Dairy consumption in Neolithic Anatolia in relation to the 8.2 ka event

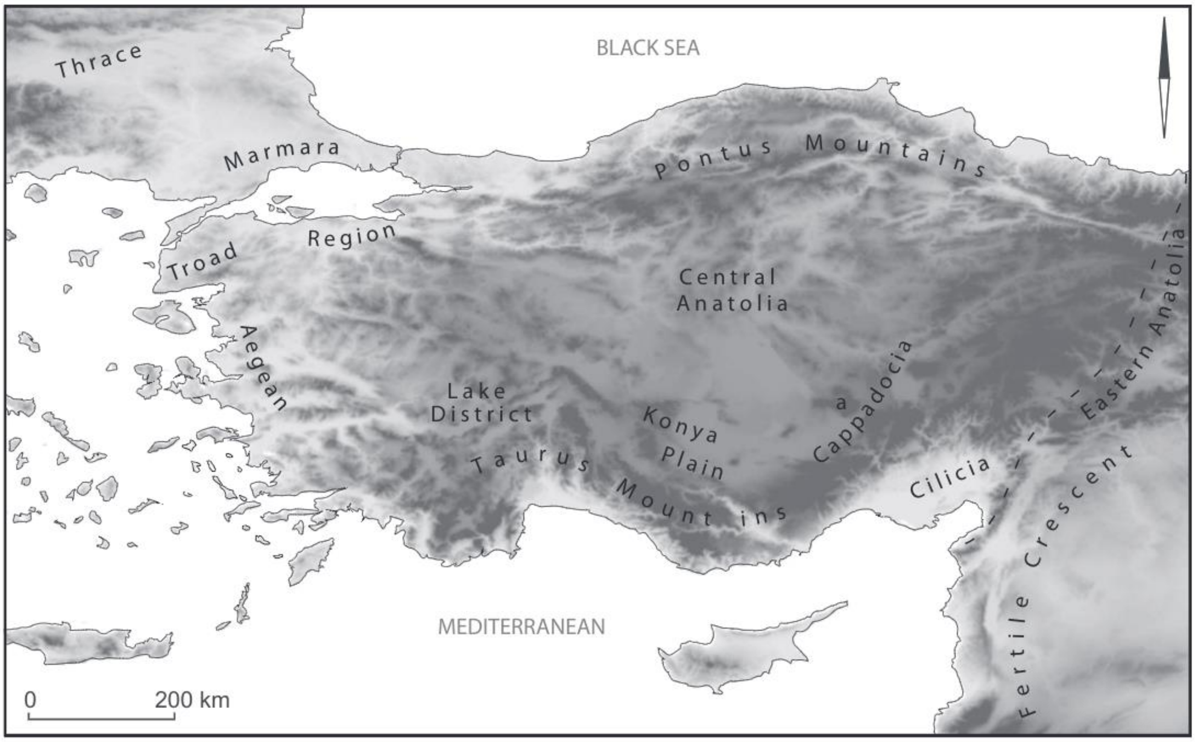

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Figure front page. After Düring 2011.

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Thank you to my mom and dad for all the faith you have in me.

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for all the help, all the late nights, every spellcheck and all the brainstorm-sessions. Without you this paper would be three pages long.
You are the best. Ever.

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1. Introduction

As in most fields, archaeological research can be seen to follow trends based on current events. On a worldwide scale, probably due to the threat and urgency of the current climate crisis, an increasing amount of research is being done on global warming and climate change, both past and present. Archaeology, logically, researches the impact of past climate change on human populations. One such climatic event is the so-called ‘8.2 ka event’, named after the time at which it took place, at ca. 8.200 BP (Before Present). This global climate event, as will be discussed in more detail later, caused lower average temperatures and decreased precipitation, mostly in the Northern Hemisphere. In calibrated years BCE (Before Common Era), it can be said to have taken place between ca. 6.300 - 6.100 BCE (Alley and Ágústsdóttir 2005; Düring 2016, 138).

While the effects of the 8.2 ka event can be measured on a global scale, its impact on a local scale probably varies greatly, depending on local geography and environmental conditions. Within the field of archaeology, the main research topic in relation to the event is whether it influenced human behaviour and cultural developments, or even caused the displacement of populations. Since the event took place during the Neolithic in the Near East, researchers have questioned whether it influenced developments at this time of innovation and cultural change (Düring 2016, 136-137; Nieuwenhuyse and Biehl 2016, 2).

Archaeological and climatological research has proposed several ways in which the 8.2 ka event may have influenced life in the Near East. Theories vary greatly, with some researchers proposing that the event led to societal collapse or warfare, while others argue for migration, local adaptation or simple continuation. For instance, in the past two decades, a multitude of studies has been done on the relationship between the event and the spread of the Neolithic into western Anatolia and Europe (Asouti 2009; Düring 2016). On a different scale, questions relating to specific sites have been aimed at settlement patterns and their shifts, such as changes in settlement organisation in Tell Sabi Abyad (Syria), or the transition between Çatalhöyük’s East and West Mound (Anatolia) (Nieuwenhuyse *et al.* 2016; Van der Plicht *et al.* 2011; Willett *et al.* 2016). Inter-settlement conflict or war is also theorised to have been connected with the 8.2 ka event (Clare *et al.* 2008). On the other hand, fewer questions have been asked about how subsistence strategies changed, while this might be interesting since the effects of the climate event may have influenced both plants and animals and the way they were exploited by humans. Changes in animal management techniques, exploitation patterns and shifts in *which* animals were held might be correlated to the event.

This thesis aims to assess whether there is a correlation between the event and increased reliance on dairy consumption. The region on which I will focus is Anatolia, since some of the earliest evidence for dairy consumption is found there, and because the region is of vital importance in studying the Neolithic in the Near East. No previous studies have been done on this scale on this specific topic to my knowledge. If a correlation can be found between the climate event and this specific change in subsistence patterns, however, it may shed light on human coping mechanisms in times of climate change. The main research question of this thesis is:

> Can the intensification of dairy consumption in Anatolia be correlated to the 8.2 ka event?

To answer this question, several themes have to be discussed. First, an introduction to the Anatolian Neolithic will be given to provide the backdrop for the discussion. This introduction will also contain an overview of the distinct regions and key sites in Neolithic Anatolia. Second, a delve into the 8.2 ka event and its effects are in order. The climatic influence may differ per region and so may the possible effects on populations. Next, an overview of the currently available evidence for dairy consumption per region is given. This is divided into three kinds of evidence: genetic evidence for lactase persistence, lipid residues in pottery and culling profiles based on archaeozoological remains.

I will approach the research question through a literature study. This study will mostly focus on secondary sources, as the focal point of this thesis is on providing an overview and discovering if there is a correlation between certain events in different regions. I will critically compare the evidence from various sources and authors, keeping in mind the limits of the available data. I will also critically review the concepts of synchronicity, causality and correlation, to ascertain to which extent archaeological evidence can provide an answer to the main question, or what is needed from future research. Finally, I endeavour to answer the main question by seeking out diachronic trends in the currently available evidence and evaluating if these trends might be correlated to the 8.2 ka event.

2. Anatolia and the 8.2 ka event

The question of whether the 8.2 ka event can be correlated to the intensification of dairy consumption in Anatolia is not easily answered; some matters must first be addressed. Firstly, the stage must be set through an introduction of the Anatolian Neolithic and subsequent spread of neolithisation. To provide a clear picture, the climatic conditions and environmental variations of the Anatolian regions must be included as well. In this introduction, the earliest and most important Neolithic sites will be discussed. Finally, this chapter will provide an overview of what the 8.2 ka event is, the possible impact it had on the various regions of Anatolia, and the kinds of climatological data in which this impact is visible.

2.1 The Anatolian Neolithic

Archaeological research into the Anatolian Neolithic and neolithisation started rather late; Neolithic occupational phases were hardly known until the 1950s. Until then it was assumed that most of Anatolia was uninhabited until the Chalcolithic Period (Kuzucuoğlu 2015). However, the excavations led by James Mellaart at Hacılar changed that conception (Brami and Heyd 2011, 166; Watkins 2016, 35). Scores of other Neolithic sites were discovered in the decades that followed. The Chalcolithic period in Anatolia starts between 6.000 - 5.500 BCE, depending on the region.

2.1.1 The origin of the Neolithic and its spread in Anatolia

The definition of the 'Neolithic lifestyle' and the time it started depends on which characteristic one wishes to stress. For instance, focusing on sedentism as the defining factor leads to considerably earlier dates than using the appearance of ceramic technology. For this paper, the defining factor for Neolithisation will be the domestication of plants and animals, because while sedentary hunter-gatherer-fisher communities are seen from the late Palaeolithic onwards, farming led to the further spread and consolidation of sedentism and other aspects of the Neolithic way of life (Düring 2013, 75).

Until recently, there was a tendency to underline the grand narratives about the dawn of the Neolithic in secondary literature, wherein sedentary groups of hunter-gatherers were inadvertently started on the path to the Neolithic Revolution when faced with harsh conditions which led to the invention of agriculture (Düring

2013, 76). Recent research has significantly complicated this narrative, however, emphasising the heterogeneous and polycentric nature of the process of neolithisation (Arbuckle 2014; Arbuckle and Atici 2013; Düring 2011, 48-50; Fuller *et al.* 2012). The narrative is complicated by the discovery that domestication of plants and animals happened in several core regions in the Fertile Crescent and under different cultural circumstances. While earlier theories put the centre of domestication in the southern Levant, specifically among the Late-Epipalaeolithic Natufians, recently researchers also emphasise the northern parts of the Fertile Crescent, among the foothills of the Taurus and Zagros mountain ranges. Overall, the regions that played a key role in the establishment of the Neolithic way of life are Upper Mesopotamia, the southern Levant and Central Anatolia (Düring 2011, 48-49). Both in time and space, the development and invention of farming cover more ground than the original, Levant-centered narrative could accomplish.

