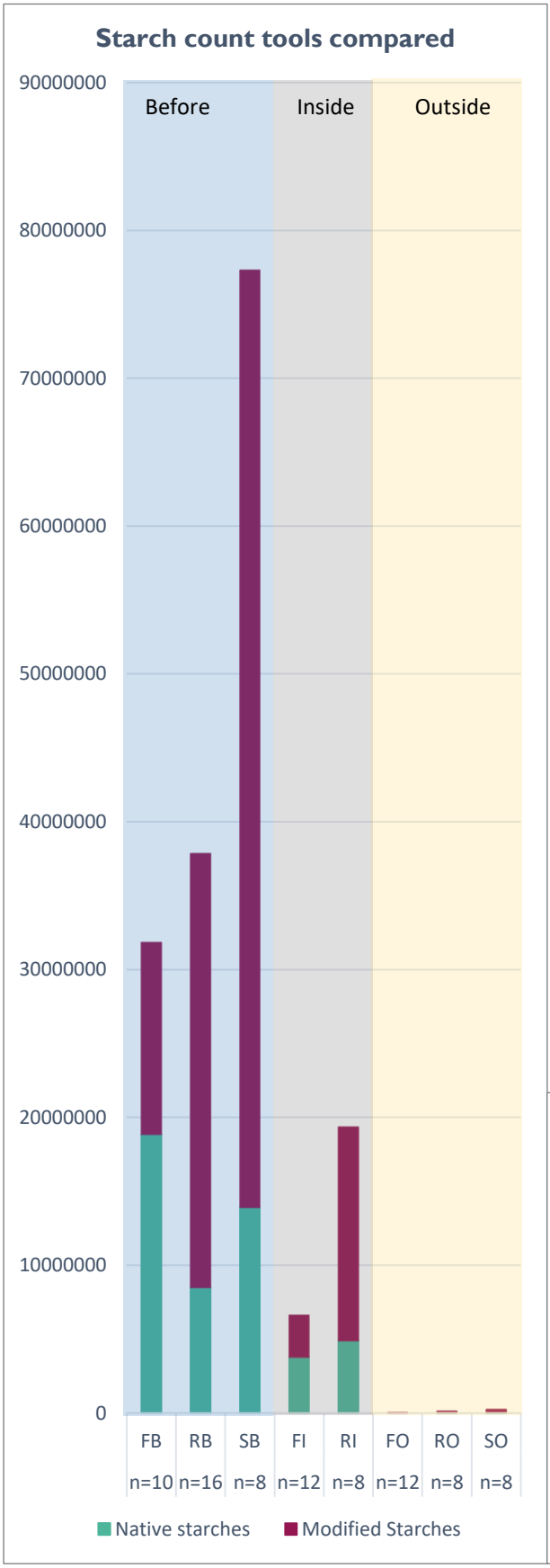


Figure 67 Starches Slabs 'Outside'. Anthriscus *a-f: small starches with denting and fracturing, some pitting like can be seen in c). d-e are viewed in cross polarised light and correspond to a-b.* T. latifolia *g-i: typical starches for this plant with a clear hilum in i) and all three showing lamellae, some denting in h). Scalebar equals 10 μ m. (Images by D.A. Derzhavets).*



4.2 STARCH COUNT COMPARED

In the stone tool there is a visible trend of flint collecting the least and grinding slabs the most (Fig. 68). The runners also score almost exactly half of what the slabs indicate. Flint has a much steeper decrease from 'Before' to 'Inside' sampling, whilst the runners lose half of the starches. There are native starches that were observed in the 'Outside' batches for runners and slabs

The plant pattern has been described in the individual cases. *Anthriscus* and *T. latifolia* leaving most starches, whilst *P. australis* left the least. *D. carota* had significantly less than the highest signalling plants but still produced enough to be retrieved from all conditions.

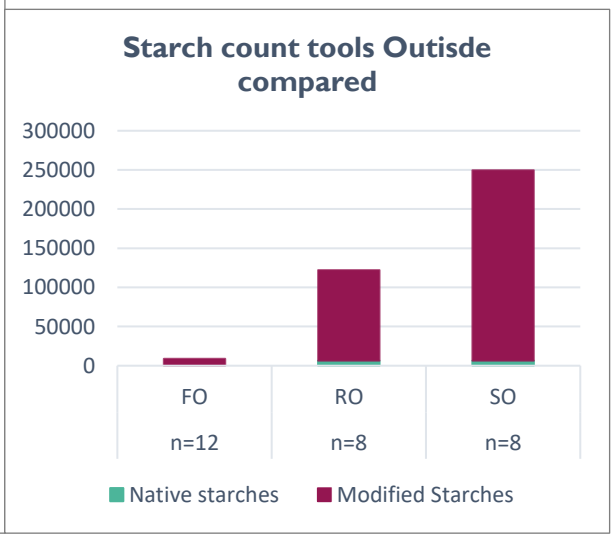


Figure 68 Stone Tools Compared. Comparison graph between total starch accumulation of stone tools. (Graph by D.A. Derzhavets)

Comparison of tools and plants

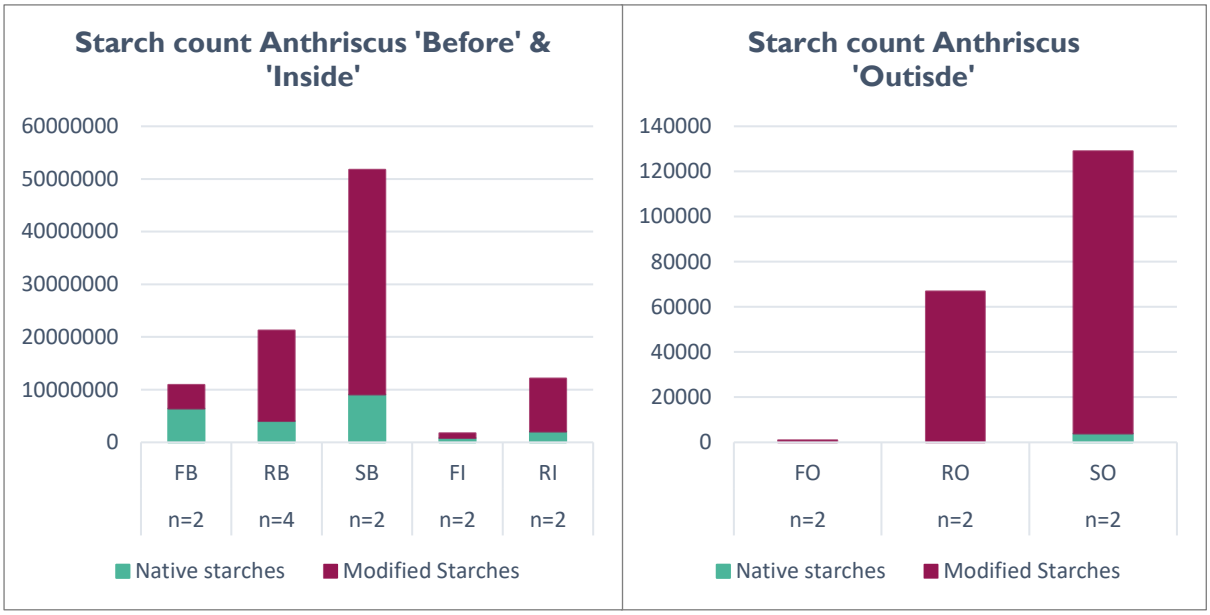


Figure 69 Anthriscus Compared. Comparison of Anthriscus starches per tool type and sampling condition. (Graph by D. A. Derzhavets)

As can be seen in Fig 70, *Anthriscus* exhibits the same pattern as the general tool comparison pattern, starch count going up significantly with the grinding stones. *D. carota* does not share this pattern and runners and slabs are almost equal in count for the 'Outside' batch (Fig. 71). Also the runners suffer a great loss after staying inside, something that cannot be said in that amplitude for *Anthriscus*.

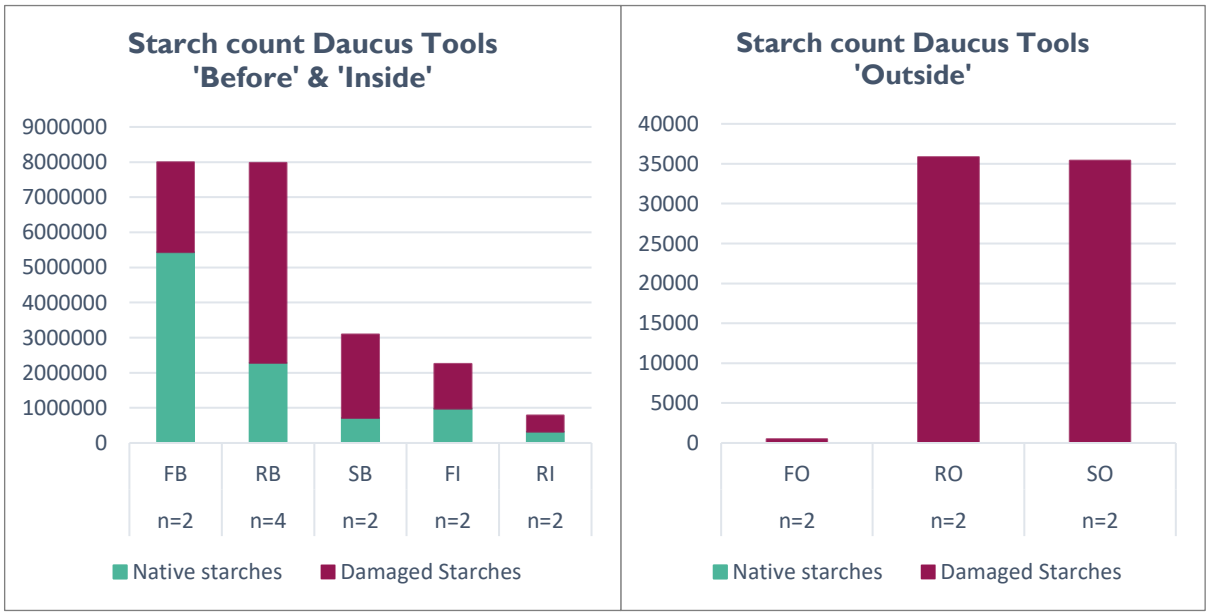


Figure 70 D. carota Compared. Comparison of D. carota starches per tool type and sampling condition. (Graph by D.A. Derzhavets)

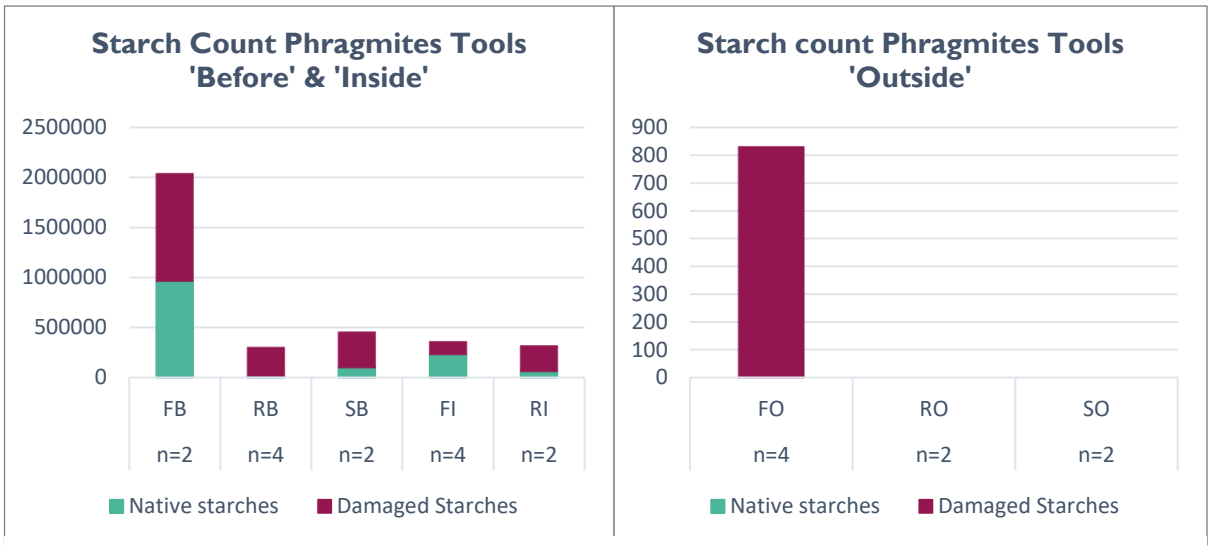


Figure 71 P. australis Compared. Comparison of P. australis starches per tool type and sampling condition. (Graph by D.A. Derzhavets)

P. australis stands out because of the flint starch accumulation on the outside tools. There is also not really a tool/starch collection pattern that can be seen through the data for this plant, it is stable on its own but does not follow the same trends as the other plants do. *T. latifolia* shows a consistency with the general tool pattern, except the 'Before' flint accumulation. *T. latifolia* has by far the most native starches in the 'Outside' batch.

4.3 PHYTOLITHS AND OTHER MICRO REMAINS

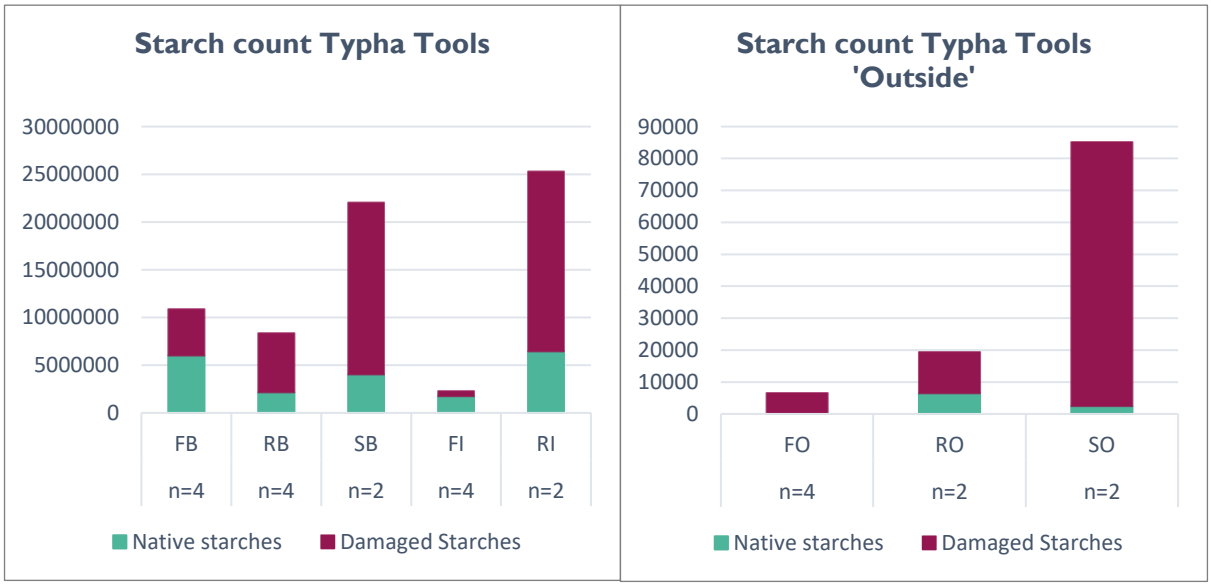


Figure 72 T. latifolia Compared. Comparison of T. latifolia starches per tool type and sampling condition. (Graph by D.A. Derzhavets)

Looking into the phytoliths was a secondary objective aimed at analysing the potential differences within the plant residues. The phytoliths presented themselves primarily in *P. australis* samples, though they were found through all plants. There is a spike of phytoliths in *Anthriscus* samples, where the root was primarily processed, but several flint tools were used to slice off the tops and peel the outer layers of the root. *T. latifolia* also showed two types of phytoliths although more could be present (Fig. 73 and Appendix C). There is an increased presence of phytoliths on the 'Outside' samples which is not uncommon and can be seen as a contamination. Smooth edged elongated phytoliths are the most common amongst all plants, but denticulate and lobate phytoliths are primarily seen in *P. australis* tools.

The following types of phytoliths were observed in the samples:

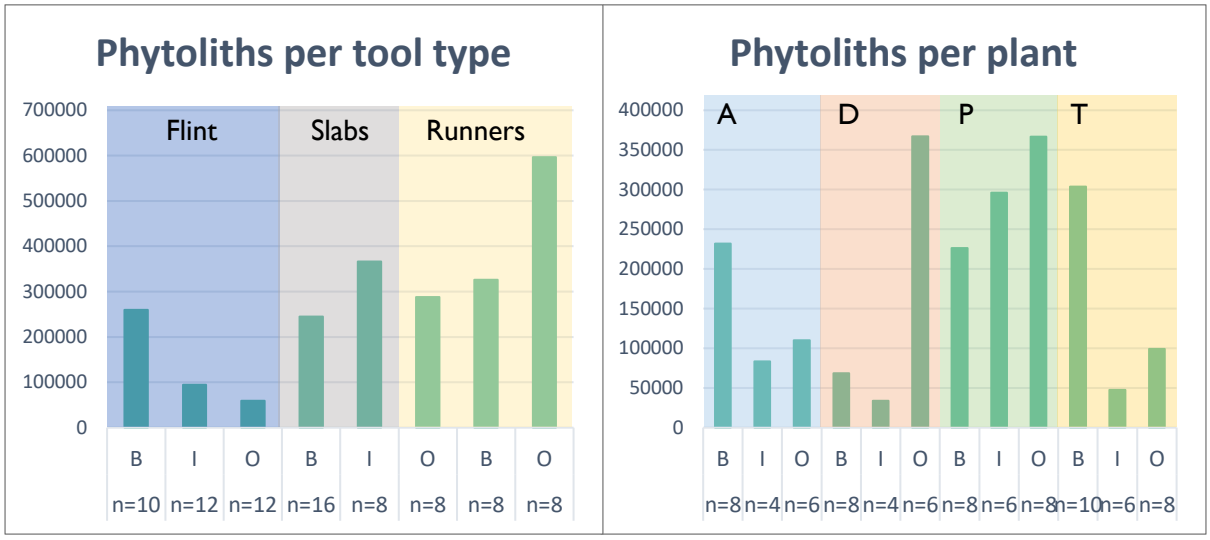


Figure 73 Phytoliths Compared. A comparison of phytolith counts between tools and across plants. (Graphs by D. A. Derzhavets).