In this context, a distinction should be made between domestication and cultivation: the latter is the act that people carry out, for instance tilling the soil, planting the seeds, and harvesting, while the former is a property of the plant, i.e. the physical and genetic changes which make it more suitable for cultivation (Fuller *et al.* 2012, 622). Based on morphological changes in the grains found in excavations, the earliest evidence for the domestication of crops comes from the 10th and 9th millennium BCE in the Fertile Crescent (Baird *et al.* 2018, E3077). On the other hand, the earliest indications of cultivation date to ca. 11.000 BCE at the site of Abu Hureyra (Fuller *et al.* 2012, 623). Some of the earliest evidence of plant domestication can be found in a few regions, like South-eastern Anatolia at the sites of Cafer Höyük, Nevalı Çori and Çayönü, dating to ca 8.700 - 8.200 BCE, while around the same time both in Nevalı Çori (South-eastern Anatolia, ca. 8.500 BCE) and Dja’de (Northern Syria, ca. 8.500 BCE) evidence has been found of early domestication of sheep, goats and cattle (Düring 2011, 48; Stiner *et al.* 2014, 8409; Vigne 2008, 181). To describe relationships between people and animals, a similar distinction is made between actual domestication and practices like herding, commensalism and pet keeping (Arbuckle 2014, 54). The intensification of animal management is difficult to see in the archaeozoological record because the line between changing hunting strategies and changing management strategies can be difficult to determine. For instance, in the northern Zagros area, some of the earliest instances of possible animal management are found at Shanidar Cave and Zawi Chemi Shanidar. A clear pattern of juvenile culling at these sites was first identified as intensive herd management, while a recent re-evaluation of the assemblage linked it to a shift in hunting strategies which can be seen in the wider geographic area at that time (Arbuckle 2014, 64).

The examples mentioned above are meant to illustrate that domestication did not happen overnight but instead was the result of changing forms and intensities of management of the wild progenitors of domesticates. Increasingly, research indicates that the development of plant and animal management strategies and domestication took centuries and was subject to both local environmental conditions as well as local cultural traditions and preferences (Arbuckle 2014, 72; Düring 2011, 49).

The same holds true for the spread of the Neolithic way of life, which happened in Anatolia during the seventh millennium BCE. In contrast to the origin of the Neolithic, its spread in Anatolia has only been studied in-depth since the mid-1990s, when questions about the later phases of neolithisation took precedence (Çilingiroğlu and Çakırlar 2013, 21; Düring 2013, 76). Before, research mostly focused on the when, where and how of the Neolithic transition, thereby condensing it to a threshold event during the Early Neolithic, while the subsequent spread of the Neolithic lifestyle was seen as self-evident (Düring 2011, 122-123; Düring 2013, 76). However, in recent decades an increasing number of studies has been carried out on Neolithic occupations during the millennia following the initial transition, shedding light on the ways in which Neolithic expansion occurred in the Near East.

The earliest Neolithic strata in Anatolia – outside of the Fertile Crescent which includes South-eastern Anatolia – are found in Central Anatolia, at the sites of Aşıklı Höyük (ca. 8.500 - 7.500 BCE), Pınarbaşı (ca. 9.800 - 7.800 BCE) and Boncuklu Höyük (ca. 8.500 - 7.500 BCE) (figure 1; Baird *et al.* 2018, E3077-E3078; Düring 2011, 52). These sites all date to the 9th millennium BCE, and their chipped stone industries share many characteristics with those of the Epipalaeolithic and Mesolithic cultures that predate them, thus indicating that the pre-existing groups that lived on the Central Anatolian Plateau were involved in the adaptation to the Neolithic lifestyle (Düring 2011, 51-52). The earliest indications of Neolithic settlement in the west and north-west of Anatolia date to the beginning of the 7th millennium BCE at sites such as Bademağacı (ca. 6.800 BCE) and Ulucak (ca. 6.700 BCE), while the true abundance of evidence for Neolithic occupation in these regions dates to the second half of that millennium. Moreover, the expansion of Neolithic occupations into the west after 6.500 BCE probably happened extraordinarily fast, within the span of a century (Düring 2013, 79-80). This rapid expansion is remarkable, especially given the fact that for more than 1.500 years the Neolithic did not expand beyond Central Anatolia. While a definitive explanation for the rapid expansion has not been stipulated, it is probably a complex mixture of factors, such as technological and agricultural advancements, cultural preferences and developments, demographic changes and changes in ecological conditions and climate[1] (Düring 2013, 82).

Within the scope of this paper, it is interesting to note that, quite recently, some researchers linked the 8.2 ka event to the expansion of the Neolithic to western Anatolia and Europe. The perceived chronological fit between the climate event and the migration of Neolithic farmers to the west led to the assumption that climate change triggered the displacement of early farmers (Düring 2016, 135-136). The correlation between the introduction of farming and the 8.2 ka event has since been debunked, partly based on chronological incoherency, and partly on the basis that the actual effects of the climate event are not yet fully comprehended (Düring 2016, 146).

Finally, specific attention must be given to the domestication of the main livestock animals – meaning sheep, goats, cattle and pigs – and the subsequent spread and development of animal husbandry practices in Anatolia, specifically to which extent and in which configuration animals were domesticated at the end of the 7th millennium. For instance, in Central Anatolia only sheep and goats were domesticated at first, cattle following a millennium later, while pigs were not incorporated until the 5th millennium BCE. All four of the previously mentioned domesticates were present at sites in the southwest and west of Anatolia, but in the north-west, pigs were domesticated after the 7th millennium (Arbuckle *et al.* 2014, 7). The most important lesson to draw from this is that there is no uniformity in the domestication; animal assemblages differ from site to site, according to all kinds of factors, such as geography, cultural preferences and habits, and environmental conditions (Arbuckle *et al.* 2014, 7-8). These data, however, only indicate the *presence* of certain domesticates in these regions. The exact configurations and exploitation patterns of the animal assemblages will be discussed in chapter 3.3 per region.

2.1.2 Regions and key sites

In Anatolia, the Neolithic way of life remained confined in the Central Anatolian steppe region for nearly two millennia before it spread further to the west (Düring 2013, 76). The debate on how and why the Neolithic lifestyle was contained in this

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[1] For an extensive discussion of these factors, see Düring 2013.

region for so long is still ongoing, but one of the factors that are frequently mentioned is the environmental and climatic conditions of Central Anatolia. These greatly resemble the Fertile Crescent, thus providing suitable conditions for the plants and animals which had then only quite recently been domesticated (Düring 2013, 83). In comparison, the environmental conditions of the western and north-western regions of the Anatolian peninsula are significantly different, which may have impeded the spread of the domesticates to these regions. To further clarify the regional differences, an introduction must be given to the geography of Anatolia.

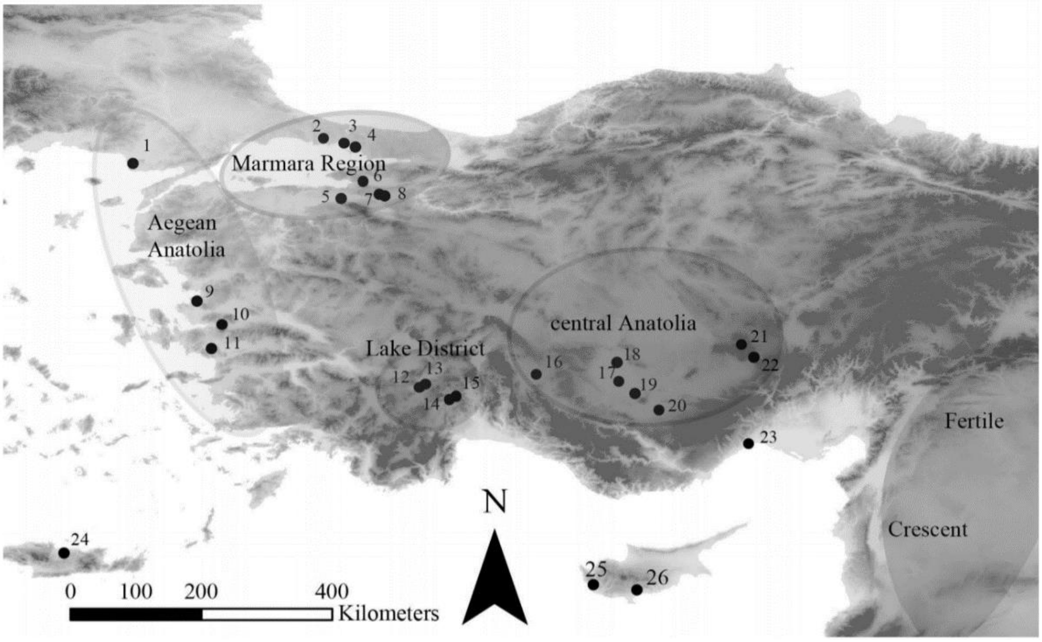

Figure 1. Neolithic sites of Anatolia. 1-Hoca Çesme; 2-Yarımburgaz and Yenikapı; 3-Fikirtepe; 4-Pendik; 5-Aktopraklik; 6-Ilıpnar; 7-Mentese; 8-Barcın Höyük; 9-Ege Gübre; 10-Ulucak; 11-Dedecik-Heybelitepe; 12-Hacılar; 13-Kuruçay; 14-Bademağacı; 15-Höyücek; 16-Erbaba; 17-Çatalhöyük East and West; 18-Boncuklu Höyük; 19-Pınarbaşı; 20-Canhasan; 21-Aşıklı Höyük; 22-Kaletepe; 23-Mersin-Yumuktepe; 24-Knossos; 25-Mylouthkia; 26-Shillourakambos. After Düring 2016.

Neolithic Anatolia can be roughly divided into five main regions based on their geography and archaeology: South-eastern Anatolia (the Anatolian part of the Fertile Crescent), Central Anatolia, the Lake District, Aegean Anatolia and the Marmara Region (figure 1). The geography of Anatolia cannot easily be summarised because of its diversity. Each of the aforementioned regions is characterised by its own climatic and geological conditions, and even within these regions, there is an incredible diversity in microhabitats. The diversity of the land is mostly determined by the multitude of mountain ranges that shape the environments, for instance, due to their influence on the hydrology and geomorphology of the surrounding terrains. Moreover, the entire peninsula is surrounded by four seas which influence the hydrology and climate of both the coastal and inland parts.

South-eastern Anatolia. This region corresponds to the mountains and valleys of the eastern Taurus mountain range. It is part of the Fertile Crescent, including the head valleys of both the Tigris and the Euphrates (Kuzucuoğlu 2015). The region is located north of the ~400 mm isohyet, which indicates that there is enough annual rainfall to support dry farming in this region (Rosenberg and Erim-Özdoğan 2011, 125). The Neolithic sites can all be found near these two rivers and their tributaries. The earliest Neolithic sites in this region are those of Hallan Çemi, Demirköy and Körtik, all of which are located around the Batman river, a tributary river of the Tigris, dating to the earliest aceramic phase of the region (Rosenberg and Erim-Özdoğan 2011, 126-127). Çayönü Tepesi, a slightly later site – which is also located near the Tigris river – is known for its long occupation sequence, of which the aceramic Neolithic phases date from ca. 10.000 to ca. 8.000 BP (Pearson *et al.* 2013, 182; Rosenberg and Erim-Özdoğan 2011, 132). Other aceramic occupations centre around the Euphrates River, with sites such as Cafer Höyük, Mezraa-Teleilat, Nevalı Çori and Göbekli Tepe, the latter of which is most famous for its unique ritual character. Although most aceramic sites in this region contain one or more public buildings, sometimes containing ritual or decorative elements, it seems that the site of Göbekli Tepe was solely used as a mountain sanctuary and not for actual habitation (Rosenberg and Erim-Özdoğan 2011, 133; Schmidt 2011, 918-919). During the early aceramic in the region, communities increased in size. In this respect, the increased importance of public spaces during the aceramic period is indicative of the social developments that accompany sedentism and increased community size, which requires new strategies to avoid and resolve social tensions (Rosenberg and Erim-Özdoğan 2011, 145). Towards the end of the aceramic period and during the early phases of the Pottery Neolithic (ca. 8.000 BP), community size decreased, probably due to increased emphasis on kinship ties, as well as critical economic changes (Rosenberg and Erim-Özdoğan 2011, 145).

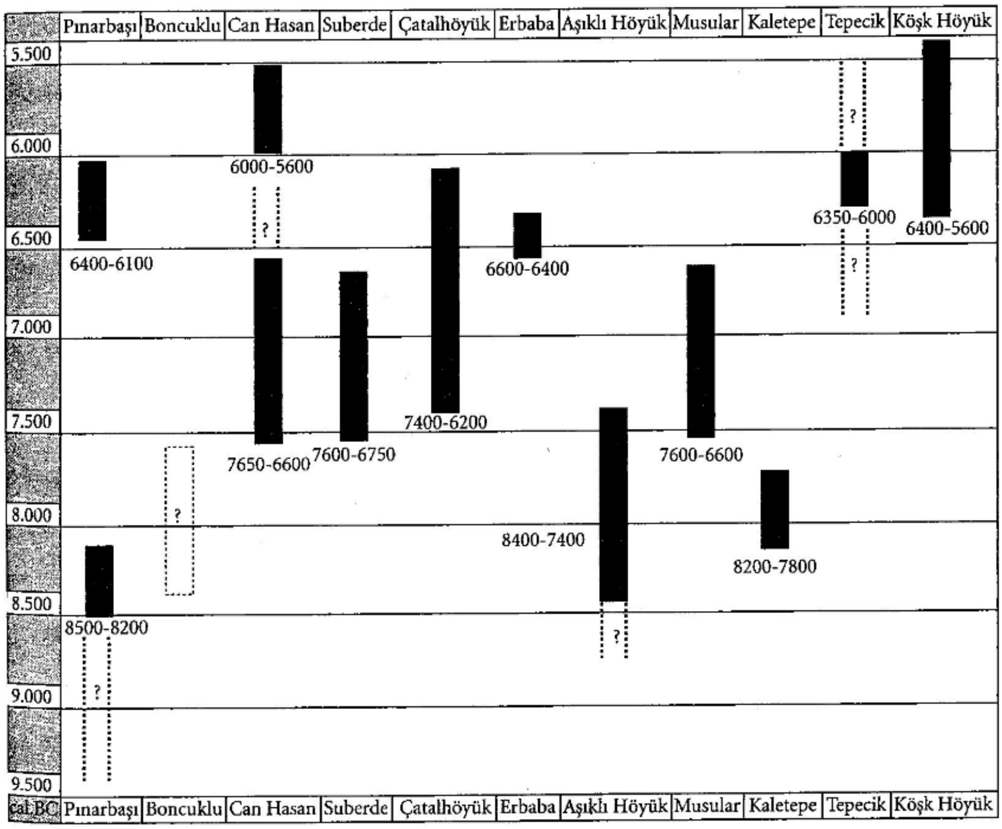

Figure 2. Chronological chart for the sites of Central Anatolia. Note that since the publication of this image, the earliest date for occupation at Boncuklu Höyük has been determined at ca. 8.300 BCE. After Özbaşaran 2011.

Central Anatolia. The area resides on the Central Anatolian plateau, which is over 150.000 km^2. The plateau consists of drained and dried up ancient lake basins and has a continental climate with dry, hot summers and cold winters. Annual mean rainfall in this region is the lowest of all five regions at 350-400 mm. Steppe vegetation covers the lowlands, while forests occur at higher elevations (Düring 2016, 139-140; Özbaşaran 2011, 100; Willett *et al.* 2016, 104). The plateau is bounded by the Pontic Mountains in the north, the Taurus Mountains in the south, a volcanic area in the east and the Lake District in the west. Two relevant subareas of the plateau are Cappadocia in the east and the Konya Plain in the west (Özbaşaran 2011, 100). The oldest Neolithic settlements in Central Anatolia date to the second half of the 9th millennium BCE. The relatively small settlement mounds of Pınarbaşı (ca. 8.500 - 8.000 BCE) and Boncuklu Höyük (ca. 8.300 - 7.800 BCE) are the oldest settlements on the Konya Plain, while Aşıklı Höyük (ca. 8.400 - 7.400 BCE) is that of Cappadocia (Baird *et al.* 2018, E3078-E3079; Özbaşaran 2011, 106-107). While sedentism is obvious in the earlier phases of the Neolithic in this region, the adoption of food production techniques that are characteristic of the Neolithic lifestyle, i.e. cultivating plants and herding animals, happens rather incongruously in the earliest phases. At the three sites mentioned here, the first adoption of farming depended greatly on the economic choices of the community: while Aşıklı Höyük invested in a mixed-farming economy, Boncuklu Höyük adopted low-intensity crop cultivation and animal management, and Pınarbaşı rejected it all and continued its hunter-forager lifestyle (Baird *et al.* 2018, E3084). The later phases of the Neolithic in Central Anatolia have been studied at several sites, including Can Hasan, Suberde, Erbaba, Köşk Höyük, Tepecik-Çiftlik, and Çatalhöyük (figure 2). The most famous and meticulously excavated of these sites is the latter, where excavations started in 1961, led by James Mellaart, and were continued in 1993 by the Çatalhöyük Research Project directed by Ian Hodder (Düring 2011, 84). The site consists of two mounds, Çatalhöyük East and Çatalhöyük West, the former being older than the latter (figure 3). Çatalhöyük East contains no less than 15 distinguishable building layers, dating from ca. 7.100 - 5.950 BCE. Both mounds existed simultaneously for a short period around 6.000 BCE, before Çatalhöyük East was abandoned and settlement continued into the Chalcolithic period in Çatalhöyük West, which was abandoned at ca. 5.500 BCE (Bogaard *et al.* 2017, 2; Düring 2011, 85-86, 133). The settlement is best known for its unique traits such as its size, the number of occupational layers preserved, the burial practices, and the exceptional amount of symbolic expressions present in the form of wall paintings, figurines, reliefs, stamps, 'history houses' and more (Özbaşaran 2011, 114). From the earliest phases of the settlement, the archaeological record has provided evidence that the community mainly relied on farming for procuring their food. Botanical remains indicate that about 75% of the caloric value of charred seeds derived from domesticated crops, while the other remains originated from wild plant resources (Düring 2011, 89). The set of crops that were cultivated at Çatalhöyük was not fixed through time but was adjusted and adapted to the changing landscape (Bogaard *et al.* 2017, 23). Faunal remains indicate that the most common animals kept at the site were goats and sheep, although cattle

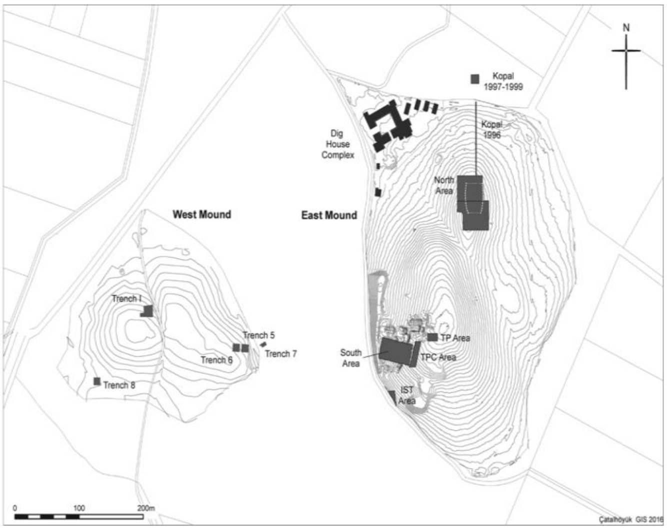

Figure 3. Plan of Çatalhöyük showing the East and West Mounds, as well as the locations that have been excavated. After Bogaard et al. 2017.

probably provided more calories in the diet of the community, due to the greater meat yield per animal (Düring 2011, 89).