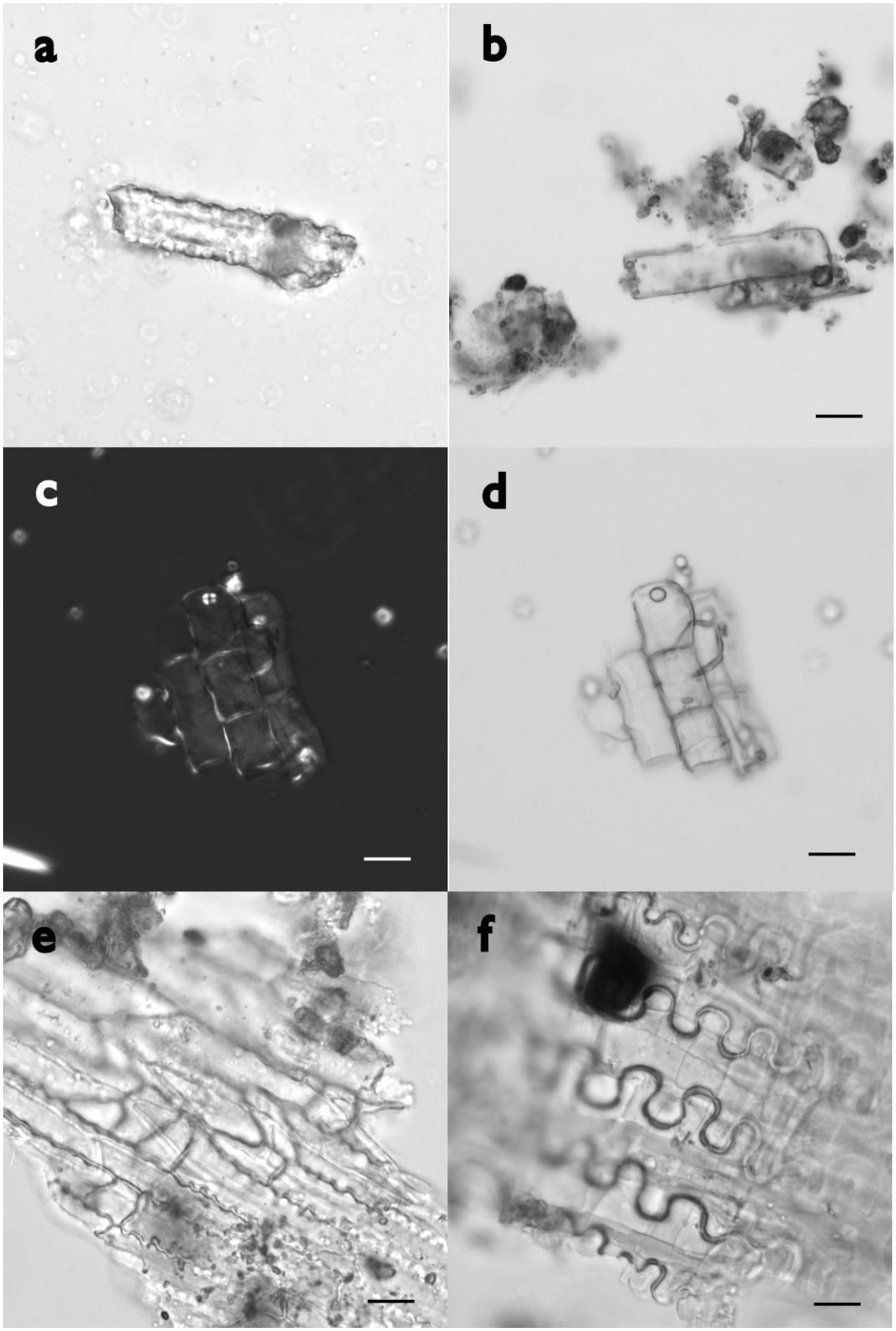


Figure 74 *Phytoliths From Samples. a: P. australis Before. b: T. latifolia Before. c-d: T. latifolia Inside, c under cross polarised light. e-f: Anthriscus Outside. Scalebar equals 10 μm. (Images by D.A. Derzhavets).*

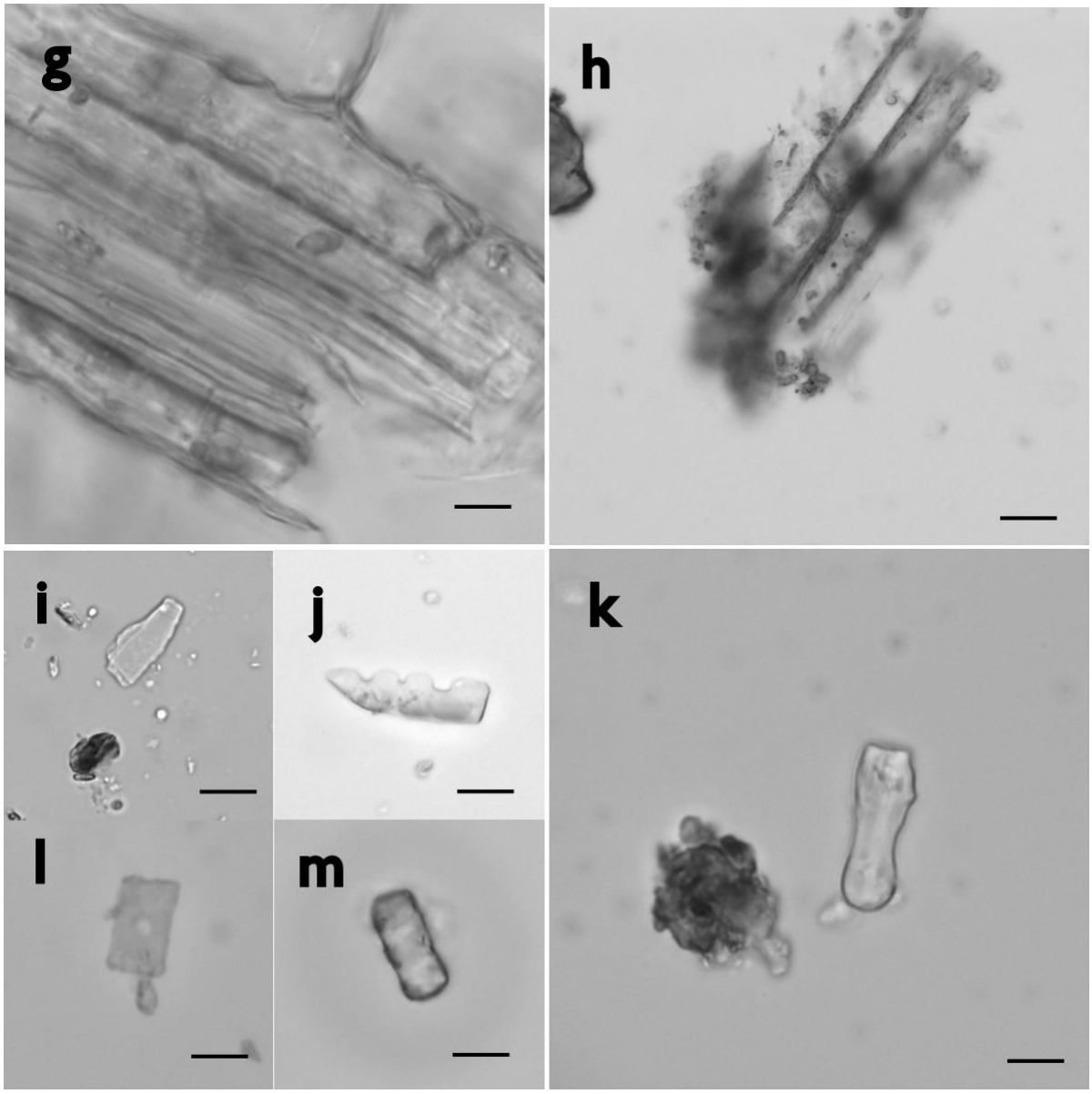


Figure 75 Phytoliths of P. australis Outside. A variety of phytoliths that were retrieved from the P. australis outside samples across all tools. Scalebar equals 10 μ m. (Images by D.A. Derzhavets).

Other microorganisms were primarily found in the 'Outside' batch and can be a useful tool for the reconstruction of the environment in which the tools were exposed to the elements and various living organisms. Though, some fungus, algae, bacteria and yeasts have made their way into the 'Before' and 'Inside' batches too. The 'Before' grinding stones show a high number of yeasts and tiny microorganisms, which is not present in the flint tool samples at all or very minimally. Next to the minerals from the grinding stones and soil outside, the most notable is the fungal and algal presence throughout the samples. Specifically fungal hyphae and spores

are clearly visible in the sample and also very saturated and abundant. Most of the algae that was observed was grouped together with other debris from plant material and microorganisms.

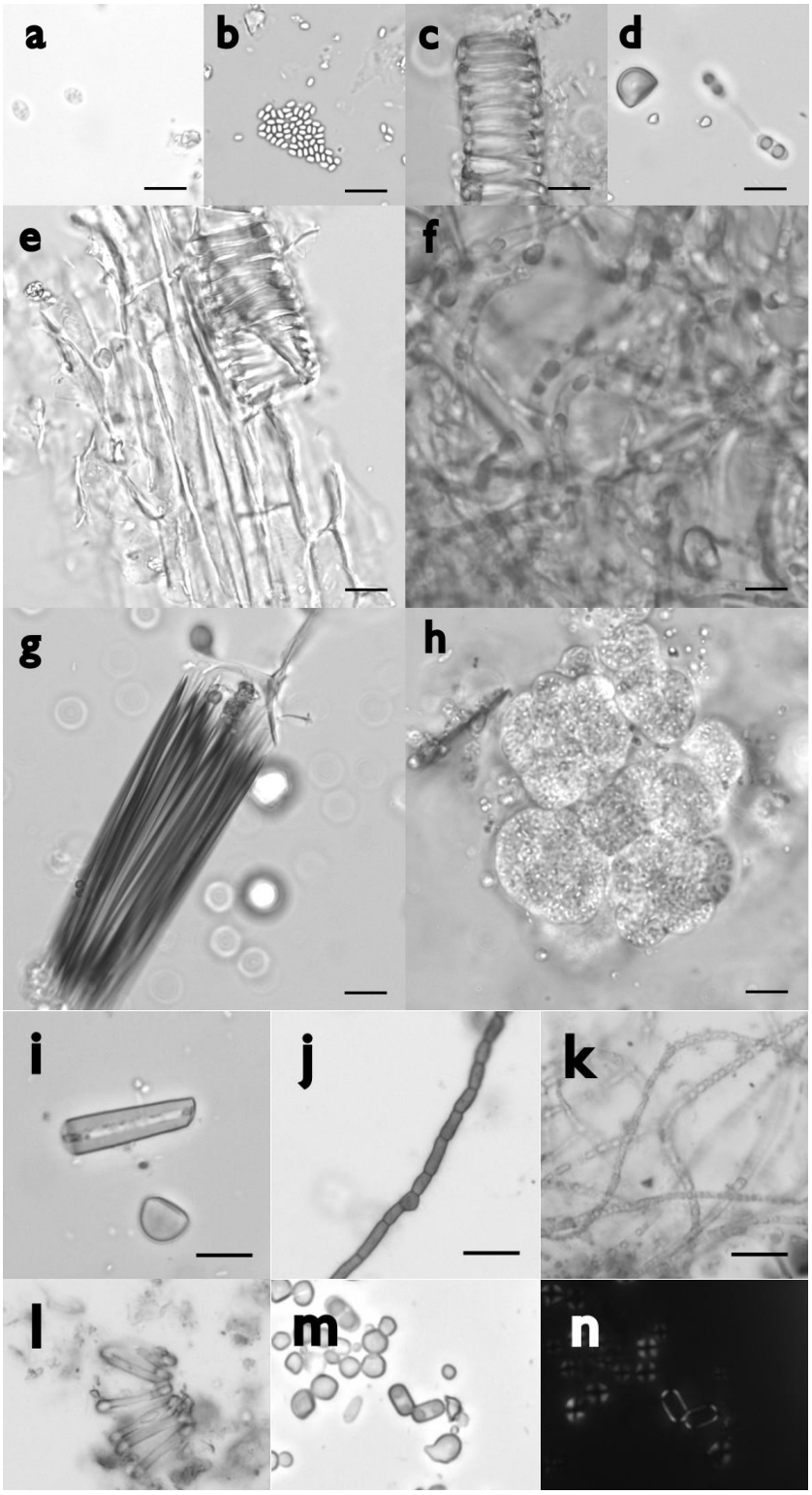


Figure 76 Micro Remains 'Before' and 'Inside': a: yeast; b: yeast; c: plant spiral; d:bacteria and Anthriscus starch; e: spiral and vegetal material; f: fungal hyphae; g: cluster of raphides; h: algal bloom; i: central part of a diatom; j: fungal hyphae; k: fungal hyphae; l: broken spiral; m-n: yeast, n is cross polarised. Scalebar equals 10 μ m. (Images by D.A. Derzhavets).

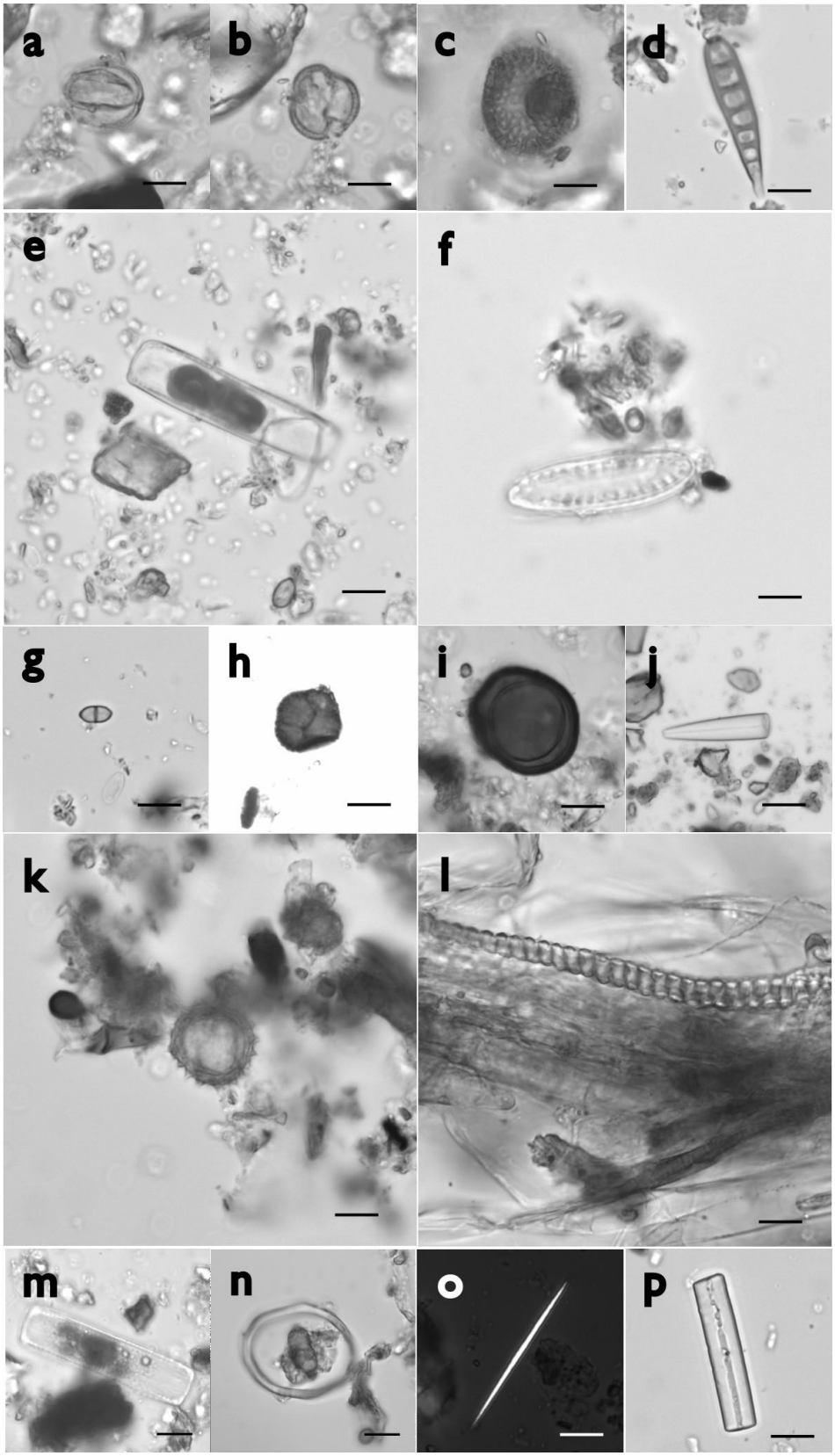


Figure 77 Micro Remains 'Outside'. a-c,k: pollen. d: fungal body; e,m: phytoplankton; f: diatom; g-i: fungal spores; j,p: part of diatom; i: spiral and vegetal material; n: unidentified recurring remain; o: raphides under cross polarised light. Scalebar equals 10 µ m. (Images by D.A. Derzhavets).

5 DISCUSSION

How and which plants were used by people during the Late Pleniglacial on the Crimean Peninsula is a research topic that is still in its infancy. Environmental reconstruction for all Crimean Palaeolithic sites has been done almost exclusively through palynology (Gerasimenko, 2011) and to this date the only known archaeological evidence of Palaeolithic plant use on the Crimean Peninsula is the Aurignacian grinding stone found at Siuren I (Revedin et al., 2010; Stepanova, 2020). Palaeoclimatically and ecologically speaking, there is enough evidence of plant availability around the Black Sea to model vegetation habitat suitability post LGM, like in the study done by Divíšek et al. (2022), or the environmental reconstruction of vegetational and climate changes on Crimea during the Late Glacial (Gerasimenko et al., 2022). The problem, however, lies in the identification of the actual residues on tools and the optimisation of their extraction and analysis, in order to be able to interpret the potential exploitation of the available plants. Below I discuss the amount and the quality of the starches from the experimentation, compared between plants and stone tools with a brief mention of phytolith presence and significance. The residue data is then used to review archaeological relevance of experimental research and residues analysis as well as look at the limitations of the project and future prospects.

5.1 MICRO REMAINS FROM EXPERIMENTATION

5.1.1 Micro remains across plants: Quantity, Quality and Distribution of starches

When choosing to work with USOs that were collected during a cold period, I expected to see high levels of starches across all plants except for *P. australis*. Across all 'Before' and 'Inside' tools there was a distinct and relatively consistent pattern of starch count. The highest numbers were in *Anthriscus* and *T. latifolia*, followed by *D. carota* and *P. australis*. The decline of starches compared between 'Before' and 'Inside' was also consistent across plants, account for a loss between 65 and 90 % and a spike in enzymatic action. Fungal hyphae, yeast and algae

were present in all samples, increasing in numbers after processing with most in the 'Outside' batch. These observations, specifically targeting USOs, are consistent with the accumulation of starches observed in the reference material and across biological studies (Brecht, 2002; Flores & Flores, 1997), as well as some studies focusing on potential *T. latifolia* exploitation (Liptay, 1988; Revedin et al., 2010). The difference between dry and fresh processing is clearly visible and has most likely to do with dispersal potential and better preservation from microorganism consumption. All USO plants have starch cells with varying content present in 'Before' and 'Inside', though *T. latifolia* has the most. The 'Outside' batch continues showing the pattern described before, which clearly indicated a specific set of plant properties. Below an in-depth elaboration is given per plant and aimed comparison.

The fact that *Anthriscus* dominates the count on every tool type or equals *T. latifolia* starch count in a consistent manner calls for further research because frequent processing or a high starch signal of *Anthriscus* has not previously been described in literature (Bello-Alonso et al., 2019; Ullah et al., 2018). In fact, only one study has included *Anthriscus* root with a clear reference and focus on phytoliths, not starches (Risberg et al., 2002). *Anthriscus* shows higher numbers of phytoliths than the other USOs making the mentioned study's angle an interesting consideration. There seems to be a, somewhat understandable, bias towards the domesticated Apiaceae plants, like Dacus carota, because of the extensive nutritional research. But there is also a lack of research regarding the exploitation of other wild Apiaceae plants. In this experimentation *D. carota* showed a consistent but a much lower signal than *Anthriscus* in the 'Before' and 'Inside' batches. Cagnato et al. (2021) have processed Apiaceae species like parsnip and celery placing them under 'wild plants' though some of the material was store or market bought. Their research yielded varying results, *D. carota* leaving no visible signals and other Apiaceae only a faint one (Cagnato et al., 2021). This study and my project data emphasise the importance of a much broader experimental reference collection with a focus on wild vegetation that helps in unveiling the subtle differences between plants. Both *Anthriscus* and *D. carota* retained their morphological characteristics and their patterns across tools and

hydration states, also showing a similar damage profiles. Damage percentages overlap, with *D. carota* showing slightly less damage in the 'Before' and 'Inside' batches. Morphologically there are also similarities in starches between 4 and 8 μm where most of the damage can be seen in both plants across all tools. *D. carota* has a distinct morphology in about 30% of its largest starches, spherical starches with multiple facets. In the 'Outside' batch these similarities made it difficult to distinguish the plants from each other, partly due to the lack of the *D. carota* diagnostic starches.

Additionally, the enzymatic degradation and fracturing and fragmentation effectively removed some morphological features which only increased the difficulty of identification. Both plants show similar patterns except for the starch count. This is interesting because the both processed a similar amount of material and showed a similar count in the reference, and yet the patterns are the same across all tools. An explanation for this could be the composition of the material itself (Bos et al., 2002). Differences in growing, starch accumulation and maturity of the plant all play a role. *Anthriscus* was gathered from a natural reserve, whilst *D. carota* from a city soil, thought their maturity was similar. Modern species are not always representative of the palaeolithic record and wild species can be crosspollinated with domesticated varieties, which can cause problems both in experimental and archaeological analyses due to a lacking reference collection (Mercader et al., 2018). Identifying these differences and similarities in this project is therefore a valuable contribution to a reference collection focusing on Apiaceae species.

The *P. australis* tools did not have a significant amount of starches on them if any at all. This was already the case in the reference material where the most diagnostic shapes were seen in the largest starches in a relatively low starch count. The starches in the 'Before' and 'Inside' batches were rarely diagnostic and small (0,7-5 μm), compared to the other plants. The common distinctive denominator in *P. australis* were the diagnostic phytoliths that appeared consistently across all tools. Between 'Before' and 'Inside' batches there was a steep decline on the flint tools whilst other tools had a similar low count. Interestingly, the 'Outside' batch of

flint was the only one showing any starches, but I would not be confident in saying that these belong to *P. australis*.-When placing the material outside, the *P. australis* slab was placed processing surface down and the runners surface up. Flint tools contained residues on both sides and received simultaneously the combination of degradation processes as the grinding tools. Sampling location, weathering conditions and mineral adhesive properties could have influenced this outcome. Unlike other plants, *P. australis* does not have much starch or mucilaginous substance that can help with adhesion to the tool. What it does have is an abundance of phytoliths in and between the cells. The dissolve rate of biogenic silica, phytoliths, is increased with saline environments that want to bond with other silicious material, flint or soil silica (Loucaide at al., 2008) trapping starches in the process (Reitz et al., 2012). The adsorption properties of biogenic silica, or micro remains in general, to stone tools as a phenomenon in palaeolithic plant processing are not yet well understood and more research is required within this topic (Mercader et al., 2018).

T. latifolia has been processed in archaeological experimental context due to its importance and versatile use throughout history, being a hardy, starch rich, waterside plant that is readily available during winter months (Liptay, 1988; Longo, Altieri, et al., 2021; Madsen et al., 1997; Revedin et al., 2015). Based on these studies, the expectation was to see a high amount of starches on the tools, which was the case. Other than the amount, there are no distinct patterns for this plant in 'Before' and 'Inside' batches. Even though morphologically there are distinct features as shown in the results, *T. latifolia* can morph to a variety of shapes, partly due to processing and growth in the cell itself, which can make it difficult to identify the plant. The starches are primarily found on grinding stone and the plants mucilaginous properties might play a role in those numbers. Specifically in the pith of the plant towards the shoot there is a distinct combination of starch and plant mucus, that hardens and adheres strongly when dried. Survival rates could be increased by this but more research is required to determine its properties and the effect taphonomic processes have on it. *T. latifolia* has a versatile damage profile which is similar to the other USOs but also a strong survival rate, native starches

appearing in ‘Outside’ batches. This can be related to the high amount of intact starch cells that were observed in both ‘Before’ and ‘Inside’ batches, serving as a means of preservation. Additionally, raphides formed in the root and are in high numbers throughout the residues, also prevent consumption by animals which can enhance the chances of preservation.