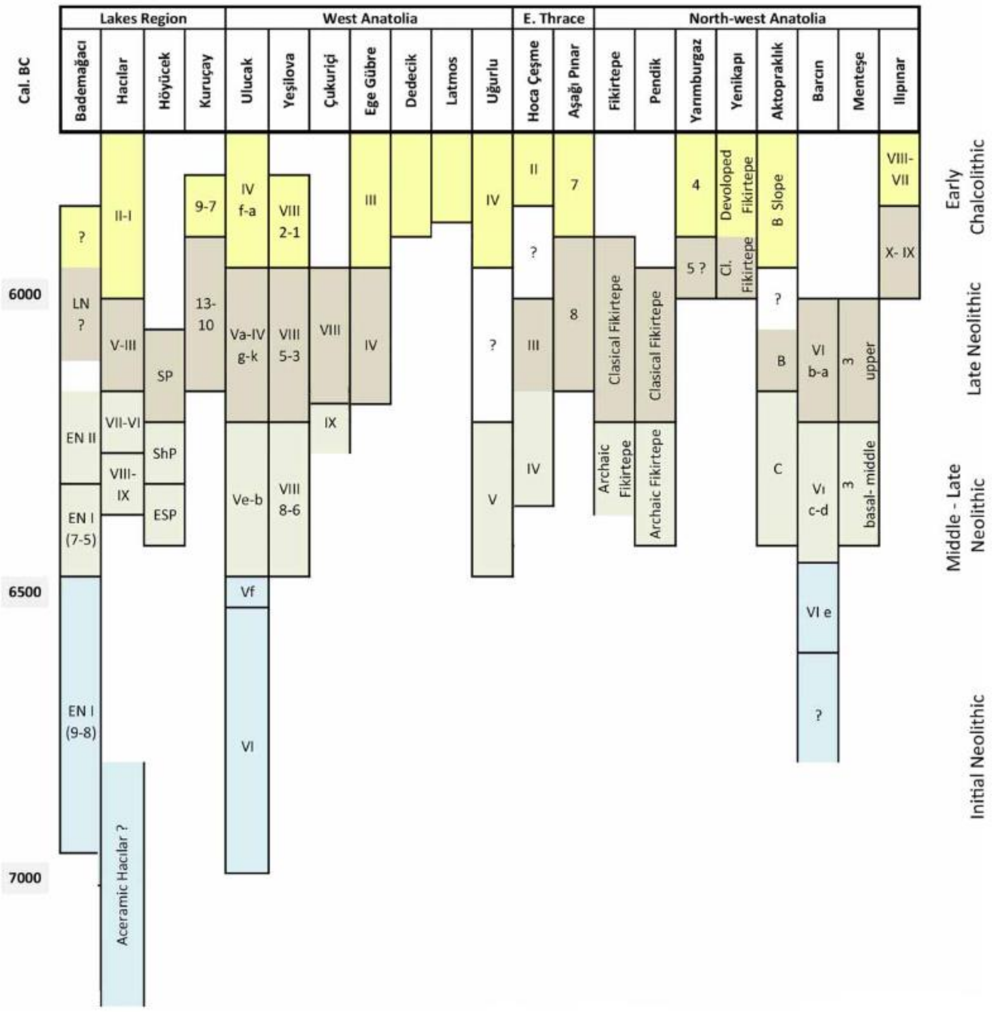

Figure 4. Chronology of western Anatolia, subdivided into the regions mentioned here, except for Eastern Thrace, which is counted as Marmara Region in this paper. The proposed earlier dates for Barcın Höyük have now been debunked, resulting in a starting date of 6.600 BCE. After Özdogan 2015.

Lake District. This district is located to the west of the Konya basin, north of the western Taurus range, south of the terraced landscape of the Central Anatolian plateau and east of the foothills of the Menderes Massif. The landscape consists of natural depressions and basins, many of which hold lakes, surrounded by plateaus and the flanks of mountain ranges. The diversity of landscapes results in heterogeneous vegetation, with arid steppe-like zones in the depressions and basins, and forests in the higher areas (Clare *et al.* 2008, 71). Overall, this region has a Mediterranean climate with hot, dry summers and mild, wet winters (Düring 2016, 140). The mean annual rainfall in this region lies between 400-800 mm per year, most of which falls during the winter and spring (Clare *et al.* 2008, 71). The main archaeological sites of this region are Hacılar, Kuruçay, Höyücek and

Bademağacı (figure 4). The beginning of the Neolithic sequence has not yet been precisely determined, since the evidence for the earliest, aceramic phases in Hacılar is not uncontested. Thus, the earliest firm evidence for Pottery Neolithic in the region can be found in Bademağacı, dating to the first half of the 7th millennium BCE (Düring 2011, 160-162; Özdoğan 2015, 35). Even during this earliest occupational phase of Bademağacı, a well-established system of herding was already in place, including the four main food-related animal domesticates: goats, sheep, cattle and pigs (Çilingiroğlu and Çakırlar 2013, 24; De Cupere *et al.* 2008, 386). After around 6.500 BCE, Neolithic strata are also found at the other sites, all of which give a clear indication that people were sedentary farmers, with the associated domesticated crops and animals (Düring 2016, 140-141). Overall, although local assemblages do differ in some ways, there is a great degree of similarity between the pottery and architecture of sites of the Lake District[2], indicating shared cultural practices and inter-site contact (Düring 2013, 89-90).

Aegean Anatolia. This region's climate resembles that of the Lake District (Düring 2016, 141). The vegetation of the region would have been similar to that of the present day, with forest-steppe and woodlands (Düring 2011, 14-15). The Neolithic strata of Aegean Anatolia show cultural similarities with and similar dates to the Lake District. Some of the oldest Neolithic strata were found at Ulucak and date to the first half of the 7th millennium BCE, while the other sites in this region are dated to after 6.500 BCE (Çilingiroğlu and Çakırlar 2013, 23; Düring 2016, 141). The main Neolithic sites of this region are Ege Gübre, Dedecik-Heybelitepe, Yeşilova Höyük and Ulucak (figure 4), the latter of which is most extensively researched at the time of writing. The earliest occupation level at Ulucak (level VI) is dated to ca. 7.040 - 6.470 BCE and consists of a red-plastered floor with hearths around it, but is completely without pottery (Çilingiroğlu and Çakırlar 2013, 23; Özdoğan 2015, 35-36). From the earliest dates of occupation, both agriculture and herding seem to have been the dominant food source (Çilingiroğlu and Çakırlar 2013, 24). The first introduction of pottery at the site, at ca. 6.400 BCE, seems to have happened rather abruptly and was probably introduced from another region, since the earliest pottery is of high quality right away (Çilingiroğlu and Çakırlar 2013, 23). Overall, the climatic and environmental conditions in the Aegean Region, especially the river plains, provided excellent farmland and conditions for cultivation. This, in combination with the proximity to the sea of many of the sites,

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[2] See Özdoğan 2015 for detailed, chronological descriptions of the assemblages of western Anatolia.

would have provided a wealth of natural resources for the population (Düring 2011, 175).

Marmara Region. The last region is located in the north-west of Anatolia and has a temperate climate, with wet summers and cold winters (Düring 2016, 139-140). The landscape consists of mountainous areas further inland and well-watered lowlands, large plains and lakes (Düring 2011, 8; Roodenberg 2011, 950). Some of the Neolithic sites of the region are Fikirtepe, Yarımburgaz, Pendik, Ilıpınar, Aşaği Pınar, Hoca Çeşme, Menteşe, Barcın Höyük and Aktopraklık (figure 4). Crucial excavations during the 1950s in the Marmara Region revealed a group of related sites known as the ‘Fikirtepe’ group when rescue excavations in the Istanbul area uncovered Neolithic strata (Düring 2011, 180). The Fikirtepe sites have assemblages that are similar to each other (Özdoğan 2015, 40), and to those of the Epipalaeolithic/Mesolithic sites of the region, indicating cultural continuity between them. Dating these Fikirtepe sites is difficult, however, due to the excavations having been rescue projects, as well as an absence of radiocarbon dating (Düring 2011, 179-182). Currently, the earliest absolute dates for the Fikirtepe tradition come from Menteşe, dating to ca. 6.400 BCE, although earlier Fikirtepe dates have been surmised to date back to ca. 6.500 - 6.600 BCE. The Fikirtepe tradition ends at ca. 5.900 BCE (Özdoğan 2011, 662-663). Preceding this tradition, the site of Barcın Höyük is the earliest Neolithic site in the region, dating to ca. 6.600 BCE. In the earliest levels of Barcın Höyük, referred to as the ‘pre-Fikirtepe’ phases, ceramics are nearly absent, but in later stages, the ceramic assemblage is of the Fikirtepe tradition (Gerritsen and Özbal 2016, 200-201). From the earliest occupation of the Marmara Region onward, the main source of food came from herding animals and cultivating crops, although the botanical data are absent for some sites, such as those excavated in the rescue missions. Faunal assemblages consist of domesticated cattle, sheep, goats and pigs, although fishbones, shells and, to a lesser degree, bones of hunted animals were also quite common (Düring 2011, 181-185).

2.2 The 8.2 ka event

The 8.2 ka event is a global cooling event that happened at approximately 8.200 BP, which corresponds to ca. 6.300 BCE. It was most probably caused by the abrupt drainage of two large meltwater lakes that were the result of the retreating Laurentide Ice Sheet in contemporary Canada (Alley and Ágústsdóttir 2005). The amount of cold, fresh water that flooded into the Atlantic Ocean in approximately six months time was roughly equivalent to twice the volume of the Caspian Sea (Morrill and Jacobsen 2005, 1). The sudden drainage of these lakes into the Atlantic Ocean disrupted the thermohaline circulation, which is a large-scale ocean circulation driven by differences in water density. The word thermohaline consists of *thermo*, meaning temperature, and *haline*, meaning salinity, both of which are factors that influence water density. This deep-ocean current is of great influence on the global climate, so the influx of such an enormous amount of fresh, cold water caused changes in average temperatures and precipitation on a global scale, although it especially affected the Northern Hemisphere. Proof of this event can be found in climate proxy records around the world, such as ice cores, speleothems, deep-sea records and pollen records (Alley and Ágústsdóttir 2005; Düring 2016, 138; Flohr *et al.* 2016, 24-25; Morrill and Jacobsen 2005; Nieuwenhuyse *et al.* 2016, 67-68; Roffet-Salque *et al.* 2018, 8705). Through the Greenland ice cores, the event has been dated to have lasted approximately 160 years, taking place between ca. 6.300 - 6.100 BCE (Düring 2016, 138).

2.2.1 The effects on the Anatolian climate

The effects of the event on Anatolia specifically are more complicated to describe, because the local effects of the 8.2 ka event vary according to the extant environmental conditions. When considering the enormous environmental and ecological diversity of the Anatolian peninsula, it is obvious that researchers must work with regional proxy data to determine the actual effect on any given region or geographical area (Asouti 2009, 4; Düring 2016, 138). These proxy data, however, do not easily provide answers. Different kinds of regional proxy data often provide divergent information on the impact of abrupt climate changes and chronological uncertainties currently hamper our ability to draw any definite conclusions (Berger *et al.* 2016, 1849). Furthermore, not all regions or sites in Anatolia have been researched with climatic data in mind, so for many sites, there are no reliable (proxy) datasets with which to research the impact of climate events. Lastly, the resolution and accuracy of a sites' chronology also dictate to which extent one can make inferences about synchronicity, especially considering that the 8.2 ka event ‘only’ lasted 160 years.

Some of the climate proxies that may be used to identify climate change – on regional, supraregional and global scales – are ice cores, deep-sea cores, pollen records and speleothems. These proxy data all measure deviations from a mean state or trend, with a ‘wiggle’ possibly indicating a change in the environment or climate. The interpretation of these wiggles, however, is also not without its difficulties. While changes in single proxy records, especially when they are concerned with local phenomena such as pollen records, may indicate any number of environmental or climatic circumstances, the appearance of similar and simultaneous wiggles in multiple proxy records may indicate larger-scale occurrences. On the other hand, the correlation of two or more events in separate proxy records may simply represent different yet synchronous events. The solution to the problem of correlation is found in ice-cores, which often reveal signs of anomalies from other regions as well (Alley and Ágústsdóttir 2005, 1124-1125). The ice cores record a great variety of climatic and environmental data with exceptional temporal resolution. Through comparison of other proxy data with the data of ice cores, the 8.2 ka event has been attested for across the entire Northern Hemisphere, although there are also proxy data that do *not* show the event (Alley and Ágústsdóttir 2005; Morrill and Jacobsen 2005; Düring 2016, 138). This may be due to insufficiently high time resolution in the data, but may also indicate that the event did not affect all regions, microhabitats or environments to the same extent. In studying the Near East, archaeologists may encounter more difficulties in interpreting proxy data. They have generally adopted global frameworks for the interpretations of past climates and ecologies. These frameworks usually focus on the climate of temperate Europe, however, which leads to skewed reconstructions of the climatological circumstances and effects in the Near East. This is because the Near East is situated at the conjunction of multiple climate zones (Düring 2011, 12). Moreover, for the Anatolian region specifically, the environmental and ecological diversity further modifies the effects climate change may have on any given region.

On a larger scale, the Near East, Asia and Africa all seem to have experienced a marked reduction in precipitation during the event (Alley and Ágústsdóttir 2005; Flohr *et al.* 2016, 25; Morrill and Jacobsen 2005; Nieuwenhuyse *et al.* 2016, 68). For some regions of and around Anatolia, there are quite some clear instances in which climate proxy data give indications about the 8.2 ka event. In Aegean Anatolia and the Marmara Region, some climate proxy data indicate

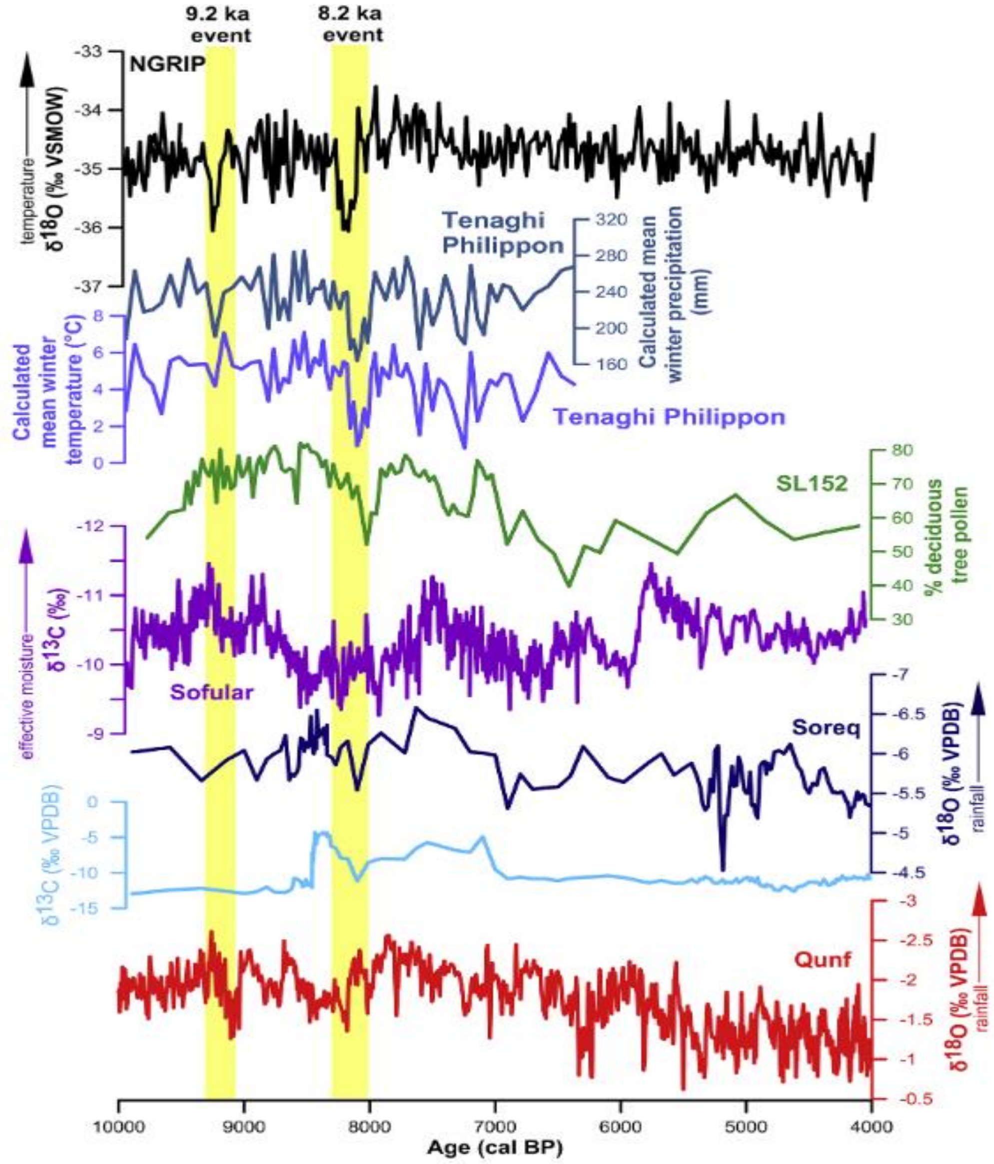

Figure 5. Selected climate proxies showing the 9.2 and/or 8.2 ka events. Greenland ice core (NGRIP) δ^{18}O, compared to high-resolution, well-dated proxies from in and nearby Southwest Asia. From top to bottom: NGRIP δ^{18}O (Johnsen et al. 2001), precipitation and temperature calculated from percentage pollen from Tenaghi Philippon in Greece (Pross et al. 2009), percentage of deciduous tree pollen in the SL152 marine core from the Aegean Sea (Kotthoff et al. 2008), δ^{18}O and δ^{13}C from Soreq Cave in Israel (Bar-Matthews et al. 1999, 2003), and δ^{18}O from Qunf Cave in Oman (Fleitmann et al. 2003). Image and key after Flohr et al. 2016.

changes in vegetation at the time of the event. For instance, pollen records from Tenaghi Philippon (northern Greece) indicate a decline in deciduous pollen, while steppe pollen increase at ca. 8.200 BP, possibly indicating a dry period (figure 5; Düring 2016, 138-139; Flohr *et al.* 2016, 26). Deep-sea cores from the Aegean and the Adriatic Sea reflect the impact of the event when the early Holocene humid phase is interrupted at ca. 8.200 BP and cores from the Marmara Sea give indications of lower surface temperatures (figure 5; Flohr *et al.* 2016, 26). Speleothem records from Sofular Cave, east of the Marmara Region on the Black Sea coast, indicate reduced precipitation dating to the 8.2 ka event (figure 5;

Göktürk *et al.* 2011, 2444). In summary, the climatic data presented above indicate that the possible influence of the event would have been most severe in the Marmara Region and Aegean Anatolia, with lower temperatures and decreased precipitation being the main effects.