5.1.2 Micro remains across tools

The major pattern that is observed is that after recalculating everything to the same surface area there is an almost exponential increase in the count per tool. Flint has the lowest count and slabs the highest, while runners are almost exactly half the count of the slabs. Flint is a material that is used rapidly and has a smooth surface which is not an ideal for preservation of perishable organic residues that can be washed, blown or eaten away easily (Hayes et al., 2017). Flint residues are much more exposed to taphonomic processes, especially in the open and when moved around. Grinding stone and specifically the slabs have more cavities which can trap the material easier and therefore also preserve it better from mechanical weathering, making it also more difficult for larger organisms to eat them. However, there is a downside to being able to trap many tiny particles in the cavities, other microscopic organisms can get in too. This is what I witnessed when comparing the flint tools to the grinding stone tools. Where there was only a bit of microbial activity in the flint tools, much more was observed in the runner samples and especially in the slabs. This doesn’t have to be an issue, though there is a consistent distinction between tools in terms of how much microbial activity they are showing. ‘Before’ and ‘Inside’ batches could be only compared properly between flint and runners, where the count pattern persists, runners having more starches.

Flint suffers a much bigger loss in the ‘Inside’ compared to the runners which can be attributed to the material properties of flint, though no relation was found between flint scars and starch accumulation as hypothesised earlier. Scars can be present but not open enough to preserve any starches, though if starches can get in, so can microorganisms making the starches an easy target in a small space. The ‘Outside’ batch also shows the general pattern of low count on flint, middle on runners and high on slabs. When looking at the total starch accumulation,

both in 'Before' and 'Outside', starches on runners are half the count of starches on slabs, seeing how two runners were used on one slab spot . This is consistent with the amount of material being processed and the processing time, potentially indicating that preservation rates are similar amongst runners and grinding slabs, even with a difference in stone material. However, there is variation between plants in the 'Outside' batch, *Anthriscus* showing the mentioned pattern, *D. carota* having an almost equal count of starches on runners and slab, and *T. latifolia* runners being only 20% of that of slabs.

There is variation in stone material of the runners but no patterns can be identified. If there is a difference, it would be small, seeing how all runners have a comparable hardness and were naturally rounded. The damage percentage and types across grinding stone tools are similar, flint and grinding stone mainly differ in the damage percentage while damage types are also similar. Disjoining was seldom observed but was mainly present in grinding tools. There is no truncation which I expected to see in the grinding stone. Even with the very dry material, I was still processing roots, not compact starch filled materials like wheat seeds. I believe that the fibrous tissues in between the starch cells acted like a cushioning agent potentially softening the blow but still crushing the starches, but to confirm this a systematic study needs to be executed. Exudation and bursting is used together in literature where examples are vague and not specifically tagged (Messner & Schindler, 2010). However, in my samples I observed both in varying degrees following the descriptions. There seems to be more exudation present in flint than in grinding stone, and specifically within the *T. latifolia* species. I cannot say with certainty that this is the case, but this is a clear example where more reference of this specific damage is needed especially outside of cooking context.

The distribution of micro remains on the tools can be identified through use-wear and experimental processing of different plants. Fresh material tends to accumulate just around the contact surface on a runner whilst dry material can move bigger distances. Contamination is therefore not uncommon, but what is notable is that only one plant contaminated a series of other samples, namely *Anthriscus*. There starches were present in four samples, F-01-B, F-20-

I, GS-15-I, GS-03-I. The only way that this could have happened was when the tools were stored or moved around. Despite meticulous cleaning between processing, this is an interesting highlight of the distribution that needs to be explored further for short exposure of starches particularly aimed at their movement on the tools.

5.1.3 Phytoliths and other micro remains

Phytoliths proved to be useful in identifying *P. australis* tools for the 'Before' and 'Inside' batches. Some phytoliths with distinct morphology were also identified in the samples of young shoots of *T. latifolia*, which was not surprising considering the processing of the new growth. Across all tools, the phytoliths increased significantly in the 'Outside' batches due to the grass overgrowth and potential decay on the tools. In this research the phytoliths were only useful to pinpoint one plant. However, *Anthriscus* showed an elevated phytolith profile when compared to other USO plants. This and the use of *Anthriscus* in a phytolith study (Risberg et al., 2002) indicates that more research and references are needed to understand the research potential of phytoliths coming from USOs.

Other significant micro remains in relation to the processing of starches were yeasts or bacteria, fungal remains and algal organisms. In the 'Before' batch, there were only a few recognisable yeasts or bacteria present, especially in the flint tools, and an occasional fungal hyphae. In this batch the starches were not as heavily attacked by digestive processes, if at all. 'Inside' batch suffered significant digestive damages in all tools' residues. Although there is a general understanding of digestive processes that affect starch granules, these processes differ per context and are dependent on many factors like other mechanical damages, humidity, pH, temperature, mineral deposits, base material and much more. My results indicate that 'Inside' tools left untouched, specifically grinding tools, are much more susceptible to harnessing the digestive organisms that can destroy starch faster, because of the potentially perfect conditions created for the micro-organisms. There are starch specific bacteria and enzymes that could be responsible for the digestion damages by micro-organisms (Hutschenreuther et al., 2017; Mercader et al., 2018). Both Apiaceae species show digestive damage in the 'Outside' batch

whilst the others don't. Comparatively across plants this damage stays the same in the 'Before' and 'Inside' batches. These results entertain the notion of micro-organisms not only being starch specific but potentially also family specific. Understanding these interactions, for individual taxa and across genus or families is something that needs further attention.

Though there are general patterns across tools and plants indicating interesting research angles and possibilities to further our understanding of starch survival rates and their interaction with the environments after processing, there are still many factors at play. Systematic experimentation can help with understanding processing movements and damage relations, plant specific composition that influences the starch preservation or adsorption rates of residues in general, but the reality of plant processing is much more complex. It is difficult to take every measurement into account whilst also trying to reproduce realistic situations. Temperature, humidity, time between processing and sampling, differences in prehension between researchers, and many other factors influence This is where understanding taphonomic processes and degradation through specific processing ties the data together for archaeological use.

5.2 UNDERSTANDING DEGRADATION: TAPHONOMIC PROCESSES IN FOCUS

The tools that were left inside and outside for the material to degrade spent approximately 3 months being affected by various processes. This is by no means a comparison to archaeological material but observations were made that could have important implications for how we view and describe taphonomic processes short and long term.

The taphonomic processes observed in this study through residue analysis are that of starch diagenesis through mechanical, digestive and environmental depositional and post depositional processes. During the depositional processes clear mechanical damage was shown in starch morphology. Low damage in flint, high in grinding stone. The post depositional processes were harder to identify and control. In this project the tools were turned halfway through to expose all sides to different processes. It is not unlikely that tools placed with worked

surface down, could suffer more digestive damage and starches could be transported further into the soil on that location. This would then depend on the adhesion or adsorption of the starches to the material since dry starches can form a protective plaque (Barton, 2009). Dry material has the potency to travel further when being ground (Dozier, 2016) but fresh material stays more localised, around the contact area on the runner contact surface and fully on the slab. Dry material is also more individually dispersed whilst fresh material can reside in clumps that are easily removed through environmental mechanical taphonomic processes. Desiccation of the starches is difficult to measure in this project let alone over thousands of years. Hilum openings could be an indicator, but whether that is happening before the processing or after needs to be looked at closer through a specialised study. There is a general assumption that people in the palaeolithic were grinding flour based on use-wear and ethnographic research (Aranguren et al., 2007; Longo, Skakun, et al., 2021), and although experimentation literature is rich in the context of cereals and agriculture (Adams, 2014), wild plant processing does not have a similar reference collection. Both dry and fresh processing have their downsides yet it is notable that throughout numerous experimentations there is very little or no deviation from the flour processing method.

How and to what extent material is removed from the stone tools after processing is also a factor that influences further taphonomic processes. It is easier to grab something that sticks together than trying to scrape dust to consume it. On top of that, sourcing of the material, time and place, influences the visibility and preservation of starches which muddles interpretations when no sufficient variety of reference material is available. Especially for wild plant research this could be problematic as market or domesticated varieties are branded 'wild' (Cagnato et al., 2021), or even in this project where the plants were not taken from the same environments, just similar ones. Soil condition influences the plant composition and growth but also starch degradation (Hutschenreuther et al., 2017), and even though material is washed, part of that soil biome resides on the plant. Therefore, sourcing details on the environment and soil would

be beneficial in understanding the taphonomic processes of the starches when conducting experimentation.

In terms of taphonomic processes in this project I can confidently say that all material in 'Inside' batches suffers greatly from digestive processes. All material shows taxonomic residue survival patterns in all batches. Flint material retains some but little residues on the tool due to the material properties and if deposited. Ground material leaves more mechanical damages which can lead to a higher degree of further degradation. Dry processed starch material in the short term is less susceptible to further degradation than fresh material. Digestive processes continue in the 'Outside' batch but taxa specific degradation needs to be considered for the Apiaceae species. Survival rates of starches depend on the plant part and collection time and mucilaginous and antimicrobial properties in plant composition could influence this rate.

Questions that need to be raised and answered concern the availability and representability of reference collections and materials for certain regions and time periods. The individual properties of plant taxa in relation to other micro-organisms that can alter the morphology of the residues. Morphological identification across genus and family of plants with a cautionary emphasis on similarities. Processing of fresh plants in more than just one ways and mapping the survival rates across tools. Further investigation of the role of phytoliths in enhancing survival rates of other micro remains through sorption.

5.3 Archaeological relevance of experimentation and residue analysis

This project was designed to test the current ideas around starch residues and contribute important morphological, taphonomic and experimental processing data to the already existing pool of plant processing research by focusing on wild plants and the Crimean peninsula during the late Pleniglacial. A vast amount of data was produced with confirmations of some methodologies and results, whilst stressing existing questions and posing new ones

around residue analysis and how to improve it experimentally. Below I briefly go over the most important finds and questions.

5.3.1 Micro remains in a broad experimental context

Distinct patterns across plants were observed, with expected outcomes in regard to starch rich wild plants. Though across different experimental studies, different results occur as can be seen for *D. carota* experiments (Bello-Alonso et al., 2019; Cagnato et al., 2021). Next to that, a lack of information is present in *Anthriscus*, a lack of alternative utilisation and residue collection is seen in *P. australis* processing, and *T. latifolia* is often used in experimentation but lacks variation in processing (Aranguren et al., 2007). As pointed out by Mercader et al. (2018), there is a lack of systematically controlled experiments, authentication obstacles and identification flaws throughout archaeological starch research, amongst other difficulties.

This research tried to tackle these problems through a systematic approach that adds to the reference material that we have already, but considers not only wild plants that have no literature reference or lack thereof, but also flint tool starch accumulation which is often deemed as irretrievable. Patterns across plant starch residues indicated that there is indeed a taxon specific degradation pattern that needs to be understood better through extensive experimentation so differences and similarities in plant family and genus can be highlighted. By including flint tools and *P. australis* in the experimentation, I showed that the role of phytoliths' role in preservation and general understanding of plant derived biomolecules adsorb onto surfaces needs close attention. Specifically in the Palaeolithic record this is of vital importance since a large part of the archaeological record are flint tools. The vast increase in starch digestion needs to be untangled in terms of the specific factors at play, especially in an open air site kind of environment and enclosed spaces like dwellings and caves. These locations can have microclimates, rapid changes in temperature, habitants that influence pH levels like bats or other animals and insects that carry with them microorganisms which could potentially alter areas with which humans also interact. These are taphonomic processes that should be investigated more by applying them in experimental contexts across multidisciplinary studies.

Additionally, we need to step away from the processing biases of things like grinding flour and start considering different methods with the same tools to better understand the broader interaction between organic material, the processing tools and the taphonomic processes involved between them. Specific attention needs to be given to micro-organism degradation and the survival rate of these organisms in closed environments.

5.3.2 Experimental research and residue analysis in the context of Crimean Late Pleniglacial

As of now there is very little information on the potential plant processing during the Late Pleniglacial on the Crimean peninsula, making it difficult to let of the persisting meat diet biases. This project has indicated that despite its short run, we need to take a closer look at plant specific residues and their degradation rates, placing their relationship to microorganisms and phytoliths as a priority and considering not only griding stone but also flint tools for residue analysis. Given the experimentations and the environmental context of the chosen sites, several considerations need to be made regarding the tools, environmental modelling and future sampling protocols and opportunities.

The sites are rich in flint material but also contain potentially unidentified grinding stone tools. For the material that has been already excavated and unwashed, there is a potential of residue being retrieved from both lithics and grinding stone tools, if that has not been done yet at the time of thesis publication. All tools would require a spot sampling approach to identify the specific location of the residues and prevent false positives from environmental contamination. For the material that has not yet been excavated, both soil and tool need to be sampled. The identification of potential taxa need to be reviewed through improved environmental modelling and new palaeoecological sampling data if required, in order to establish a baseline of potential vegetation families and execute experimentation within and them and across species increasing accuracy of the identification and authentication of micro-remains. Reference collections with material from the Crimean Peninsula need to be made and compared across similar plant processing, keeping in mind the climatic differences and modern

vegetation variation. At this moment, there is no clear evidence that indicates plants were not used, the evidence is scarce and we need to understand it better before knowing what to look for in the archaeological record. Therefore this research is fundamental in adding valuable information on starch research by highlighting variations between tools and plants and highlighting the importance of a more diverse and regionally specific reference collection.

The main takeaway from the results of this project is that there are some persistent biases towards certain plants and foods, some of which we still understand poorly or exaggerate the expectations of in certain contexts. In order to truly further our understanding of the field of residue analysis and develop new and more effective and efficient methodologies we need to take a step back and focus the organisation and execution of systematic experiments with control variables as well as still looking into the taphonomic impact on the process. This research needs to be accessible, representative of reality considering a wide range of plants species, reproducible, with high standards when it comes to analysis and identification and potential development of standardised protocols that test specific properties like microbial influence, mechanical damages, adsorption properties or residue leeching into surrounding soil, just to name a few.

5.4 METHODOLOGICAL REVISION, LIMITATIONS AND FUTURE RESEARCH

Great amounts and quality of data were achieved during this project, though there are always improvements to be made, things that could be changed and objectives that also change with time and research perspective. In this section I would like to briefly elaborate on some of the flaws in the methodology, the limitations that this and many other projects face and the possibilities that these considerations can bring to future experiments and residue analysis research.

5.4.1 Methodology

Experimentations are rarely flawless from the start and perfecting them is what makes research exciting and makes us go forward. This experiment was designed to be a pilot study

to see which tools I would require, what methods, what materials and gauge the initial signals of the residues in multiple ways. Main improvement that would have to be made is more authentic tools, meaning from the region itself and/or made by a professional flintknapper. The flake tools did the trick, so did the grinding stone, though these tools also have their own properties and even the slightest variable can change outcomes completely sometimes. Another thing that I would change or rather would want to do more of, is spot sample multiple spots and compare the signals. Due to the required feasibility we decided to just sample the tools once per condition. This alone already started showing promising results. By improving both materials that were used to reflect a more authentic experience and take the time to experiment with more and bigger tools samples can be compared across surfaces. There would be a huge influx in reference material that aims to be unbiased and inclusive of wild plants and the variations within those populations.

5.4.2 Limitations of experimental archaeology and residue analysis

There are of course boundaries that we have not yet been able to cross with experimental research and residue analysis. One of the obvious ones is that foods from the past don't necessarily need to have the same composition of nutrients and the way our bodies interact with those nutrients and the energy we have or don't, is not the same as it was thousands of years ago. As a society today we leave a mark on the past and it is difficult to get away from that.

To experiment with ancient techniques is not to replicate flawlessly, it is to understand, therefore we can say with certainty that we will never be able to truly replicate what was eaten or done, but we can definitely come very close to it and perhaps find new ways to interact with other material. Then there is the question, which tools do you sample and which do you leave to be washed? This too plays into the biases that we have accumulated by looking at rocks, giving them functions and then only occasionally considering that there might be more to the rock and its life history than placing it together with similar rocks. Residue analysis too is difficult if not impossible to interpret sometimes due to the lack of vast and accessible reference

collections and sometimes also due to a lack of protocol communication or uniformity in some cases.

Examining wild plants also requires time and a lot of knowledge, what is seen as wild in one region may not be in another and we have to ask ourselves the questions what we are actually trying to achieve when we know that some material or conditions will never be available to us to see or experiment with.

5.4.3 Future possibilities

The limitations mentioned earlier are in essence just things that will either get solved with time and research or will be bypassed in another way, using a proxy or another model or a combinations of various techniques. Though not included in the research, a quick look was taken at the flint tools where a specialist saw differences in polish between the plants and also something that they have not seen before on *Anthriscus* and *D. carota* tools. The polish from herbaceous vegetal material is a tops in and of itself and needs more research so better interpretations can be made in regard to plants but also other materials. The future possibilities with this type of research are endless, because there is still so much that needs to be experimented with and looked at through the microscope. Especially for the Crimean Peninsula creating a vast reference collection that also is connected to other areas of the Black Sea, we can improve existing protocols on residues gathering, but also understand the variation within plants, collection and processing times and whether they had any influence on the choices people made. Additionally, by understanding the different wild plants and the way they could have been consumed but also potentially altered without it being reflected in the climate but reflected on the tools, we can start thinking about the still invisible impacts that humans made already then.

6 CONCLUSION

The aim of this research was to investigate the potential of experimental archaeology and residue analysis to better understand the possibilities of plant exploitation of the Crimean peninsula during the second half of the Late Pleniglacial (LPG) period (19-15 ka cal BP). The main reason for this research is the still persisting biases within diet research of the palaeolithic, focussing primarily on butchery and not often entertaining the notion of vegetational consumption or use of wild foods, while evidence points to favourable climates and a rich vegetation especially at the onset of deglaciation of Eurasia.

There is reason to believe that Crimea must have been a refuge for a large group of organisms during and after the Last Glacial Maximum, harbouring a large biodiversity of plants and animals. Hence it is curious that plant material has not been included in many experimental or residue analysis studies while the palaeoclimatic, archaeological and ethnobotanical data are all there waiting to be processed. In order to answer this plant exploitation question several experiments were executed based on theoretical framework of the Crimean Upper Palaeolithic, paleoenvironmental reconstructions of the environment and tool assemblages which could have been used for the processing of plants during the Late Pleniglacial. Additionally, a wide range of experimental research focusing on plants was consulted to develop the experimental protocol.

Four plants were chosen based on their potential presence on the Crimean peninsula during the LPG, nutritional value based on experimental, ethnobotanical and biochemical studies, comparison possibilities amongst each other and ethnographic and archaeological use or significance. These plants were *Anthriscus* sp., *Daucus carota*, *Phragmites australis* and *Typha latifolia*. These plants can be found together on wet terrain but survive in a wide range of biomes, such as mountainous regions like the foothills of the Crimean Mountains during the Late Pleniglacial. Based on a find at the Site of Siuren I, I chose to process the plants with grinding stones. Other sites like Buran Kaya III and Skalisty Rock Shelter were chosen because

of their stone assemblages as well as the environmental reconstructions that were made for these sites. I decided to include flint processing in this study since flint is not used often on herbaceous plants or studies including starch identification and collection. There were several expectations for the plants and the processing, them being high signals of starch in the more commonly known experimental plants like *Daucus carota* and *Typha latifolia*, but less starches in *Phragmites australis* and potentially also in *Anthriscus.* Additionally I expected the grinding stones to collect more starches than the flint tools. The results of the experimentation provided me with several clear patterns that are of significance not only to the understanding of the Upper Palaeolithic diet in Crimea, but can be useful in trying to reconstruct and monitor the authenticity of micro fossils, like starches.

There are several patterns that have been identified. Firstly, the tool pattern is the comparison between tools that has indicated that the accumulation of starches can greatly depend on the tool that you are using. Flint had the least amount of surviving starches, runners significantly more and grinding stones surfaces collected the most. This is not new, but what is interesting is that this doesn't count for all plants and there might be a reaction going on between stone tools and how specific plant micro remains adsorb to the tools. Then there is the plant pattern, which across most of the tools and processing times continued to be stable. This pattern also elucidated the need for a revised and improved reference collection because Anthriscus sp. has not been included let alone considered in many studies, while Daucus carota has, all because one is wild and the other is the wild variant of a domesticated plant.

Analysing various damages and other micro remains gives us a clearer understanding of what the role of taphonomy could be in these studies, where these taphonomic factors are difficult to control or monitor. By creating a better reference collection we are then able to not only set up experimental studies in the region of Crimea, but also have a ready to guide as to what we can expect in the archaeological record based on an extensive and broad experimentations. Starch morphology is one of these things but the interactions of the starch with its environment is something that needs to be explored more extensively, like interactions

with other microorganisms or survival rates enhancement due to plant composition. By extensively analysing our plant exploitation possibilities and engaging more with a hands on critical approach to experimental archaeology and residues analysis, we will hopefully one day be able to draw a much more balanced dietary representation for the Palaeolithic record.