In contrast, the proxy data for Central Anatolia hardly indicate any effects of the 8.2 ka event (Düring 2011, 15-16; Düring 2016, 138). Isotopic research into animal fats recovered from pottery fragments from the site of Çatalhöyük used to recreate paleoclimatic records, showed only a modest signal for reduced rainfall during the event (Roffet-Salque *et al.* 2018, 8707-8708). The pollen evidence from Lake Van, located in South-eastern Anatolia, shows some changes in vegetation, but none that are indicative of aridification in the region (Flohr *et al.* 2016, 26). These results lead to the conclusion that, while there are indications that the 8.2 ka event may have influenced the environment and plant species in South-eastern and Central Anatolia, the actual effect of the event was probably not of great significance in those regions (Düring 2016, 138).

For the Lake District, being positioned between Aegean and Central Anatolia, it is harder to determine the exact effect the 8.2 ka event had on the environment. Proxy records from Lake Golhisar fail to provide clear evidence for the climate event (Flohr *et al.* 2016, 26). However, the climate of the Lake District is similar to that of Aegean Anatolia. Its position near the Aegean Sea, where some evidence for cooling was measured, then, may indicate effects of the climate event nonetheless.

Besides the 8.2 ka event, climate proxy data also show another climate event that happened around the same time: deep-sea cores from the Aegean provide a climate reconstruction in which a broader, milder climate oscillation can be observed, dating to ca. 6.400 - 5.900 BCE. This event is called the ‘mega 8.2 ka event’ (Düring 139). This climate event, as opposed to the 8.2 ka event, was probably part of a recurring cycle of climatic deteriorations at semi-regular intervals during the Holocene (Alley and Ágústsdóttir 2005, 1142; Budja 2015, 172; Rohling and Pälike 2005, 978). During the mega 8.2 ka event, the Aegean Sea was 2 to 3 °C colder in winter, with the effects on land probably being more severe. Especially in the north of the Aegean and in the Marmara Region, the event may have caused regular occurrences of very cold and dry winters (Düring 2016, 139-143). Speleothem data from Sofular cave also indicates a decrease in precipitation starting around 8.600 BP (Düring 2016, 139; Flohr *et al.* 2016, 26; Göktürk *et al.* 2011, 2444). This signals that, although the 8.2 ka event may have been of great influence, it was superimposed on an even larger event, which may also affected the cultural developments of Neolithic populations.

2.2.2 Effects on Anatolian populations

The environmental and ecological changes due to the 8.2 ka event may have also influenced human behaviour. Especially considering that people in the Near East had just transitioned to an agricultural way of life – or were still partly in the process of transitioning, depending on the region one chooses to investigate – the impact of changing environmental conditions may have been severe (Roffet-Salque *et al.* 2018, 8705). In recent years there have been numerous articles related to the 8.2 ka event and its impact on Neolithic societies. The various kinds of societal impact that are proposed by researchers for the 8.2 ka event – or any other abrupt climatological or environmental event in the past – vary from societal collapse, war, abandonment of sites and mass migrations to adaptation, continuation and dispersion of the Neolithic way of life (Asouti 2009; Clare *et al.* 2008; Flohr *et al.* 2016, 24; Nieuwenhuyse *et al.* 69-70).

For instance, during the last two decades, it has not been uncommon for researchers to correlate the Neolithic expansion to western Anatolia and Europe with the 8.2 ka event. While it seems clear that the expansion in western Anatolia and the Aegean, which occurred around 6.500 BCE, significantly predates the event, some scholars used different dates for the event, leading them to opt for an ‘early 8.2 ka event’. The greatest flaw in these studies is that they use inaccurate chronologies for the event and selective archaeological data (Düring 2016, 142). Moreover, as has been discussed above, the effects of the event in Central Anatolia were probably limited, thus negating the need for migrating into other regions (Düring 2013, 87; Düring 2016, 138). Studies on the demographic pressure in Central Anatolia at the time of the event, although not unproblematic or uncomplicated, seem to indicate an increase in the number of sites, at least on the Konya Plain. While this may be an indication of increased population pressure, it certainly provides no evidence for the departure of parts of the population (Asouti 2009, 3-4; Düring 2013, 86).

Another group of researchers proposed that the event resulted in societal unrest, ranging from disruption of site occupation and changes in site composition to warfare. Site relocation and temporary abandonment have been attested for at a few sites around the time of the event. For example, at the site of Çatalhöyük, there was a settlement shift from the East Mound to the West Mound at ca. 6.000

BCE that has, in multiple studies, been correlated to the 8.2 ka event (Clare *et al.* 2008; Düring 2016, 137). While the move to the West Mound does happen around the time of the event, there are several arguments against it being an important driver for the change. Most importantly, apart from the actual move, the most important changes in the social and economic organisation of the site are dated to ca. 6.450 BCE, before the move from East to West (Asouti 2009, 4; Willett *et al.* 2016, 108-109). And again, the absence of strong evidence for environmental change in Central Anatolia due to the 8.2 ka event counters the causal relationship between the two (Düring 2016, 138; Willett *et al.* 2016, 108).

Evidence for warfare is attested for most in the Lake District. At multiple sites in the region evidence for site fortification and large-scale fires has been found (Clare *et al.* 2008). While fires may also happen accidentally, the fact that the attested fires destroyed larger parts of the settlements simultaneously indicates that they were intentional. Moreover, *in situ* finds of artefacts at all sites and the discovery of unburied victims of fire at the sites of Bademağacı and Hacılar further strengthen the claim that the fires may have been caused by conflict. Finally, slings and sling missiles are widely attested for at most sites, with their occurrence starting or increasing around the time of the 8.2 ka event (Clare *et al.* 2008, 73-77). While the causal relationship between these indications of warfare and the climate event is not pressed, the rough synchronicity is striking, to say the least. Warfare is, however, only one of the possible explanations for the fires; they may also have fulfilled a ritual purpose (Düring 2011, 165).

While some of the aforementioned studies provide reasonable arguments for *possible* synchronicity between the climate event and the proposed effect, the greatest hurdle for most of them is a lack of sufficiently detailed and accurate chronologies. Some studies, however, present incredibly detailed analyses of archaeological materials, chronological sequences and environmental impact, thus offering key insights into the possible impact of the event on past societies. One such study, although not strictly in Anatolia, is that of the neighbouring Syrian site of Tell Sabi Abyad (figure 6; Van der Plicht *et al.* 2011). At this site, researchers were able to establish synchronicity between the effects of the 8.2 ka event and

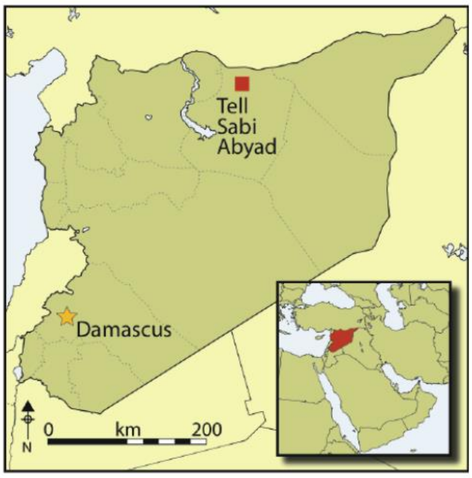

Figure 6. Location of Tell Sabi Abyad in Northern Syria. After Van der Plicht et al. 2011.

several socio-economic changes by analysing detailed chronologies and corresponding archaeological strata and materials. At the time of the event, the location of the settlement changed from the western side of the tell to the east, while at the same time new architectural forms were introduced, such as multi-chambered storage buildings. Furthermore, the archaeological record shows that alongside this architectural transition, there were changes in animal husbandry practices, as well as the introduction of stamp seals and tokens and new forms of pottery (Van der Plicht *et al.* 2011, 231). All of these developments may have been the result of changing environmental conditions, mainly the aridification of the region, which led to changes in community structure and practices. However, the authors are cautious in assigning causality and only point to definite synchronicity (Van der Plicht *et al.* 2011, 237). It is obvious that the case study of Sabi Abyad is exceptional, for nearly no other site in the Near East has been dated in such detail and with such accuracy. Another site studied in similar detail is the site of Çatalhöyük, which will be discussed in the following chapter.

In the past decades there have been numerous studies that indicate synchronicity – and sometimes even causality – between the 8.2 ka event and apparent changes in contemporaneous societies. As was demonstrated above, a lot of these base their conclusions either on faulty theories or inaccurate data. While the given evidence for synchronicity may be based on ^{14}C-dating, it is of vital importance that these undergo quality checks to ascertain their usefulness in being linked to the archaeological stratigraphy (Flohr *et al.* 2016, 24). Some studies, mostly those by climate researchers, adopt a deterministic approach, where climate change is seen as the 'trigger' for changes in the socio-economic behaviour of human societies (Düring 2016, 136). This way of looking at changes in past societies suffers from the implicit assumption that cultural systems are stable over long periods of time, and only change when forced to do so by outside influences. In archaeology, this way of viewing past societies got debunked in the 1980s, although it is still being used by climate researchers and archaeologists alike, and can therefore still be found frequently in contemporary scientific articles (Düring 2016, 137). These theoretical paradigms will be further discussed in chapter 4. Furthermore, some archaeological researchers base their conclusions of synchronicity on loose chronologies or fail to take into account other factors, such as social or economic ones, that may have influenced the behaviour they link to the climate event (Düring 2016, 137). Of course, those factors may change the outcome of the research altogether.

The Neolithic in Anatolia is very divergent, as it was present in Central Anatolia for a long time before it was adopted in the other regions. This is probably due to cultural differences between the regions, as well as variations in climatological and environmental conditions. A few significant sites have been discussed, such as Çatalhöyük (Central Anatolia), Bademağacı (Lake District), Ulucak (Aegean Anatolia), Fikirtepe and Barcın Höyük (Marmara Region). The findings in relation to animal husbandry, and thus dairy consumption, will be discussed in chapter 3. The effects of the 8.2 ka event, a global cooling event, appear to have been very diverse throughout the regions. In Central and South-eastern Anatolia, the effects were probably limited, while the other regions may have been affected to a greater extent. Climate proxy data, however, are quite scarce on a regional scale. The possible changes in dairy consumption and whether these can be linked to the 8.2 ka event is discussed in chapter 4, in which I will expand on the effects and problems with synchronicity and causality while highlighting the limitations of the data.

3. Evidence for dairy consumption

Discovering if and how people consumed dairy products in the past consists of several methodical approaches. This paper will analyse three kinds of evidence for the possible consumption of dairy in the past. In the first subchapter, DNA evidence for lactase persistence will be discussed, especially focusing on the timing of its occurrence in the human genome and what this means for dairy consumption during the Neolithic. In the second subchapter, lipid residues in archaeological ceramics will be discussed, since these provide direct evidence for dairy processing. Then, the third subchapter will give an overview of the evidence from archaeozoological research in relation to dairy consumption. Finally, the fourth subchapter summarises the evidence presented.

3.1 aDNA and lactase persistence

Among all the animal products humans use and consume, dairy products stand out because most adult mammals are incapable of digesting one of its main components: lactose. Only around 32% of today's world population can digest lactose after the age of seven or eight (Gerbault *et al.* 2013, 983; Wiley *et al.* 2018, 322). This is due to the fact that this percentage of the population is genetically lactase persistent (LP; Lactase Persistence), indicating that their bodies continue to produce the enzyme lactase after childhood. Lactase breaks up the rather large carbohydrate lactose into two components, namely glucose and galactose (Gerbault *et al.* 2013, 983). People who are lactase non-persistent (LNP; Lactase Non-Persistence) experience gastrointestinal discomforts when they consume lactose-rich foods. This is due to the bacterial fermentation of lactose in the large intestines – which produces various gases – as well as the osmotic effect of undigested lactose, which leads to diarrhoea (Gerbault *et al.* 2013, 987). There are other conditions that can lead to an inability to digest lactose, which can be grouped together as 'lactose intolerance', but this paper focuses only on genetic LP and LNP, not on these other forms of lactose intolerance (Ségurel and Bon 2017, 299).

3.1.1 Lactase persistence on a global scale

It is interesting to note that LP in people is not evenly distributed worldwide. Frequencies range from 5% in some populations, such as those of south-east Asia and southern Africa, to nearly 100% in others (figure 7; Ségurel and Bon 2017, 298). There is even a parallel, to a great extent, between the ancestral reliance on dairy products and the frequency of LP in populations (Campbell and Ranciaro 2021, R98; Ségurel and Bon 2017, 306). One of the best-known examples is that northern Europe relied on dairy immensely and almost 100% of its population is LP. However, this degree of overlap in reliance and genetic adaptation is not always the case: some populations rely heavily on dairy products, yet do not have the prevalence of genetic LP, and vice versa (Ségurel and Bon 2017, 298-299; Wiley *et al.* 2018, 319-320).

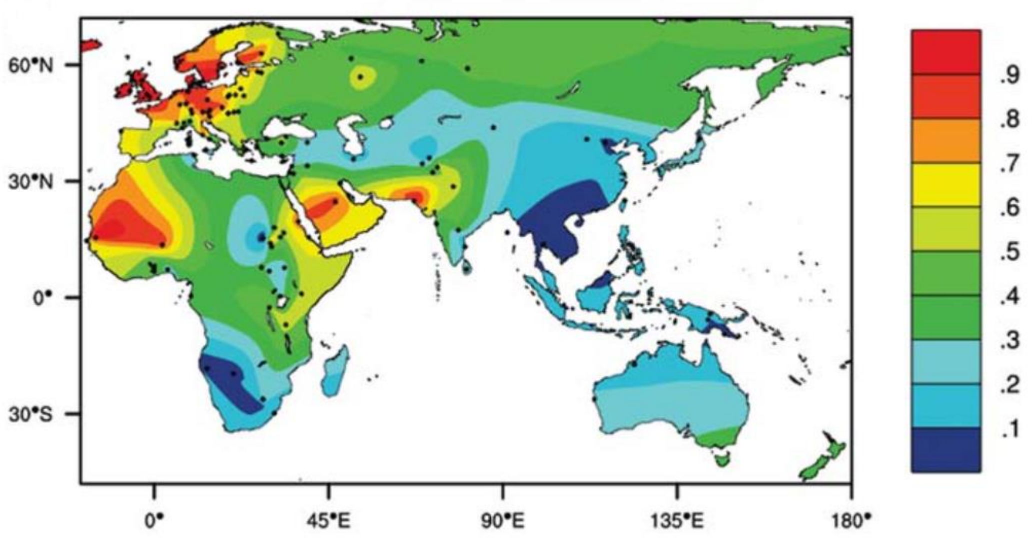

Figure 7. Interpolated map of Old World LP phenotype frequencies. Colours and colour key show the frequencies of the phenotype estimated by surface interpolation, where collection locations are represented by dots. Image and key after Gerbault et al. 2013.

Currently, there are five known genetic variants that code for the LP phenotype. These mutations are not equally spread across LP populations but occur in distinct geographical areas (Gerbault 2013, 985; Ségurel and Bon 2017, 302-303). Additionally, the intensity of natural selection for the LP phenotype is among the strongest known for the human genome. The combination of these facts indicates that the genetic mutation for LP did not only occur at least five different times in different geographical areas, but it was also strongly selected for in every case. Most studies indicate that the selection for LP occurred recently, approximately within the last 10.000 years, and almost simultaneously in different continents soon after the beginning of cattle and camel domestication in the Neolithic (Ségurel and Bon 2017, 303-304; Wiley *et al.* 2018, 323).

Studies on ancient DNA (aDNA) also indicate the recent timing of selection for LP. By studying the aDNA of human archaeological remains, researchers have been able to provide a unique insight into the evolution and admixture of the phenotype among populations. The available samples are limited, however, because both degradation over time and external influences such as heat reduce the available samples (Ségurel and Bon 2017, 310). Overall, aDNA evidence for LP has not been found anywhere before 5.000 BP, and even after that, frequencies of the allele remain rather low for millennia. The oldest samples of its occurrence were found in Europe, where mainly due to the favourable conditions of the region aDNA is preserved. The evidence for LP in aDNA in Europe increases substantially after the Iron Age and becomes dominant during the Middle Ages (Ségurel and Bon 2017, 311; Wiley *et al.* 2018, 323). Evidence for LP in the aDNA from the Near East is limited and provides no evidence for the occurrence of the alleles during Neolithic times.

The positive selection for LP is seen as a prime example of gene-culture coevolution: the change in food production practices during the Neolithic – in this case specifically the consumption of dairy – led to an increased selection for the genetic modification that allowed for its consumption (Campbell and Ranciaro 2021, R98; Ségurel and Bon 2017, 299). In this statement lies the inherent assumption that there would be a selective advantage to the consumption of dairy products which was beneficial to individuals, leading to the high frequencies of LP we encounter in modern populations.

3.1.2 Dairy consumption despite Lactase Non-Persistency

While LP people are at a seemingly obvious advantage due to dairy being a rich source of minerals, vitamins, proteins and fat, LNP individuals are *also* able to consume dairy products under certain circumstances without suffering from negative symptoms of their non-persistency. The severity of disadvantageous symptoms among LNP individuals varies wildly, depending on, for instance, the quantity of milk consumed, the degree to which dairy products have been processed, and the individual’s colonic microbiota (which may even be positively altered to dairy consumption by regular exposure) (Ségurel and Bon 2017, 305). These variables need to be factored in when researching dairy consumption. Although Neolithic farmers were not LP at that time, some circumstances made it possible and advantageous for them to consume dairy products nonetheless.

For Neolithic Anatolia, the degree to which dairy products were processed probably played a vital role in their consumption by LNP individuals. This is because processing, mainly fermentation, greatly reduces the amount of lactose in milk products. While raw milk and whey contain high amounts of lactose, processed dairy products such as cheese or yoghurt only contain negligible amounts of it, thereby making it possible for LNP people to consume them (Gerbault *et al.* 2013, 987; Wiley *et al.* 2018, 320). While the first farmers of Neolithic Anatolia may not have been LP, they would still have been able to profit from the nutritional advantages of eating dairy.[3]

Different sources of archaeological data, as will be presented below, do indicate dairy consumption centuries before the genetic adaptation to LP. Therefore, it must be concluded that the earliest consumption of dairy must have involved processed products, as opposed to raw milk (Gerbault *et al.* 2013, 987; Wiley *et al.* 2018, 320). Further evidence for processing and consuming dairy can be found in archaeological remains and artefacts, such as pottery and animal bones.