ABSTRACT

This thesis focuses on the use of experimental archaeology and residues analysis to further our understanding of the plant exploitation possibilities on the Crimean Peninsula during the Late Pleniglacial period (19 -15 cal BP). Crimean plant exploitation during this period is not well understood despite palaeoenvironmental, archaeological and ethnobotanical data being available. The aim was to elicit the types of residues that would have been collected and how these residues could be made useful in archaeological applications. This was done by executing several experiments with stone tools and plants likely to have been on the peninsula during that period. The results showed interesting plant specific correlations with the tools as well as a consistent performance of starch accumulation across all tools. These results are a vital step towards creating a broader and a more inclusive reference collection for wild plants in order to understand the residues and what we need to look for in the field from an archaeological and palaeobotanical perspective.

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FIGURES

TABLES

APPENDICES

APPENDIX A: TOOL ID AND DIVISION

Division of tools per action, plant part and hydration state as indicated in the processing of plants. The order follows the sequence of processing, not an alphabetical one.

T. latifolia

Action/Plant Part	Root	Young shoot
Shaving	F-01 | F-03 | F-05	F-07 | F-09 | F-11
Sawing	F-02 | F-04 | F-06	F-08 | F-10 | F-12
Grinding/Pounding	GS-01 | GS-02 GS1 – TFB	GS – 03 | GS - 04 GS1 - TDB
Action/hydration state	Fresh	Dry

P. australis

Action/Plant Part	Shoot	Young Shoot	
Shaving	F-13 | F-15	F-17 | F-19 | F-21	
Sawing	F-14 | F-16	F-18 | F-20 | F-22	
Grinding/pounding		GS – 13 | GS – 14 GS2 – PFB	GS – 15 | GS – 16 GS2 – PDB
Action/Hydration state		Fresh	Dry

Anthriscus sp.

Action/Plant Part	Root	
Shaving	F-23 | F-25 | F-27	
Slicing	F-24 | F-26 | F-28	
Grinding/pounding	GS – 09 | GS – 10 GS2 – AFB	GS – 11 | GS – 12 GS2 - ADB
Action/Hydration state	Fresh	Dry

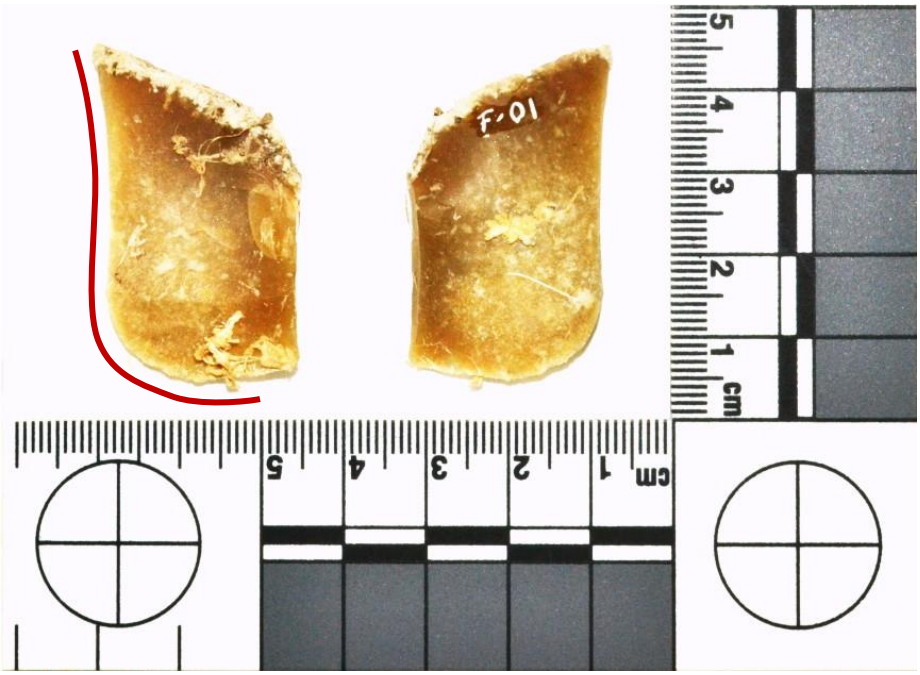
D. carota

Action/Plant part	Root	
Splitting	F-29 | F-31 | F-33	
Slicing	F-30 | F-32 | F-34	
Grinding	GS – 05 | GS – 06 GS1 – DFB	GS – 07 | GS – 08 GS1 - DDB
Action/Hydration state	Fresh	Dry

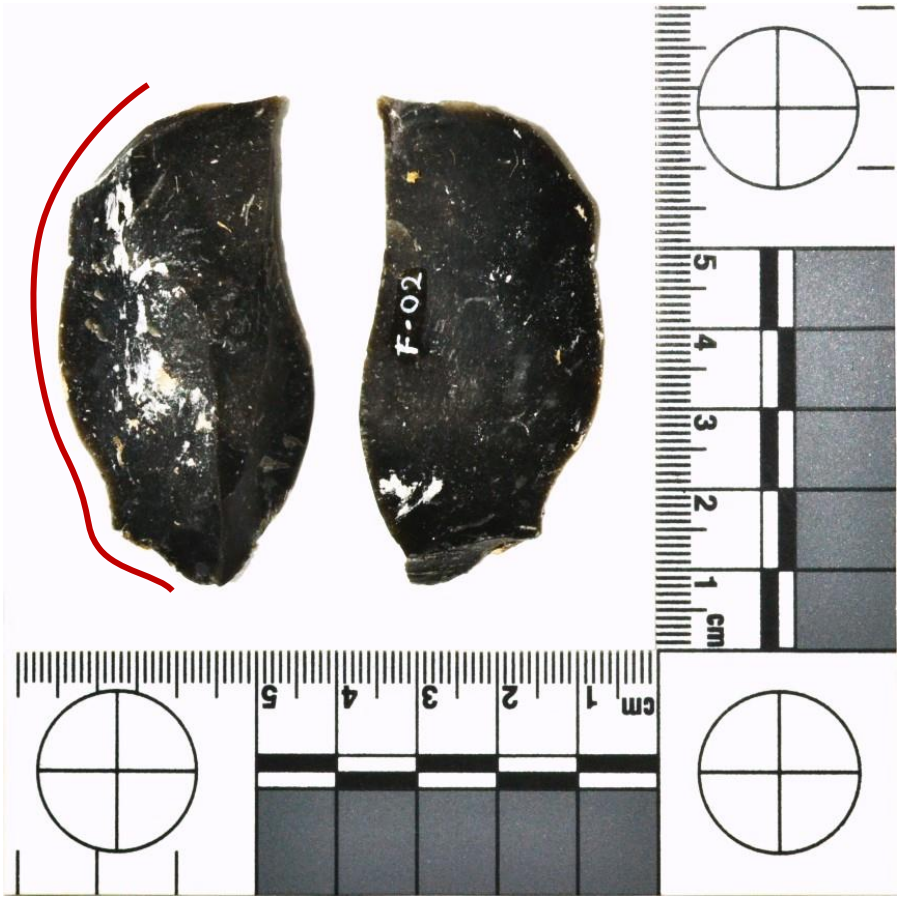
APPENDIX B: PROCESSING TOOLS POST PROCESSING AND SAMPLING

These are all tools photographed right after processing plant material. Flint tools are presented ventral and dorsal sides next to each other, cutting edge is indicated per tool with a red line along the used edge, on the left when facing away from each other, in the middle when facing each other. With the runners there is an indication of sampling visualised on the tool, Pink for 'Before' sampling, Green for 'Inside' or 'Outside' sampling. Grinding stones are shown fully with both processing spots before sampling and a closeup of the 1st and 2nd sampling. Tool ID, plant name and part and processing time (in minutes) are indicated above the image.

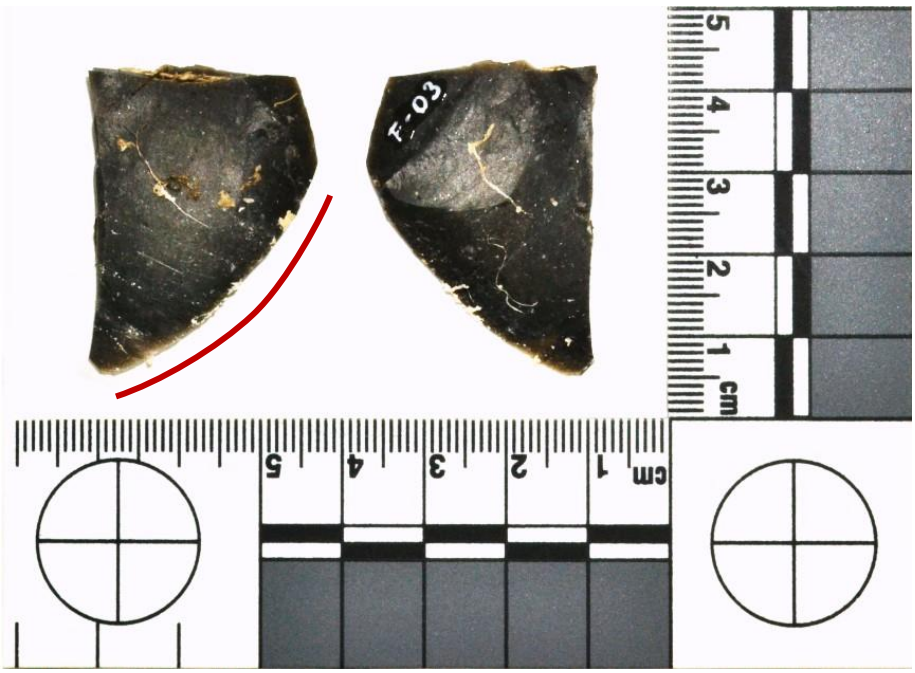
Flint
F-01 | T. latifolia Root/Rhizome | 7:05



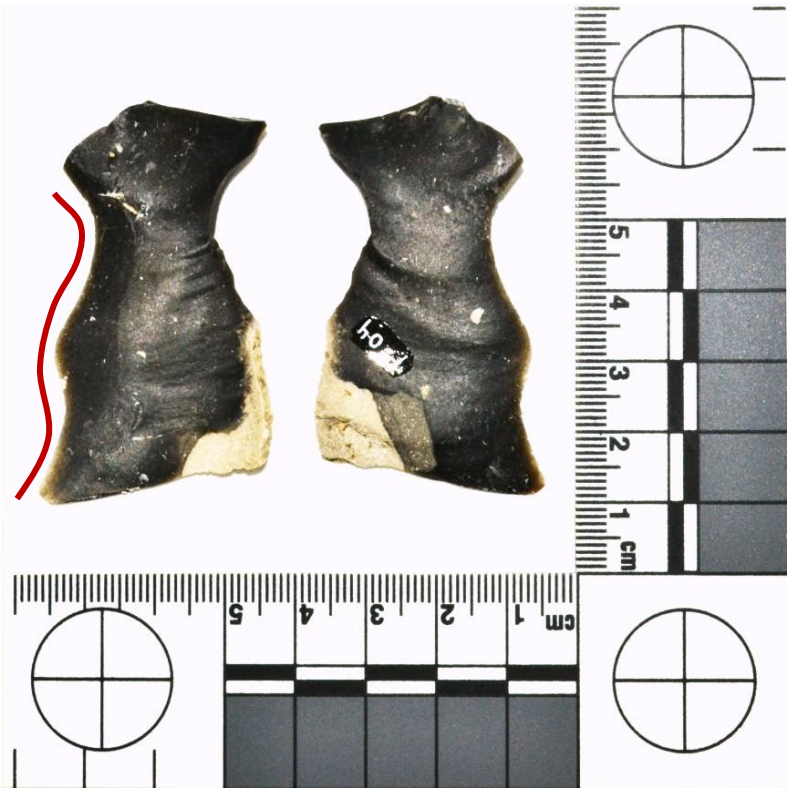
F-02 | T. latifolia Root/Rhizome | 5:30



F-03 | T. latifolia Root/Rhizome | 9:19



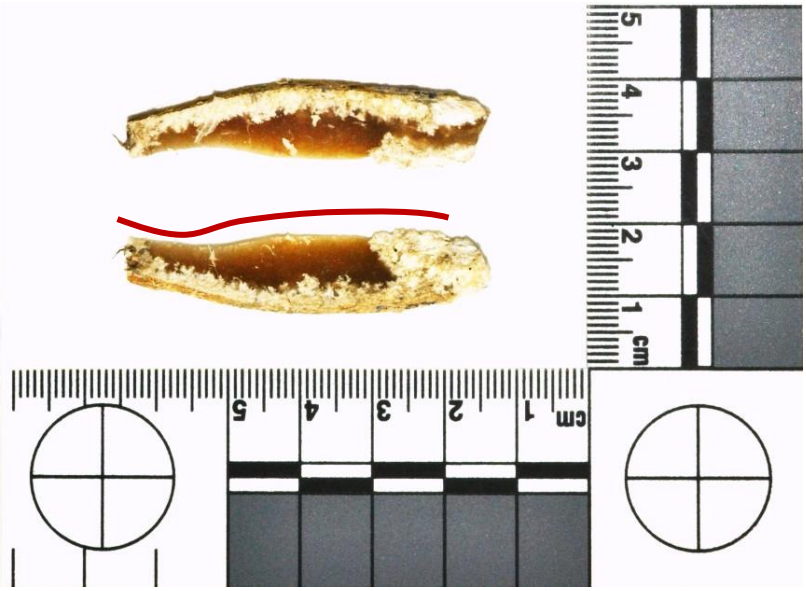
F-04 | T. latifolia Root/Rhizome | 9:17



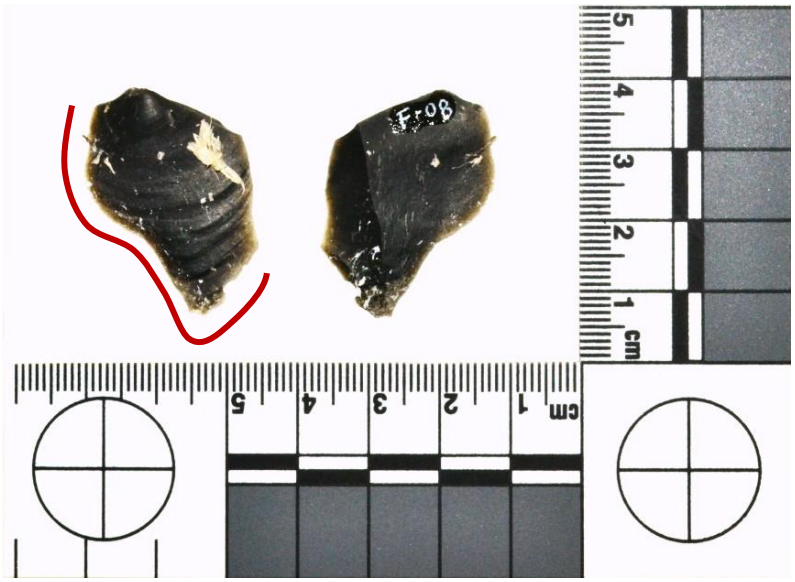
F-05 | T. latifolia Root/Rhizome | 11:05

F-06 | T. latifolia Root/Rhizome | 11:20

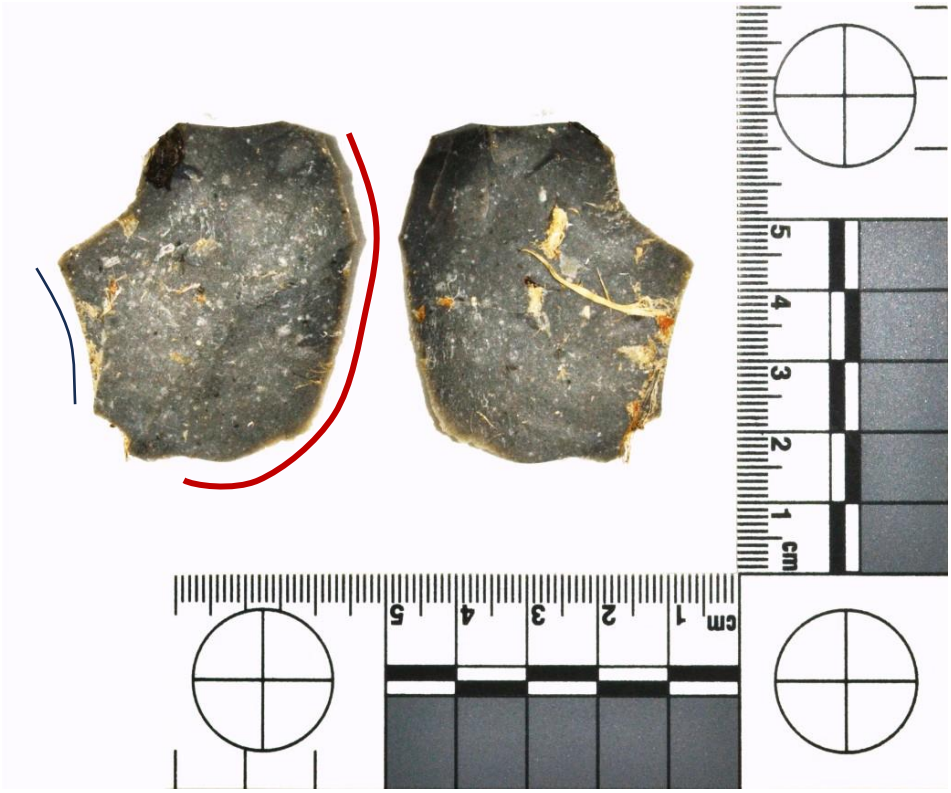
F-07 | T. latifolia Young Shoot| 8:00



F-09 | T. latifolia Young Shoot | 3:00



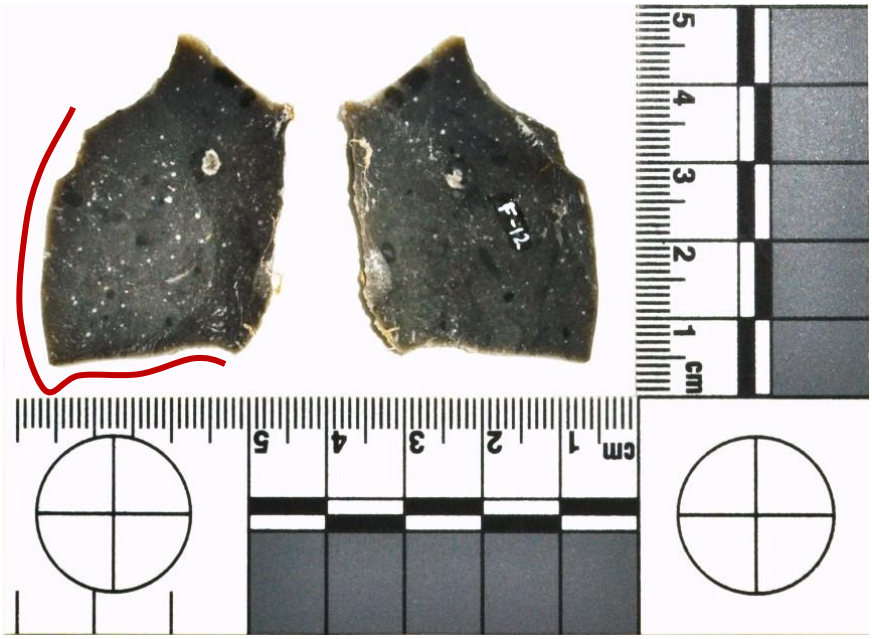
F-09 | T. latifolia Young Shoot | 12:00



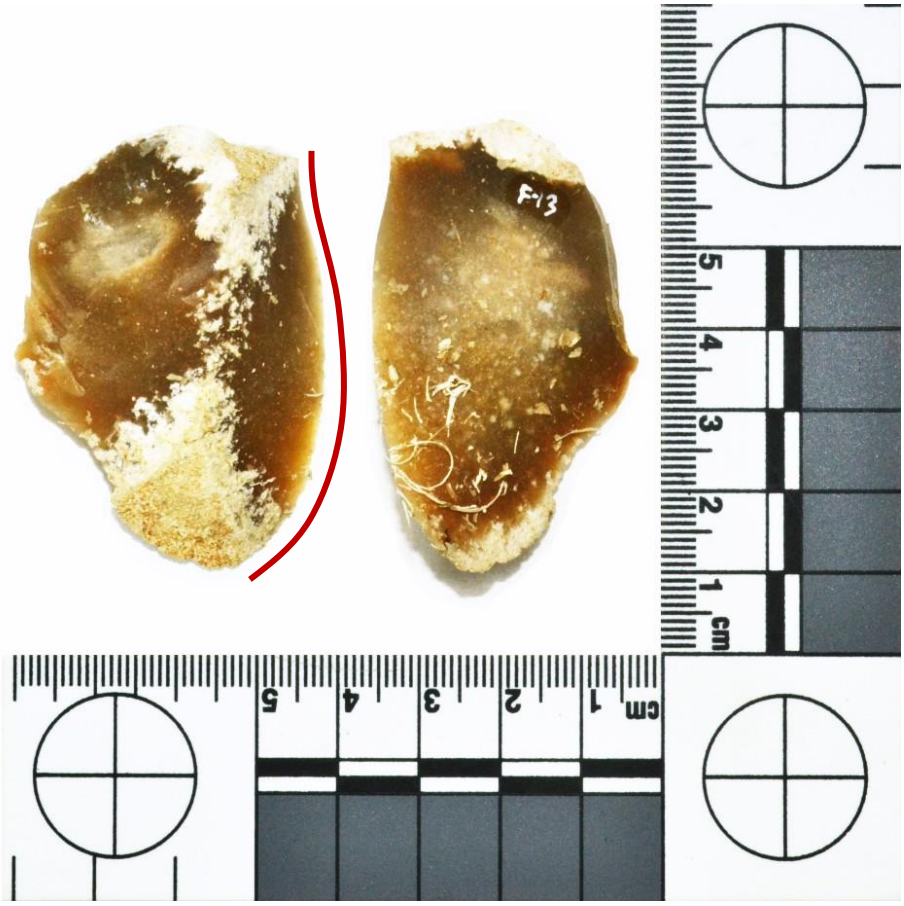
F-10 | T. latifolia Young Shoot | 2:25

F-11 | T. latifolia Young Shoot | 11:20

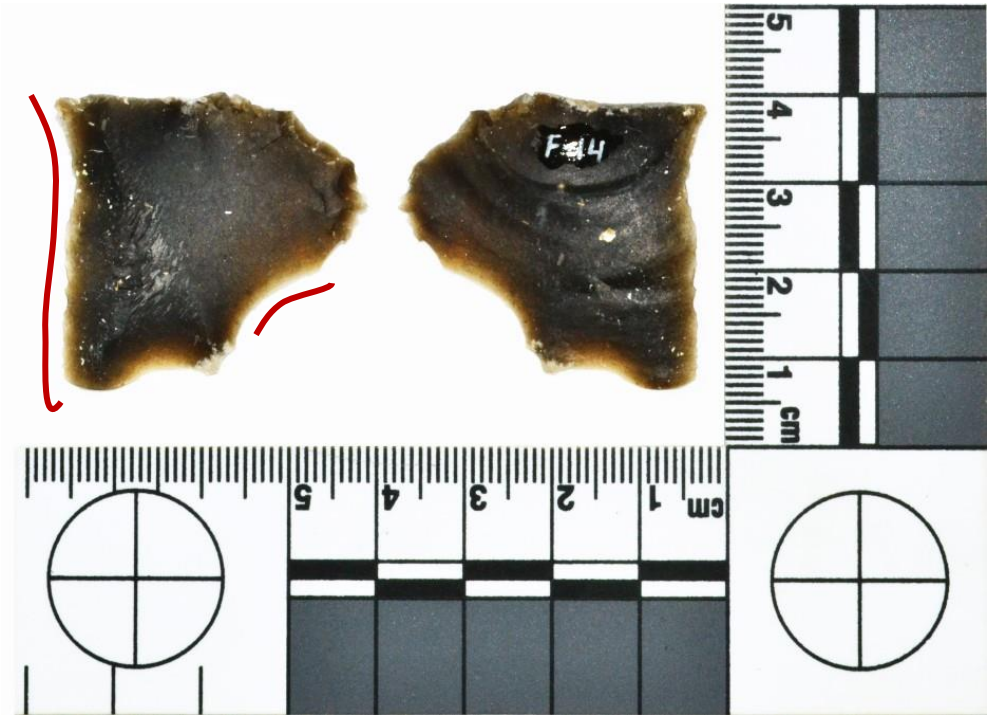
F-12 | T. latifolia Young Shoot | 2:42



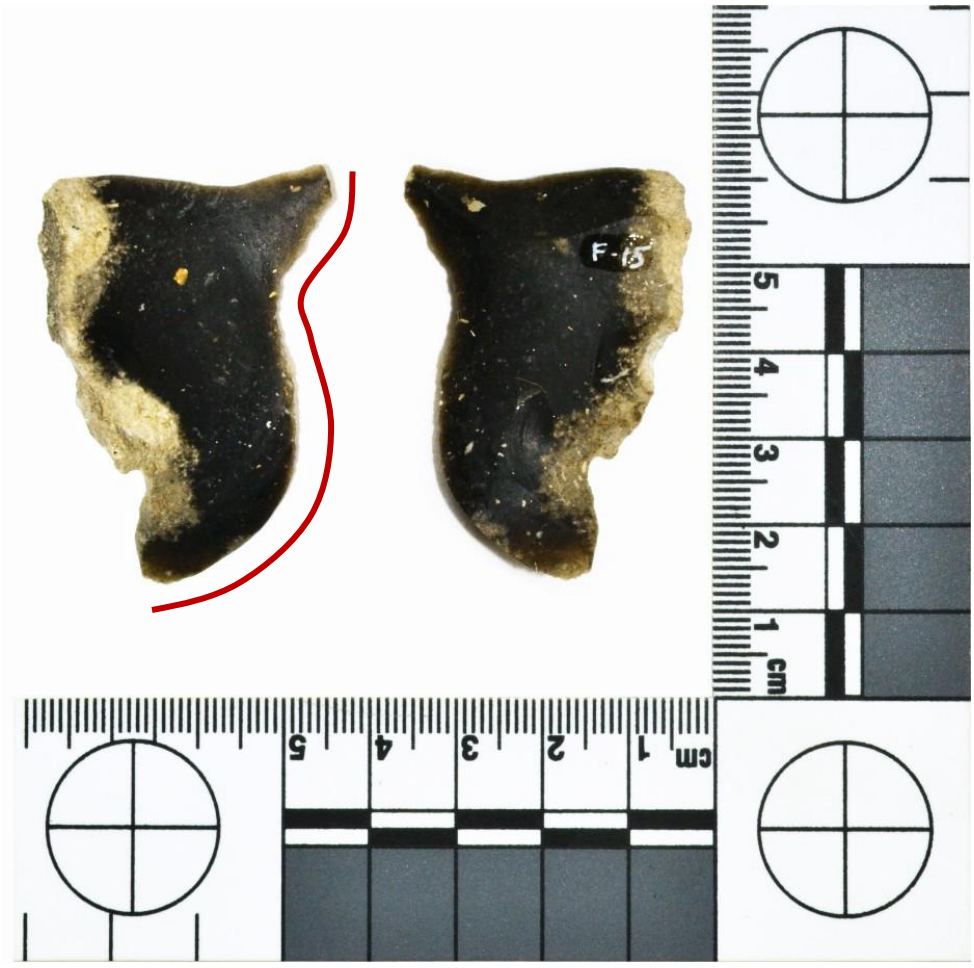
F-13 | P. australis Shoot | 10:43



F-14 | P. australis Shoot | 7:20

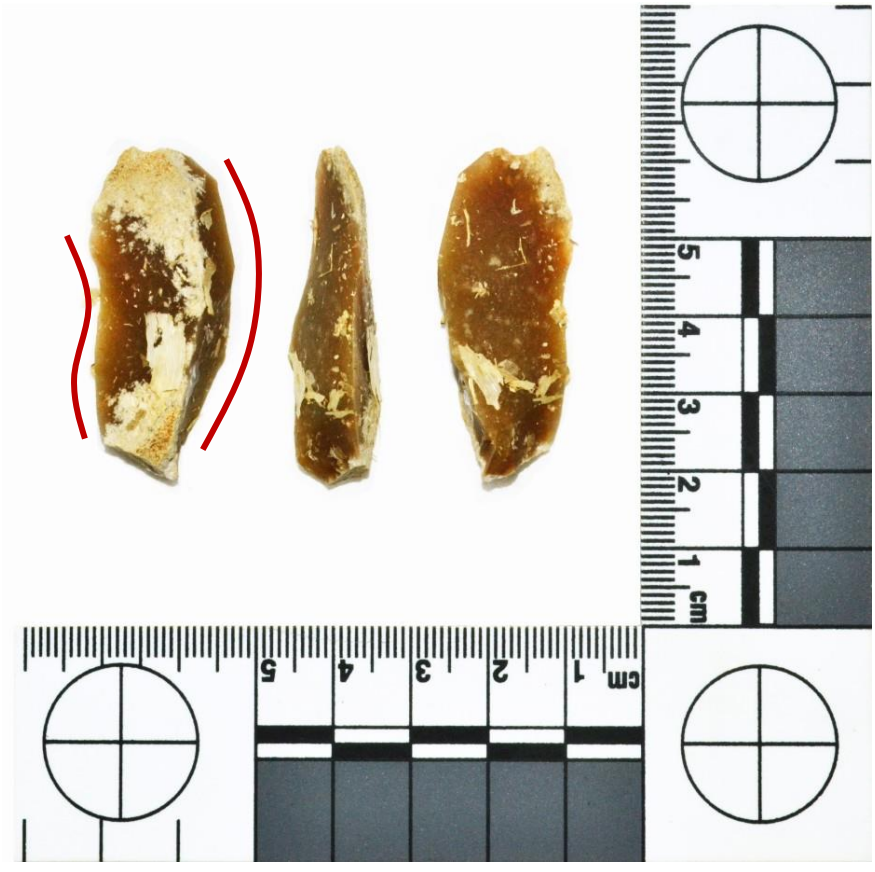


F-15 | P. australis Shoot | 15:00

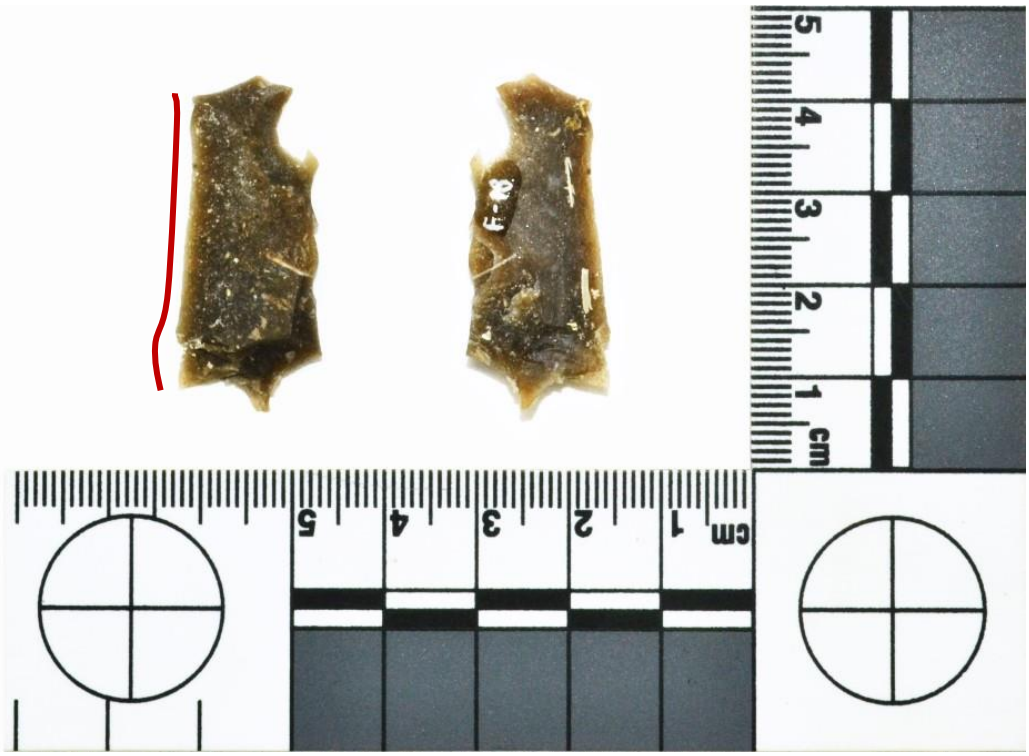


F-16 | P. australis Shoot | 6:25

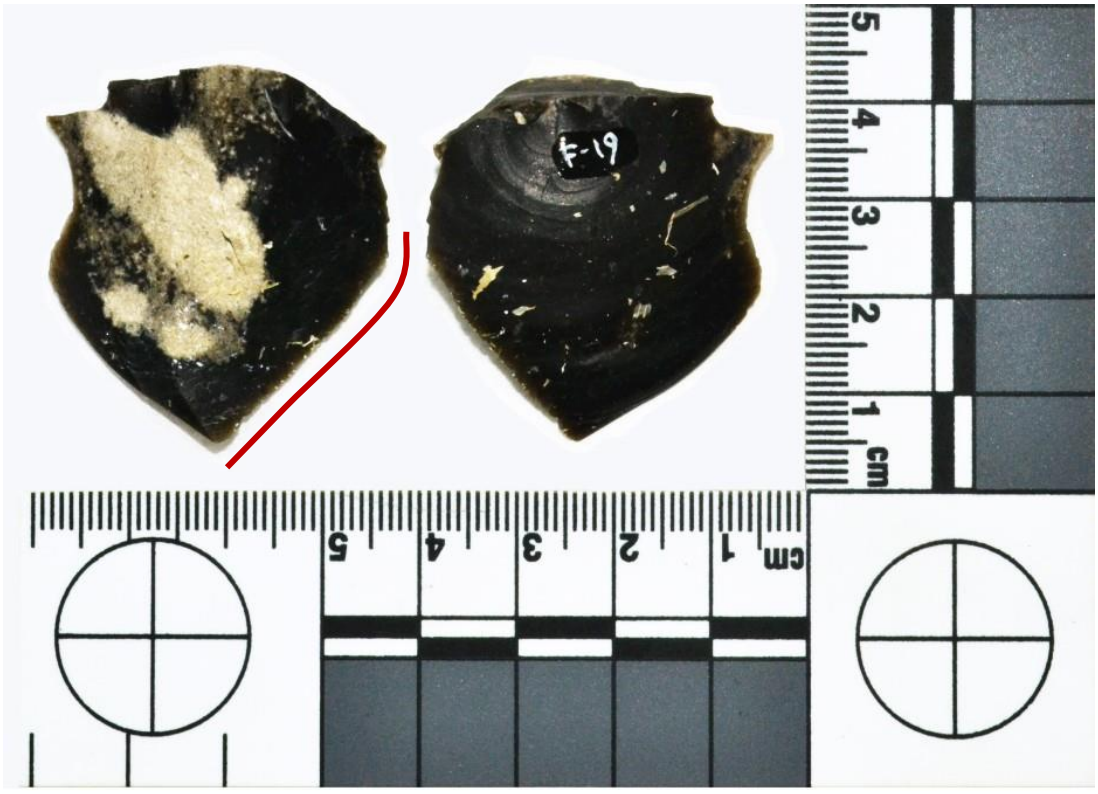
F-17 | P. australis Young Shoot | 7:30



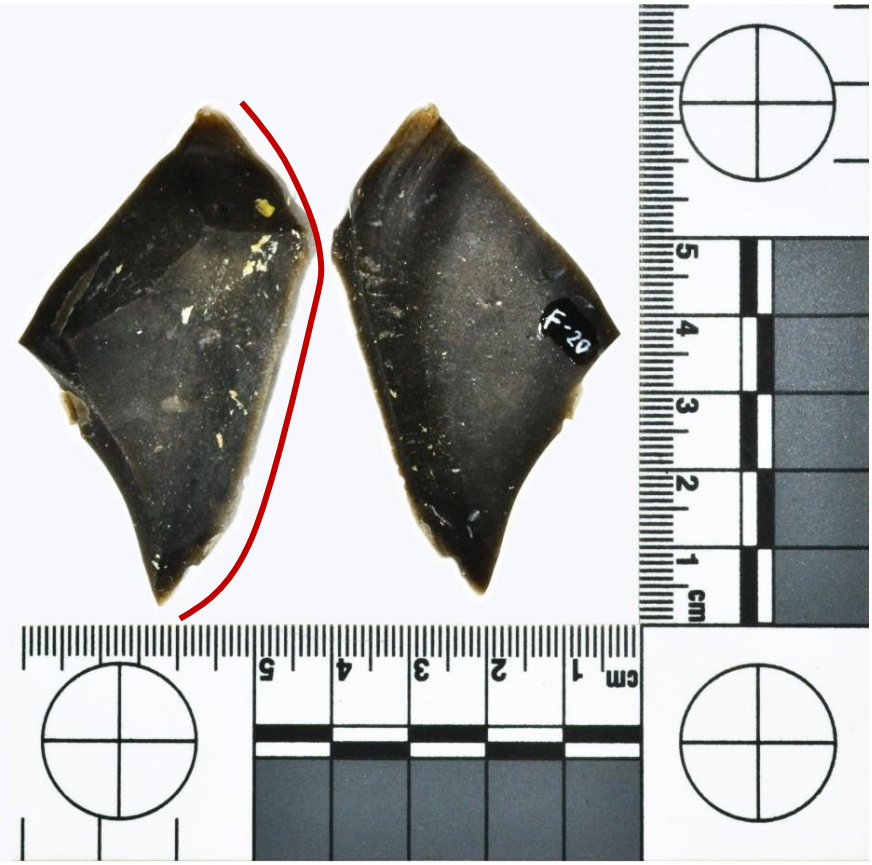
F-18 | P. australis Young Shoot | 4:35



F-19 | P. australis Young Shoot | 8:21



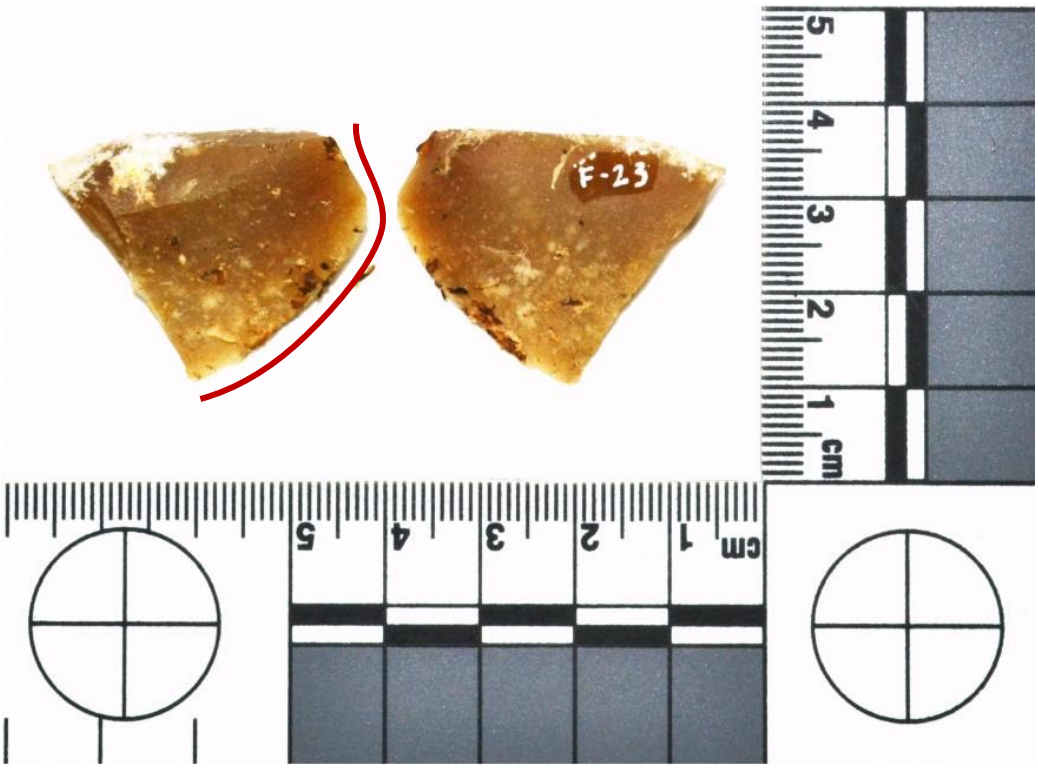
F-20 | P. australis Young Shoot | 4:34



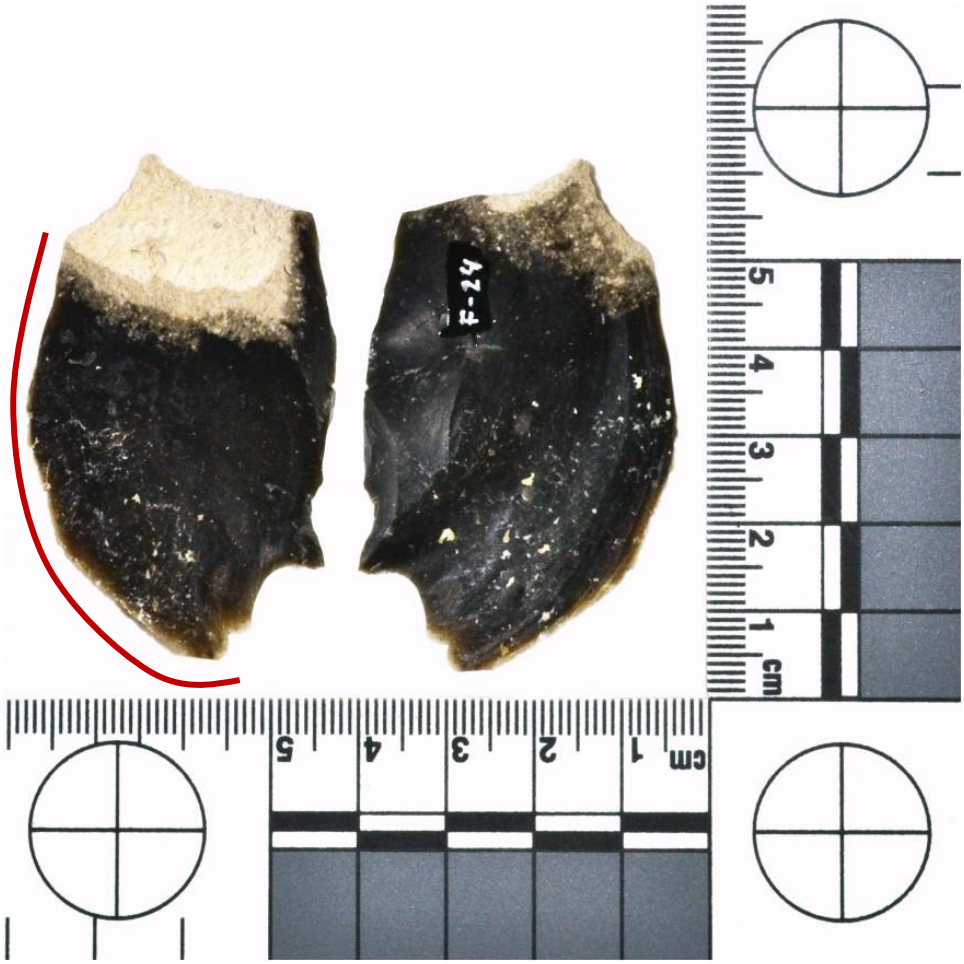
F-21 | P. australis Young Shoot | 8:23

F-22 | P. australis Young Shoot | 4:50

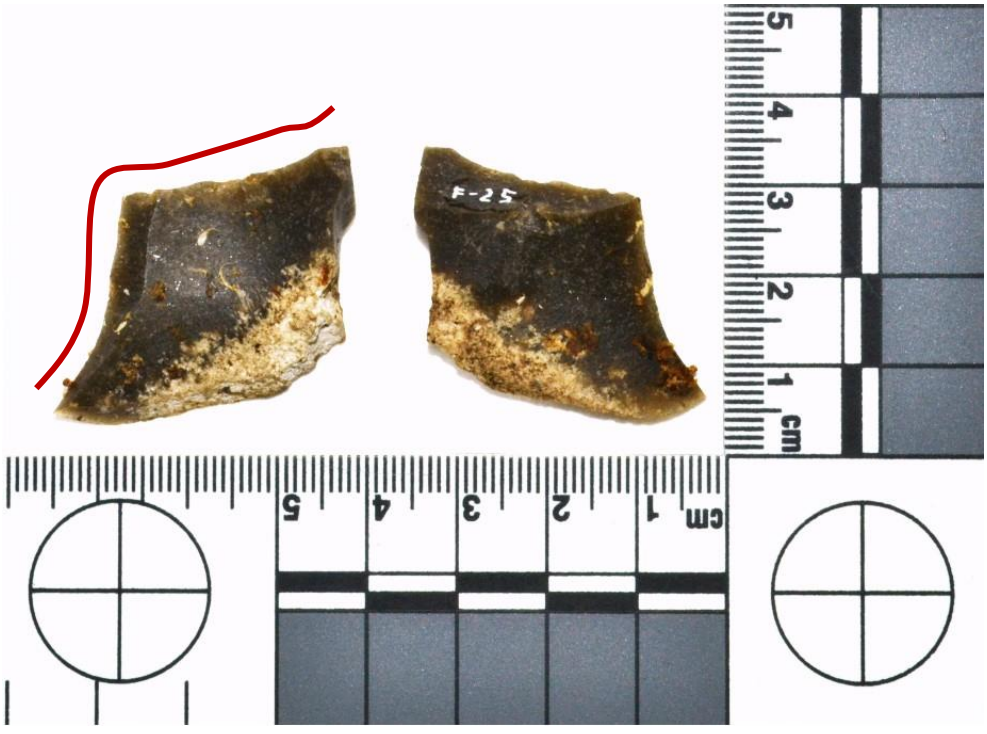
F-23 | Anthriscus sp. Root | 16:43



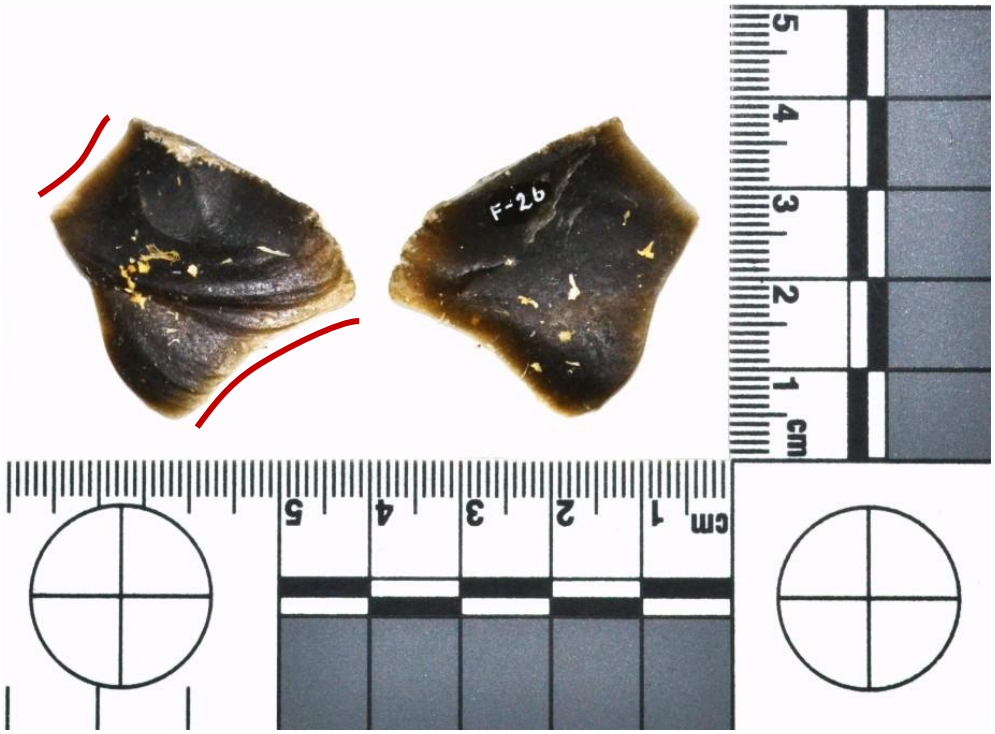
F-24 | Anthriscus sp. Root | 4:16



F-25 | Anthriscus sp. Root | 19:24



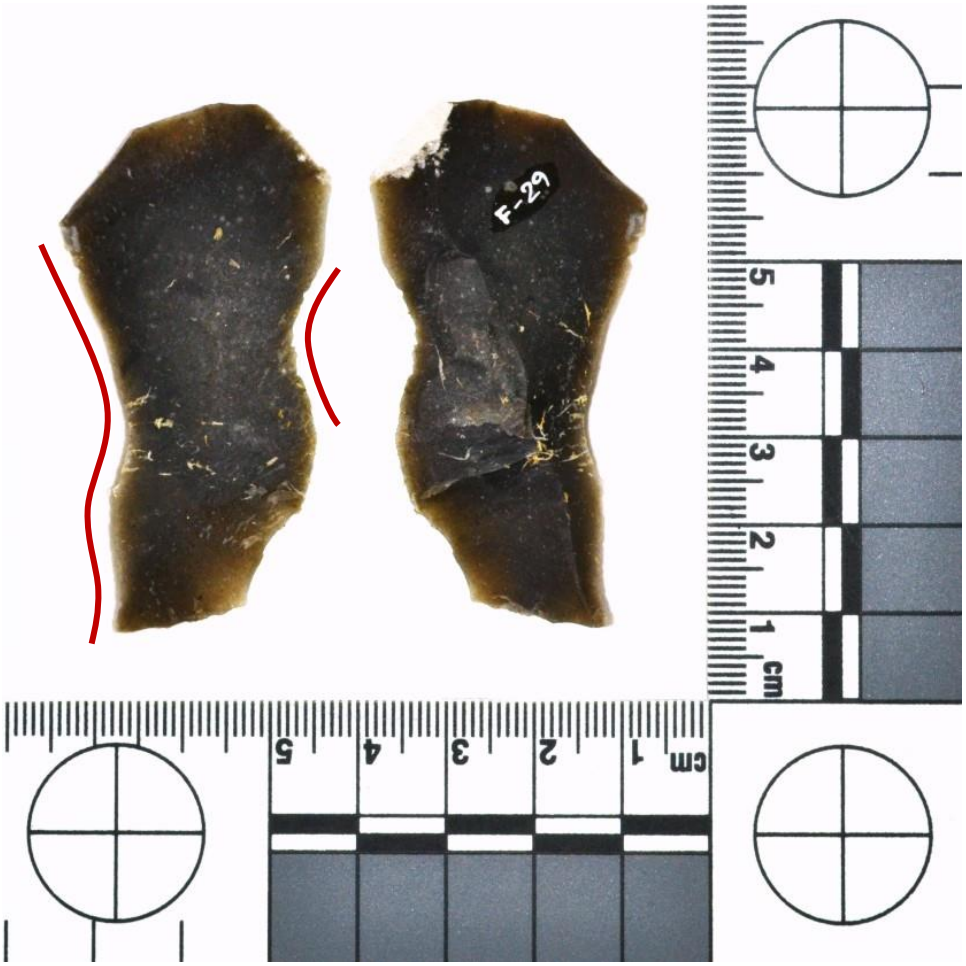
F-26 | Anthriscus sp. Root | 3:51



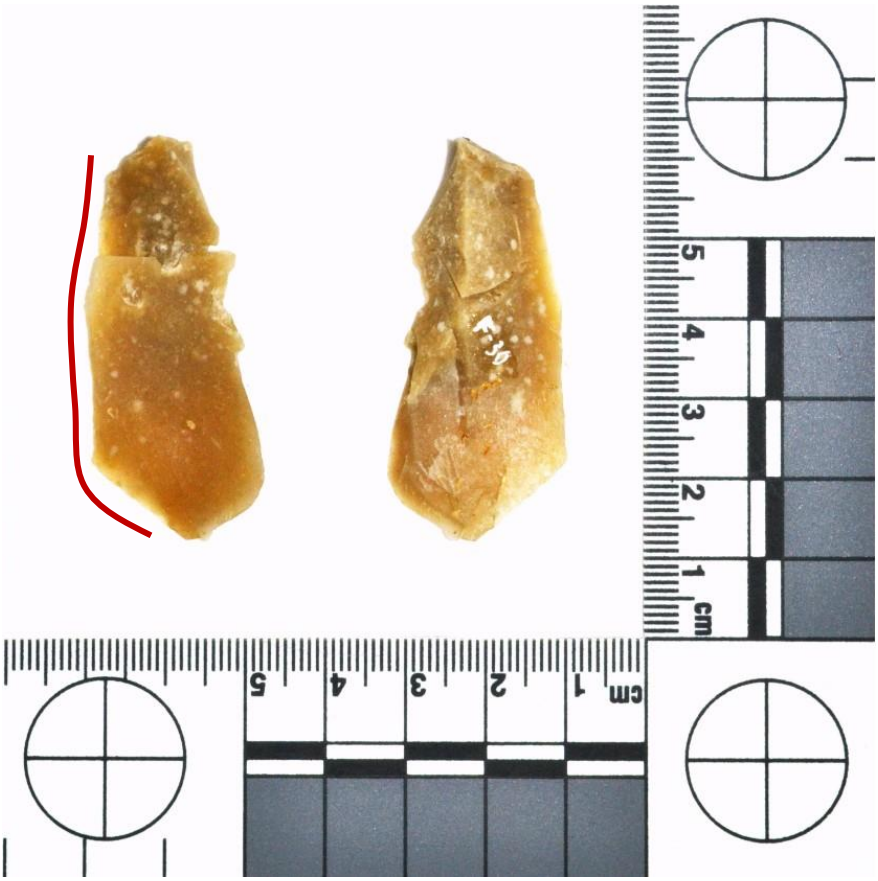
F-27 | Anthriscus sp. Root | 17:32

F-28 | Anthriscus sp. Root | 4:50

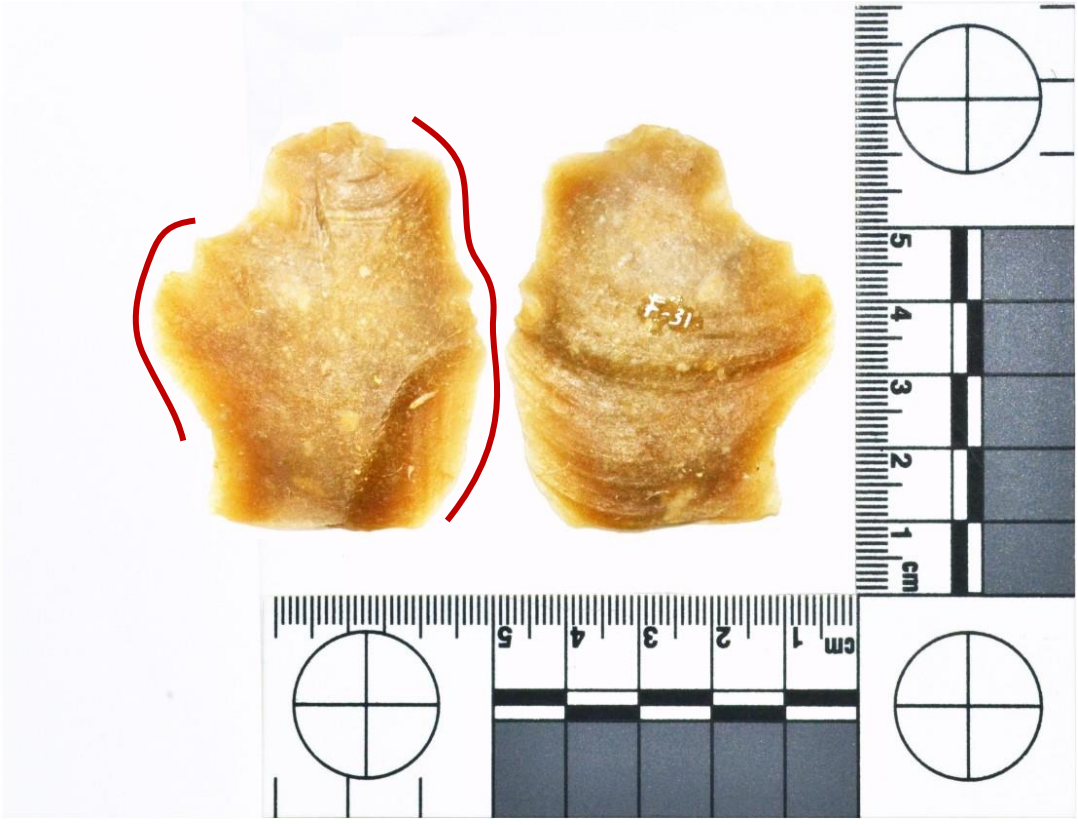
F-29 | D. carota Root | 4:00



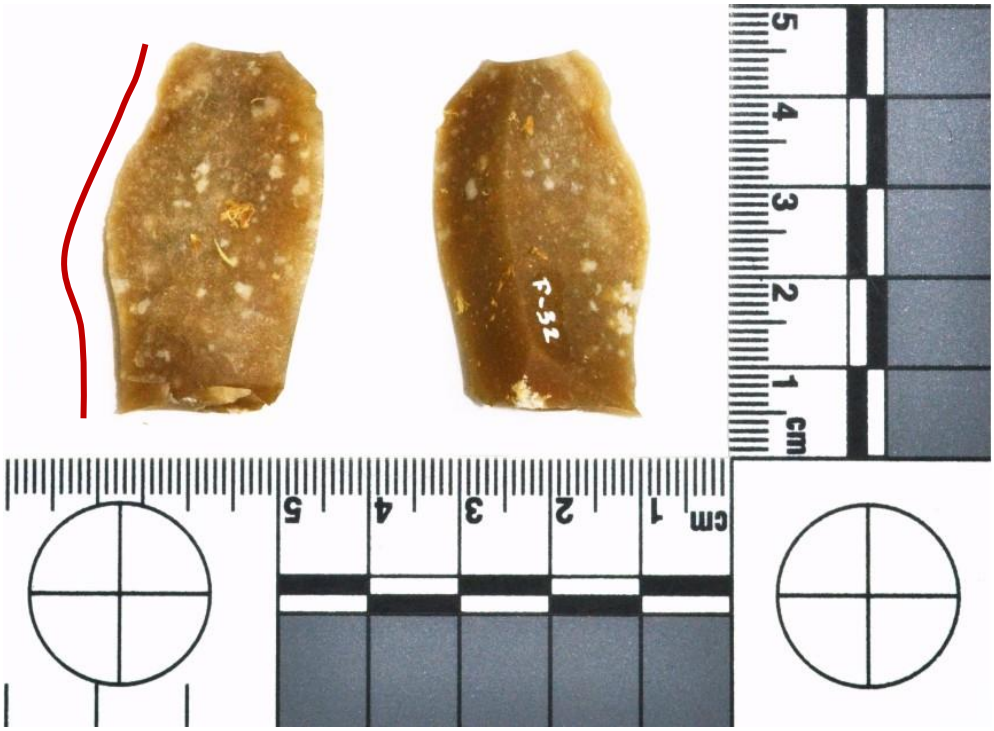
F-30 | D. carota Root | 6:30



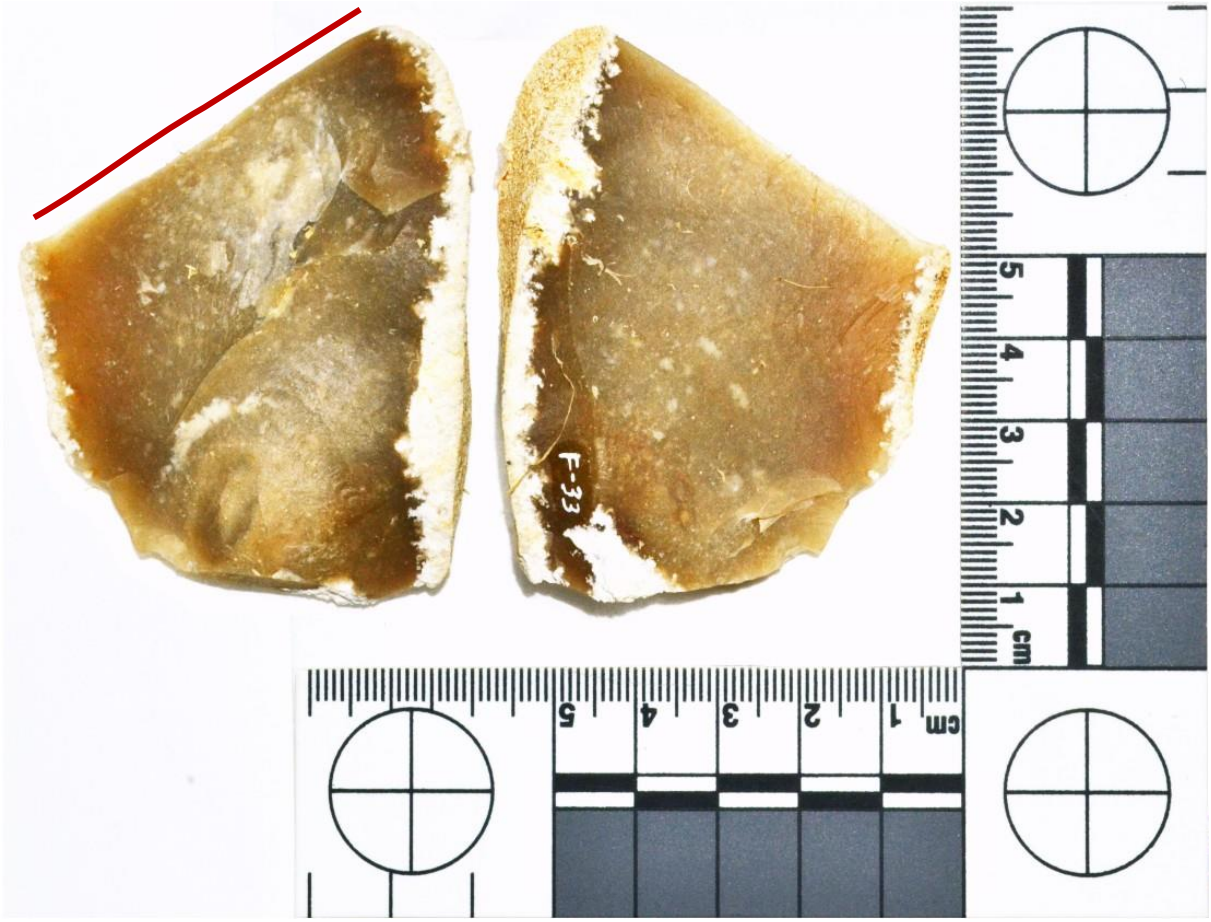
F-31 | D. carota Root | 8:04



F-32 | D. carota Root | 3:10



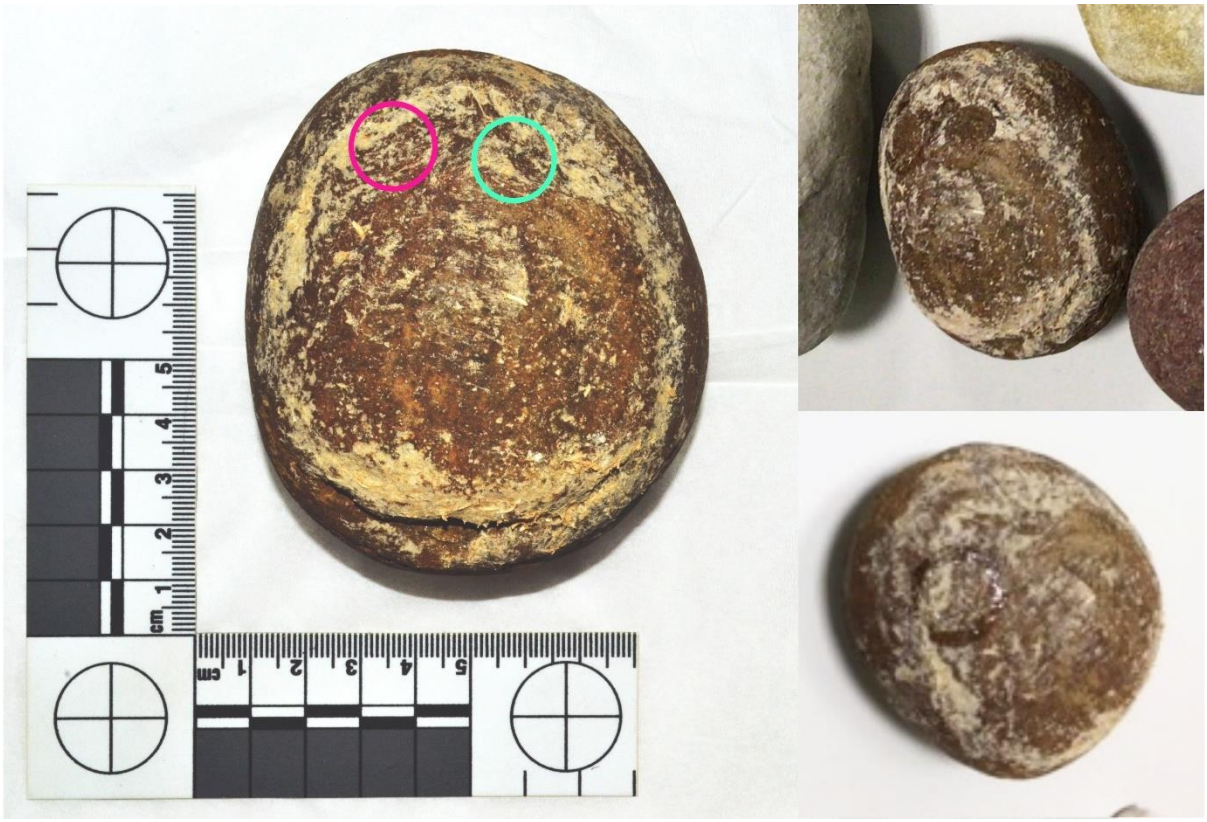
F-33 | D. carota Root | 7:07



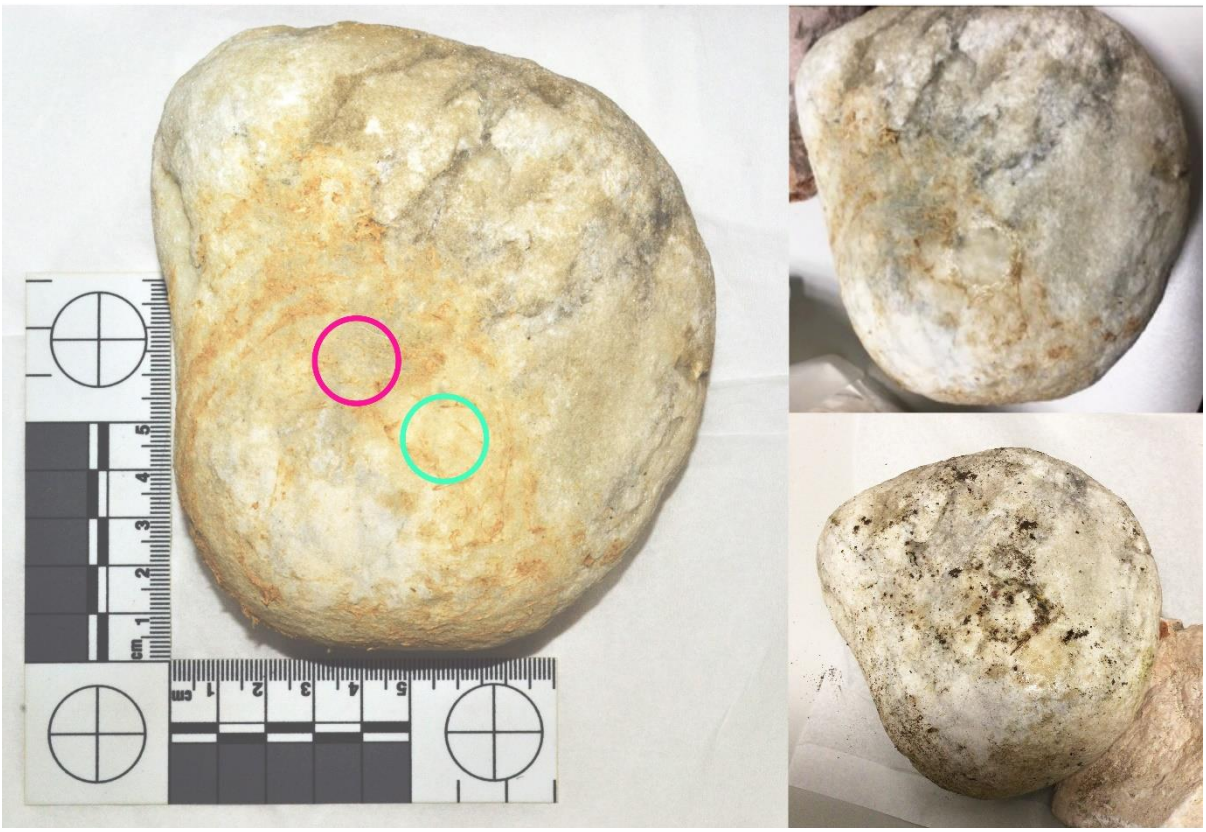
F-34 | D. carota Root | 4:07

Runners

GS-01 | T. latifolia Fresh| 17:00



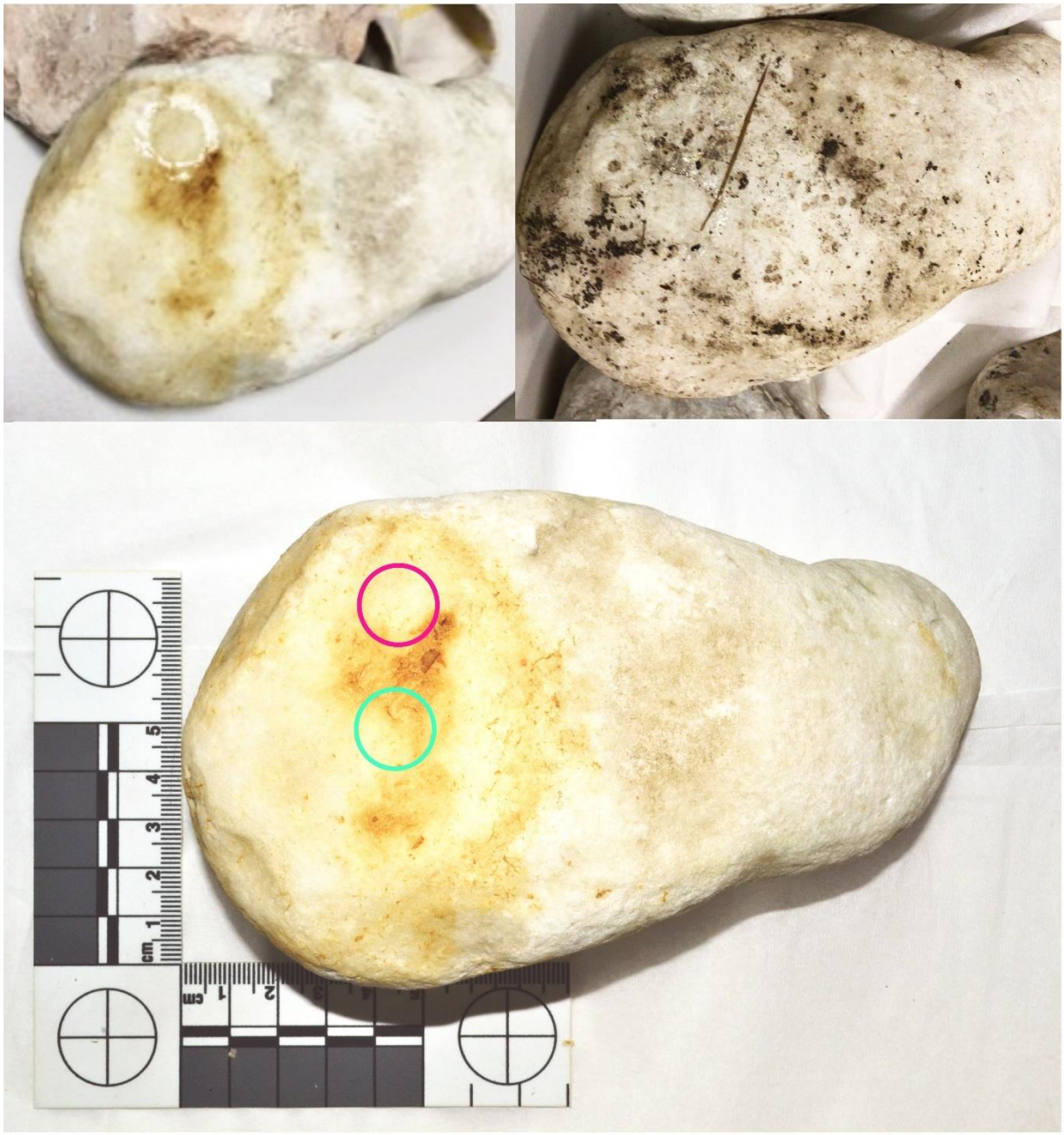
GS-02 | T. latifolia Fresh | 10:49



GS-03 | T. latifolia Dry| 19:00

GS-04 | T. latifolia Dry | 17:35

GS-05 | D.carota Fresh | 14:23



GS-06 | D.carota Fresh | 10:31

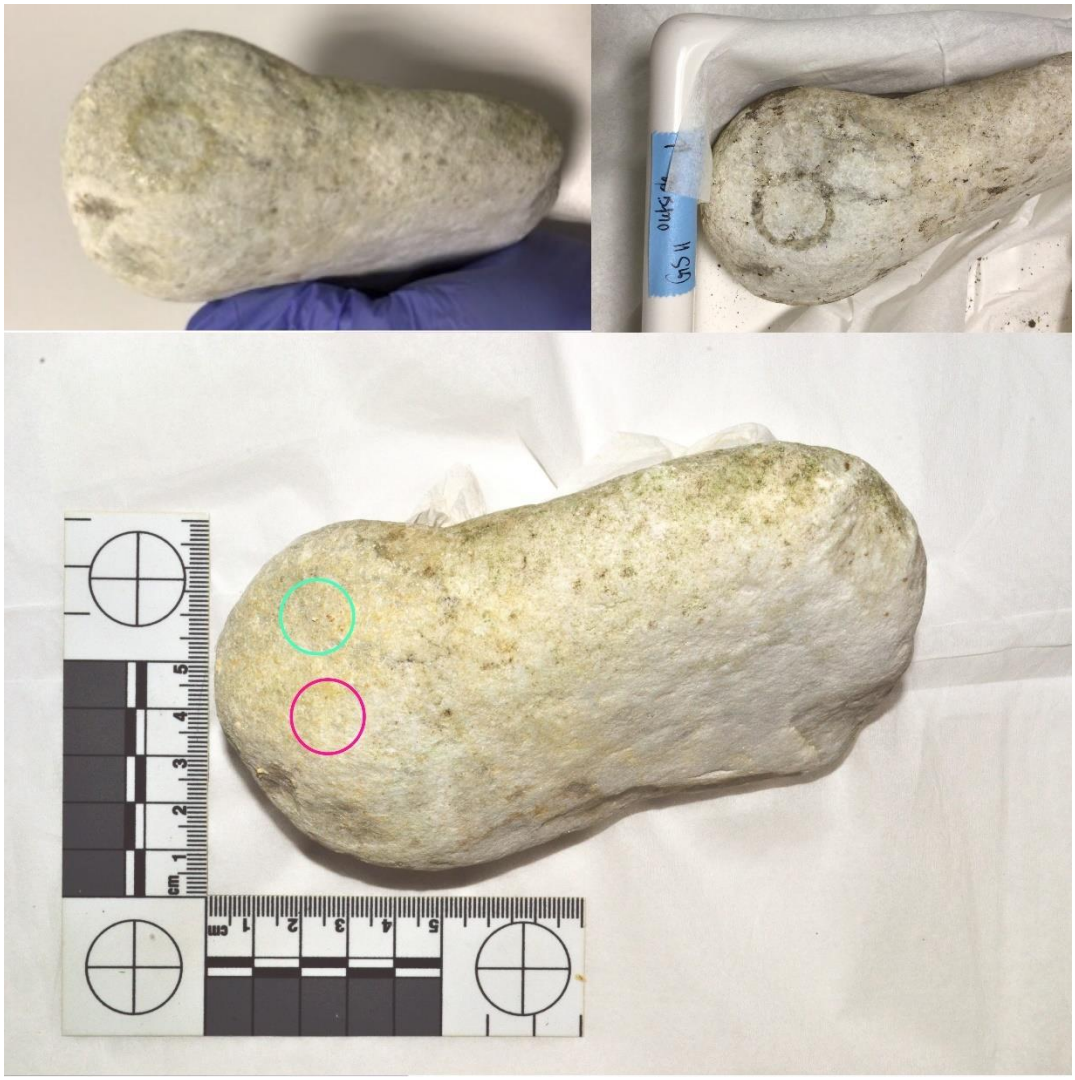
GS-07 | D.carota Dry | 12:19

GS-08 | *D. carota* Dry | 18:00

GS-09 | *Anthriscus* sp. Fresh | 9:40

GS-10 | *Anthriscus* sp. Fresh | 10:00

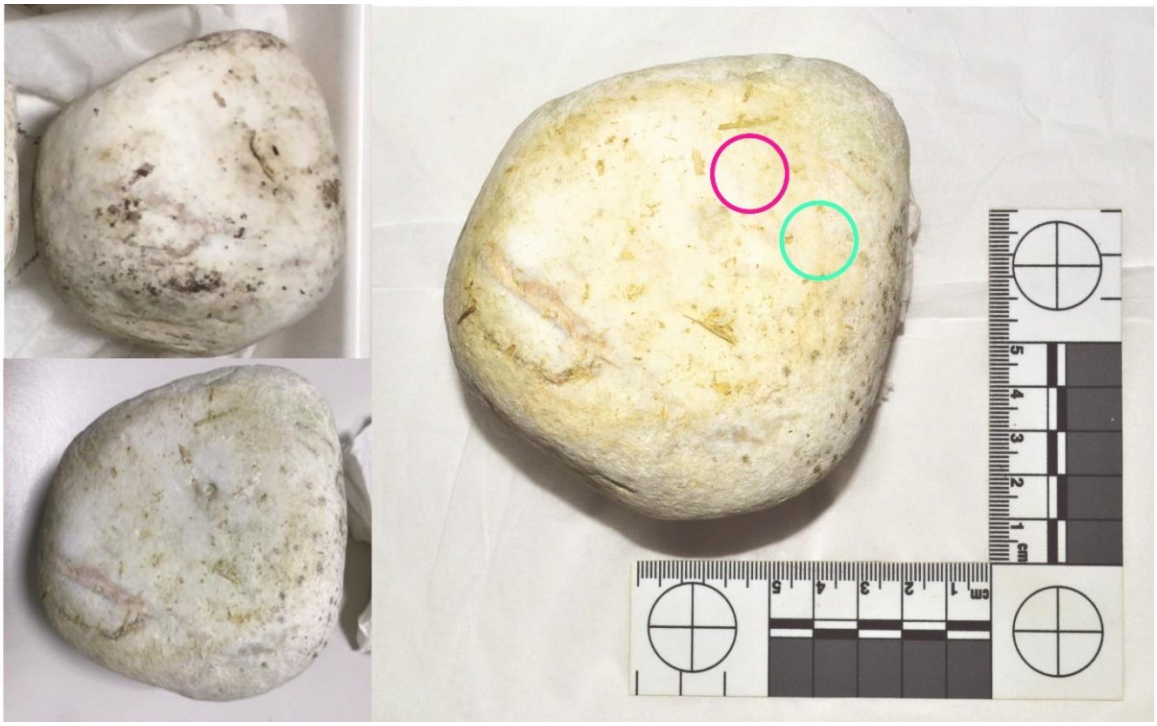
GS-11 | *Anthriscus* sp. Dry | 9:15



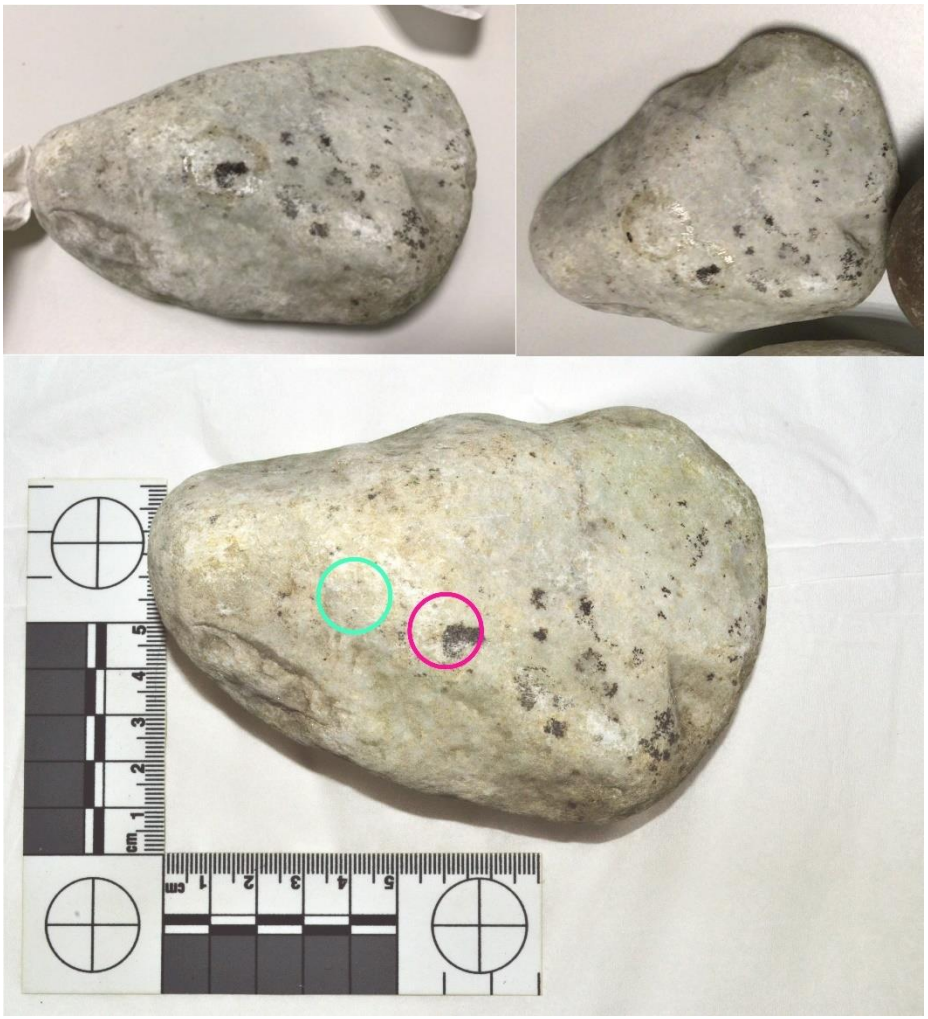
GS-12 | *Anthriscus* sp. Dry | 9:45

GS-13 | *P. australis* Fresh | 12 :15

GS-14 | *P. australis* Fresh | 15 :00



GS-15 | *P. australis* Dry | 13 :00



GS-16 | *P. australis* Dry | 12 :15

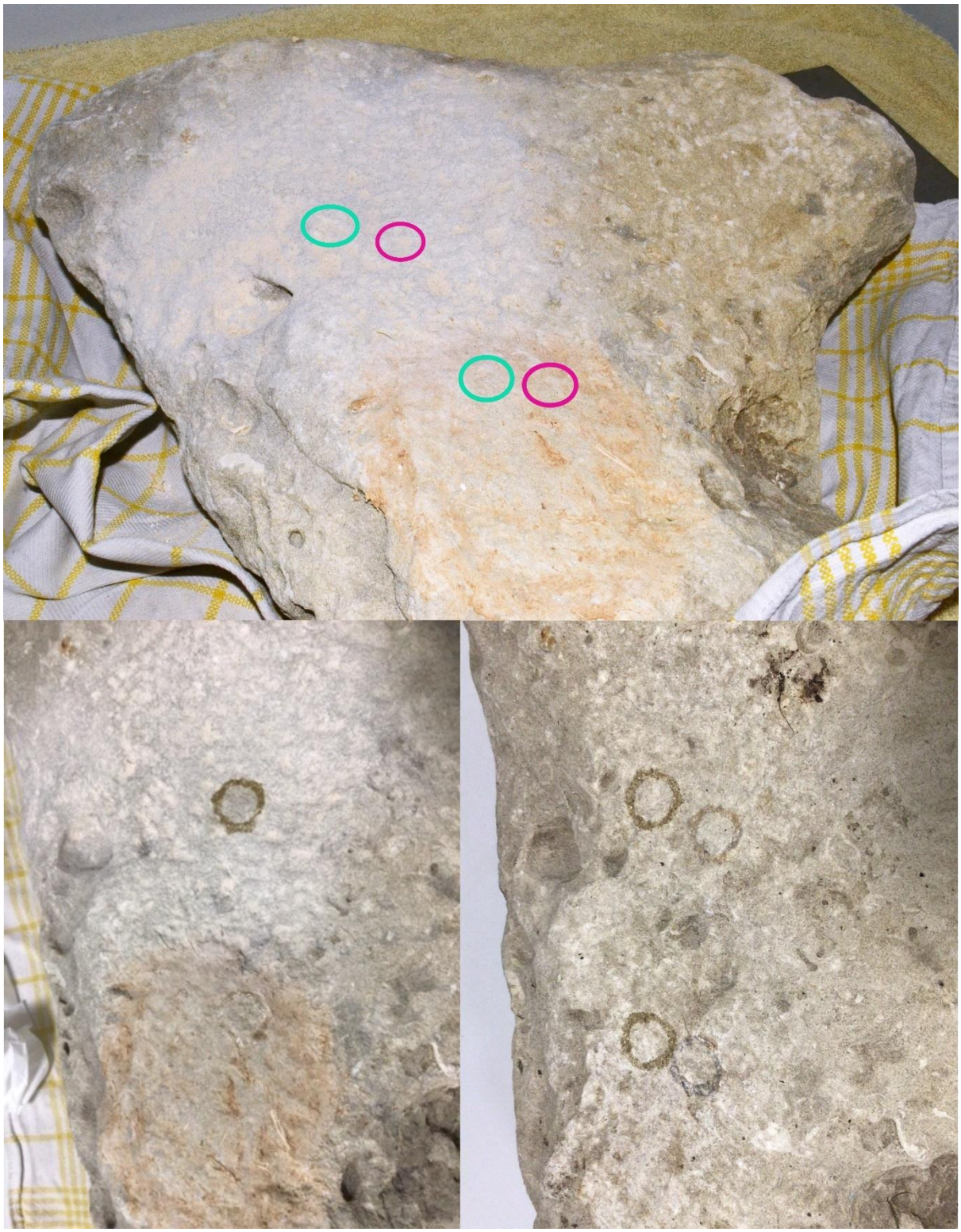
Grinding slabs

GS1 *D. carota*:

Top, post processing. Bottom left, sampling ‘Outside’, bottom right sampling ‘Before’.

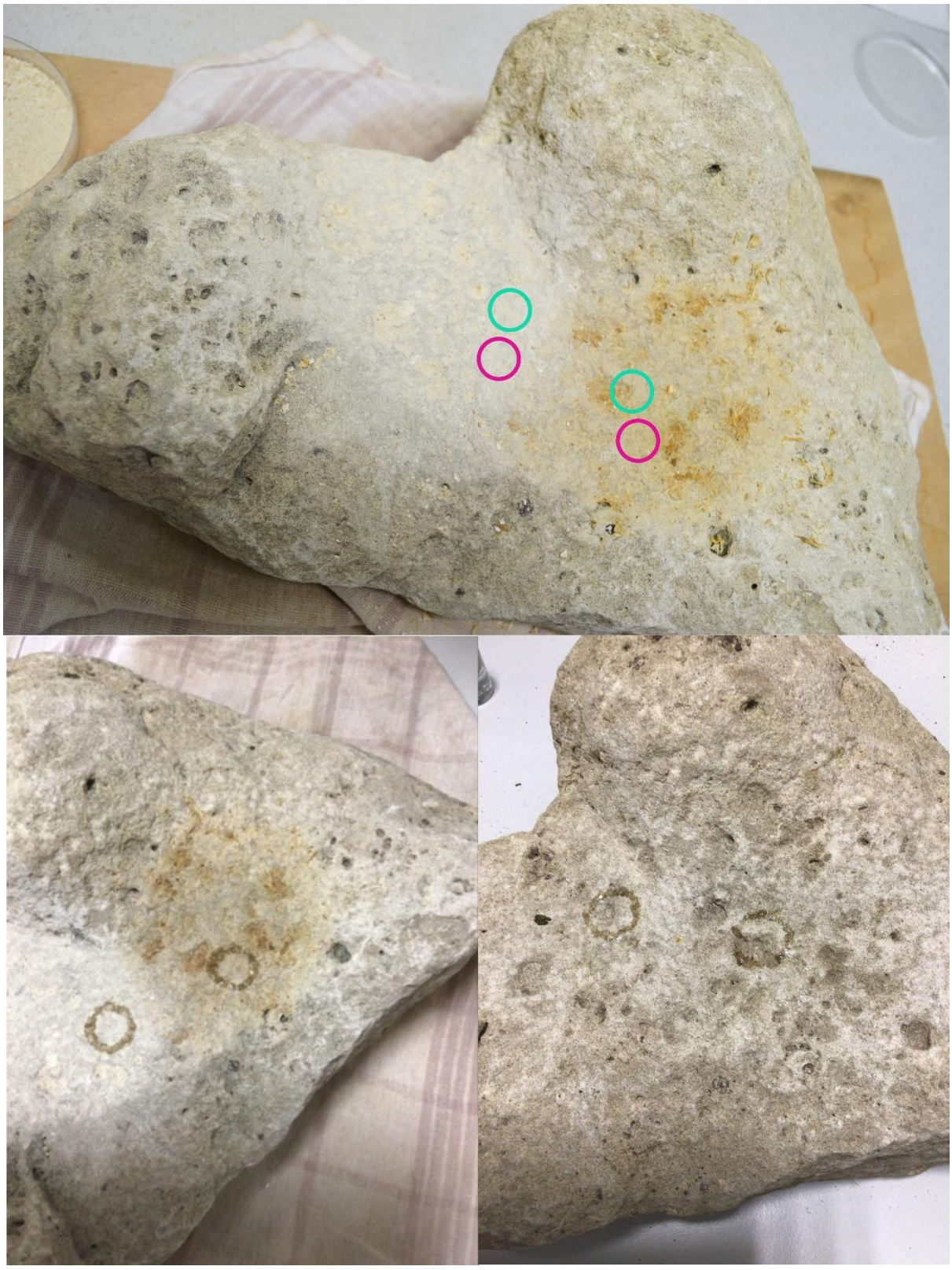
GS1 *T. latifolia* :

Top, post processing, bottom left ‘Before’ sampling, bottom right ‘Outside’ sampling.



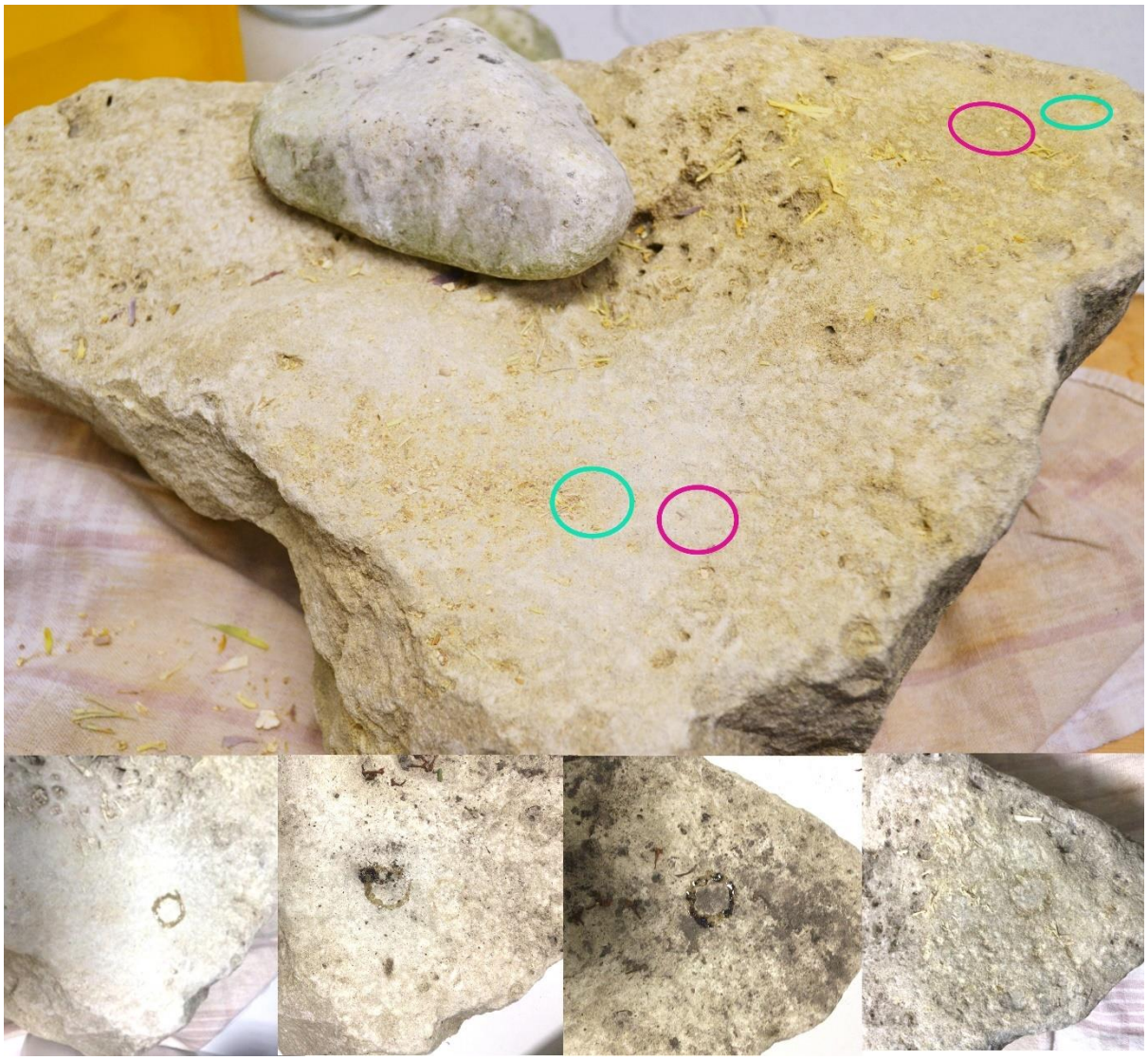
GS2 *Anthriscus* sp. :

Top, post processing, bottom left ‘Before’ sampling, bottom right ‘Outside’ sampling.



GS2 *P. australis*:

Top, post processing, bottom left sampling dry processing area for ‘Before’ and ‘Outside’, bottom right sampling fresh processing area for ‘Outside’ and ‘Before’.



APPENDIX C: PHYTOLITH COUNT PER TOOL

Below the tools and the phytolith count can be seen organised per tool group and their sampling condition (indicated behind the tool ID with a letter). Starting with Flint, Runners and finishing with Grinding slabs.

Tool ID	Phytolith count	Tool ID	Phytolith count	Tool ID	Phytolith count
F-25-B	3489	F-27-I	3117	F-23-O	11008
F-26-B	940	F-28-I	2375	F-24-O	3814
F-29-B	367	F-31-I	917	F-33-O	808
F-30-B	708	F-32-I	0	F-34-O	441
F-17-B	30031	F-15-I	19452	F-13-O	8697
F-18-B	23904	F-16-I	8414	F-14-O	14109
F-01-B	2662	F-19-I	16467	F-21-O	2371
F-02-B	5456	F-20-I	21248	F-22-O	10692
F-07-B	183923	F-03-I	3363	F-05-O	1250
F-08-B	8200	F-04-I	6091	F-06-O	1292
		F-09-I	8401	F-11-O	1555
		F-10-I	4809	F-12-O	3134

Tool ID	Phytolith count	Tool ID	Phytolith count	Tool ID	Phytolith count
GS-09-B	0	GS-12-I	19360	GS-09-O	34848
GS-10-B	4114	GS-10-I	5518	GS-11-O	47916
GS-11-B	63549	GS-07-I	3969	GS-05-O	77440
GS-12-B	22216	GS-06-I	29137	GS-08-O	30492
GS-05-B	6679	GS-15-I	5372	GS-14-O	25555
GS-06-B	11616	GS-13-I	72794	GS-16-O	7841
GS-07-B	23232	GS-03-I	169206	GS-02-O	47916
GS-08-B	23232	GS-01-I	61178	GS-04-O	16214
GS-13-B	12003				
GS-14-B	5518				
GS-15-B	7115				
GS-16-B	32186				
GS-01-B	6873				
GS-02-B	7115				
GS-03-B	4259				
GS-04-B	15488				

Tool ID	Phytolith count	Tool ID	Phytolith count
GS2-ADB	110739	GS2-ADO	7744
GS2-AFB	27104	GS2-AFO	4888
GS1-DDB	2952	GS1-DDO	229997
GS1-DFB	0	GS1-DFO	28120
GS2-PDB	52853	GS2-PDO	129131
GS2-PFB	625323	GS2-PFO	168335
GS1-TDB	8712	GS1-TDO	13552
GS1-TFB	61178	GS1-TFO	14520

APPENDIX D: DATABASE

The following tables are the data that was procured and documented during the analysis of the experimentation and analysis of the material.

Flint tools

Tool ID	Condition	Plant	Processing time	Volume Sample µl	Damaged starches slide	Starch count slide	Material condition	Phytolith count	Action
F-01-B	Before	Typha	07:05:00	650	798	2336	Fresh	6	Shaving/ scraping
F-02-B	Before	Typha	05:30:00	452	940	3031	Fresh	15	Sawing
F-03-I	Inside	Typha	09:19:00	460	79	590	Fresh	5	Shaving/ scraping
F-04-I	Inside	Typha	09:17:00	206	765	2340	Fresh	14	Sawing
F-05-O	Outside	Typha	11:05:00	141	2	2	Fresh	7	Shaving/ scraping
F-06-O	Outside	Typha	11:20:00	136	0	0	Fresh	15	Sawing
F-07-B	Before	Typha	08:00:00	281	602	882	Fresh	9	Shaving/ scraping
F-08-B	Before	Typha	03:00:00	336	494	1381	Fresh	6	Sawing
F-09-I	Inside	Typha	12:00:00	416	63	294	Fresh	17	Shaving/ scraping
F-10-I	Inside	Typha	02:25:00	253	270	2077	Fresh	14	Sawing
F-11-O	Outside	Typha	11:20:00	360	7	7	Fresh	5	Shaving/ scraping
F-12-O	Outside	Typha	02:42:00	212	9	9	Fresh	7	Sawing
F-13-O	Outside	Phragmites	10:43:00	286	0	0	Fresh	24	Shaving/ scraping
F-14-O	Outside	Phragmites	07:20:00	131	2	2	Fresh	34	Sawing
F-15-I	Inside	Phragmites	15:00:00	199	59	109	Fresh	27	Shaving/ scraping
F-16-I	Inside	Phragmites	06:25:00	498	53	79	Fresh	8	Sawing
F-17-B	Before	Phragmites	07:30:00	350	147	595	Fresh	14	Shaving/ scraping
F-18-B	Before	Phragmites	04:35:00	297	384	527	Fresh	38	Sawing
F-19-I	Inside	Phragmites	08:21:00	402	23	153	Fresh	28	Shaving/ scraping
F-20-I	Inside	Phragmites	04:34:00	228	19	141	Fresh	38	Sawing
F-21-O	Outside	Phragmites	08:23:00	147	0	0	Fresh	14	Shaving/ scraping
F-22-O	Outside	Phragmites	04:50:00	476	0	0	Fresh	26	Sawing
F-23-O	Outside	Anthriscus	16:43:00	139	1	1	Fresh	25	Shaving/ scraping
F-24-O	Outside	Anthriscus	04:16:00	301	1	1	Fresh	7	Slicing
F-25-B	Before	Anthriscus	19:24:00	433	322	580	Fresh	5	Shaving/ scraping
F-26-B	Before	Anthriscus	03:51:00	303	990	2007	Fresh	3	Slicing

F-27-I	Inside	Anthriscus	17:32:00	287	603	861	Fresh	3	Shaving/ scraping
F-28-I	Inside	Anthriscus	04:50:00	328	236	694	Fresh	2	Slicing
F-29-B	Before	Daucus	04:00:00	190	527	2251	Fresh		Splitting
F-30-B	Before	Daucus	06:30:00	115	978	2514	Fresh	3	Slicing
F-31-I	Inside	Daucus	08:04:00	193	2625	4555	Fresh	2	Splitting
F-32-I	Inside	Daucus	03:10:00	188	262	609	Fresh	0	Slicing
F-33-O	Outside	Daucus	07:07:00	158	0	0	Fresh	7	Splitting
F-34-O	Outside	Daucus	04:07:00	142	2	2	Fresh	2	Slicing

Runners

Slide ID	Condition	Plant	Processing time	Volume Sample µl	Damaged starches slide	Starch count slide	Material condition	Phytolith count
GS-01-B	Before	Typha	17:00:00	71	644	811	Fresh	2
GS-01-I	Inside	Typha	17:00:00	100	644	4848	Fresh	4
GS-02-B	Before	Typha	10:49:00	49	658	722	Fresh	3
GS-02-O	Outside	Typha	10:49:00	66	1	1	Fresh	15
GS-03-B	Before	Typha	19:00:00	22	351	675	Dry	4
GS-03-I	Inside	Typha	19:00:00	114	263	332	Dry	1
GS-04-B	Before	Typha	17:35:00	40	1064	1621	Dry	8
GS-04-O	Outside	Typha	17:35:00	67	3	5	Dry	5
GS-05-B	Before	Daucus	14:23:00	69	276	518	Fresh	2
GS-05-O	Outside	Daucus	14:23:00	100	2	2	Fresh	16
GS-06-B	Before	Daucus	10:31:00	80	852	1055	Fresh	3
GS-06-I	Inside	Daucus	10:31:00	82	43	79	Fresh	1
GS-07-B	Before	Daucus	12:19:00	30	477	740	Dry	16
GS-07-I	Inside	Daucus	12:19:00	86	71	113	Dry	7
GS-08-B	Before	Daucus	18:00:00	60	269	374	Dry	8
GS-08-O	Outside	Daucus	18:00:00	90	6	6	Dry	7
GS-09-B	Before	Anthriscus	09:40:00	70	332	369	Fresh	0
GS-09-O	Outside	Anthriscus	09:40:00	90	8	8	Fresh	8
GS-10-B	Before	Anthriscus	10:00:00	85	96	115	Fresh	1
GS-10-I	Inside	Anthriscus	10:00:00	111	615	835	Fresh	1
GS-11-B	Before	Anthriscus	09:15:00	101	1984	2278	Dry	13
GS-11-O	Outside	Anthriscus	09:15:00	110	6	6	Dry	9
GS-12-B	Before	Anthriscus	09:45:00	51	2404	3384	Dry	9
GS-12-I	Inside	Anthriscus	09:45:00	188	742	838	Dry	8
GS-13-B	Before	Phragmites	12:15:00	31	75	83	Fresh	8
GS-13-I	Inside	Phragmites	12:15:00	184	21	27	Fresh	19
GS-14-B	Before	Phragmites	15:00:00	38	3	3	Fresh	3
GS-14-O	Outside	Phragmites	15:00:00	48	0	0	Fresh	11
GS-15-B	Before	Phragmites	13:00:00	21	26	26	Dry	7
GS-15-I	Inside	Phragmites	13:00:00	79	17	19	Dry	16
GS-16-B	Before	Phragmites	12:15:00	35	84	84	Dry	19
GS-16-O	Outside	Phragmites	12:15:00	81	0	0	Dry	2

Grinding stone

Slide ID	Condition	Plant	Processing time	Volume Sample µl	Damaged starches slide	Starch count slide	Material condition	Phytolith count slide
GS2-ADB	Before	Anthriscus	19:00:00	1144	717	874	Dry	2
GS2-AFB	Before	Anthriscus	19:40:00	80	759	861	Fresh	7
GS1-DDB	Before	Daucus	20:19:00	61	602	647	Dry	1
GS1-DFB	Before	Daucus	24:54:00	51	247	480	Fresh	0
GS2-PDB	Before	Phragmites	25:15:00	52	79	87	Dry	21
GS2-PFB	Before	Phragmites	27:15:00	34	94	142	Fresh	38
GS1-TDB	Before	Typha	36:35:00	60	3777	4150	Dry	3
GS1-TFB	Before	Typha	28:00:00	158	922	1306	Fresh	8
GS2-ADO	Outside	Anthriscus	19:00:00	40	52	54	Dry	4
GS2-AFO	Outside	Anthriscus	19:40:00	101	5	5	Fresh	1
GS1-DDO	Outside	Daucus	20:19:00	216	3	3	Dry	22
GS1-DFO	Outside	Daucus	24:54:00	83		1	Fresh	7
GS2-PDO	Outside	Phragmites	25:15:00	116	0	0	Dry	23
GS2-PFO	Outside	Phragmites	27:15:00	74	0	0	Fresh	47
GS1-TDO	Outside	Typha	36:35:00	70	3	3	Dry	4
GS1-TFO	Outside	Typha	28:00:00	50	30	31	Fresh	6