3.2 Lipids in pottery

A great milestone in studying the earliest dates of intensified use of dairy products in the Near East during the Neolithic came with the 2008 study by Richard Evershed and his colleagues. In their study, the researchers analysed pottery from archaeological sites, extracting lipids and determining whether these were fatty acids from meat or from milk (Evershed *et al.* 2008). Through this method, researchers had already determined that the earliest use of milk products in another region, namely the south of Britain, coincided with the earliest stages of the Neolithic in that region. These findings contrasted one premise of the 'secondary products revolution' theory, which is that secondary products were exploited significantly later than the onset of animal domestication. The results from Britain, however, indicated that secondary products came into use approximately at the same time as the primary products of animal domestication (Evershed *et al.* 2008, 528). The 2008 study, which will be highlighted later on, sought to determine whether this was also the case in south-eastern Europe, the Levant and Anatolia.

The dairy products consumed in Anatolia were presumably processed foods, not raw milk. There are several practical reasons for processing dairy. For one, it keeps longer than the raw counterpart. This is convenient for all populations, of course, but even more so given the climatic conditions in the Near East, where high temperatures are common. Secondly, another type of durability is important in the sense that humans do not just want food to keep, but also to store it for

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[3] For extensive information on the nutritional and selective advantages of consuming dairy products, see Wiley *et al.* 2018.

longer periods of time. Especially with products that are reliant on the seasons or do not keep coming in at the same speed, it can be important to store specific food sources for other seasons, when they may be less abundant. Thirdly, for some communities, especially non-sedentary ones, it can be convenient to process their dairy products since processed products tend to be a lot smaller and easier to carry around (Ségurel and Bon 2017, 309). Lastly, as has been illustrated above, since most people were still LNP, they would have been unable to digest raw milk products. Processing it may then have been the only way to consume dairy at all.

3.2.1 Theory and method

Until a few decades ago, the archaeological evidence for the use of dairy products in prehistory was limited to indirect sources of evidence, such as specialist types of ceramic vessels or the evidence provided by faunal remains. Direct, chemical evidence for the use of dairy products was absent until the early 2000s when research into fatty acids preserved within archaeological pottery provided the first evidence for dairy processing (Copley *et al.* 2003). The essence of this line of research lies in the distinctly different chemical composition – mainly the $\boldsymbol{\delta}^{13}C$ values – of fatty acids derived from animal meat (i.e. adipose) and processed dairy products. The emphasis on the *processing* of dairy products is important because the fatty acids in fresh milk do not appear to preserve in pottery, both due to their rapid degradation when buried, as well as the fact that the short-chain fatty acids in raw milk are more water-soluble than their long-chain counterparts in processed products (Copley *et al.* 2003, 1524; Evershed *et al.* 2008, 531; Hendy *et al.* 2018, 6; Thissen *et al.* 2010, 166). From this, it follows that the only available evidence for dairy products from archaeological pottery must be that of processed dairy products. On the other hand, it is important to be aware of the fact that although the evidence from pottery is the earliest of this kind we can find, this does not mean that it is the earliest date at which the processing of milk occurred. Non-ceramic vessels and objects were probably used to process milk before the adaptation of pottery to that function (Düring 2013, 85; Thissen *et al.* 2010, 161).

While both adipose fat and processed dairy fat contain long-chain fatty acids, the detectable difference between the two lies in the $\boldsymbol{\delta}^{13}C$ values of the $C_{18:0}$ fatty acids of each of these. The $\boldsymbol{\delta}^{13}C$ values indicate the relative contributions of the stable carbon isotopes of $C_{18:0}$ fatty acids, of which there are four variants ($C_{18:0}$; $C_{18:1}$; $C_{18:2}$; $C_{18:3}$), where the 'y' in '$C_{18:y}$' indicates the number of double bonds in the molecule (Copley *et al.* 2003, 1525-1526; Evershed *et al.* 2008, 528). Through experiments on modern samples of animal fats, researchers were able to conclude that there is a significant difference of approximately 2.3‰ between the $\delta^{13}C$ values of dairy and adipose fatty acids (Copley *et al.* 2003). This difference is explained by the fact that mammary glands are unable to biosynthesize $C_{18:0}$ and must therefore obtain $C_{18:0}$ directly from plants, leading to a relatively high ratio of $C_{18:1}$, $C_{18:2}$ and $C_{18:3}$. Meanwhile, adipose fats are, to a significant extent, derived from the biosynthesis of $C_{18:0}$, resulting in relatively lower $\delta^{13}C$ values (Copley *et al.* 2003, 1526).

The first step in analysing the pottery is the selection of relevant potsherds. In most studies, researchers select fragments of vessels that were most likely used in cooking or other processes of food preparation (Copley *et al.* 2003, 1524; Evershed *et al.* 2008, 528). The criteria used in this selection may depend on, for instance, the available material and the exact research goals. After sample selection, the material must be prepared for analysis. The extraction of fatty acids from archaeological pottery is an invasive technique, performed by first cleaning the surfaces of the pottery and then grinding the potsherds into a fine powder. An internal standard (which is a chemical compound used for the calibration of measurements) is added, after which the powder is dissolved to extract the lipids. The solvent is then evaporated, leaving the ‘total lipid extract’. These, then, are the samples that are subjected to analysis by gas chromatography (GC), gas chromatography-mass spectrometry (GC/MS), and other analytical methods (Copley *et al.* 2003, 1524-1525).

3.2.2 Lipid analyses on Neolithic Anatolian pottery

The study by Evershed *et al.* analysed over two thousand potsherds from 23 sites. The results from their research were groundbreaking because they provided the oldest and first direct evidence for the use of dairy in this phase of the Neolithic in the Near East. This study will form the basis for this subchapter, although other research has also been done on the subject and will be presented as well. In this (and the following) subchapter the evidence for dairy consumption will be discussed per region.

Region	Site	Date (kyr BC)	Number of sherds analysed (per region)	
NW Anatolia	Aşaği Pınar	5.5 - 5.0	703	> 30 % milk fats
	Toptepe	5.5 - 5.0		> 30 % milk fats
	Yarımburgaz	6.0 - 5.5		> 30 % milk fats
	Fikir Tepe	6.0 - 5.5		> 30 % milk fats
	Hoca Çesme	6.5 - 5.5		> 30 % milk fats
	Pendik	6.5 - 6.0		> 30 % milk fats
Central Anatolia	Domuztepe	5.9 - 5.5	187	milk fats undetectable
	Tepecik Çiftlik	5.9 - 5.6		milk fats undetectable
	Çatalhöyük	7.0 - 6.0		< 30 % milk fats
SE Anatolia	Akarçay Tepe	7.0 - 6.2	236	milk fats undetectable
	Çayönü Tepesi	6.5 - 6.0		milk fats undetectable
	Mezraa Teleilat	6.5 - 6.0		milk fats undetectable

Table 1. Details of sites, dates, sherds, lipid concentrations of the sites studied by Evershed et al. 2008. After Evershed et al. 2008.

South-eastern Anatolia. Evershed *et al.* studied three sites in the south-east, all of which are dated between 7.000 and 6.000 BCE: Akarçay Tepe, Çayönü Tepesi and Mezraa Teleilat. A total of 236 potsherds were analysed, 13 of which provided a significant amount of fatty acids (table 1). None of these, however, provided evidence for milk fats, thus indicating that dairy processing using ceramics was not prevalent at these sites during this time interval (Evershed *et al.* 2008, 529-530).

Central Anatolia. Studies in this region mainly focus on the site of Çatalhöyük, although lipid research has also been done on the sites of Domuztepe and Tepecik Çiftlik. At the latter two of these sites, no evidence for dairy fats was found in the ceramics (Evershed *et al.* 2008, 529). At Çatalhöyük, Evershed *et al.* found evidence for the moderate use of dairy products as early as 6.800 - 6.300 BCE, in pottery from the East Mound (table 1; Evershed *et al.* 2008, 530; Hendy *et al.* 2018, 2). Among the potsherds that were investigated, less than 5% contained dairy lipids. The lipid evidence for the use of dairy products in Çatalhöyük is among the oldest in the Near East, even though the frequency at which it was found in the ceramic assemblage is rather low (Evershed *et al.* 2008, 529-530; Nieuwenhuyse *et al.* 2015, 65). A more recent study by Hendy *et al.* on ceramics from the same site, albeit from the younger layers of the West Mound, dating to 6.000 - 5.800 BCE, provided more robust results for the use of dairy products (Hendy *et al.* 2018). Hendy's team studied both the lipids from potsherds, as well as the calcified deposits that were formed while the ceramics were in use, to ascertain what foodstuffs had been made in them. They found that the majority of the vessels they had researched contained traces of dairy and that the dominant source of milk proteins at Çatalhöyük were goats and sheep (Hendy *et al.* 2018, 3). During the earlier occupational phases at Çatalhöyük (ca. 6.800 - 6.300 BCE), goats and sheep are also theorised to be the main sources of dairy products, although the intensity of milk consumption was probably lower (Evershed *et al.* 2008, 530; Thissen *et al.* 2010, 163). For the site of Çatalhöyük, another aspect of pottery may shed light on the timing of dairy production, namely an important change in pottery technology at ca. 6.500 BCE (Thissen *et al.* 2010). This new technology in pottery production enabled people to better maintain and control the temperature of their cooking vessels. The development of this new technology may only indicate improved time management, although it may also indicate an adaptation to a new foodstuff being consumed, such as milk. The improved cooking vessels would have been better suited to processing milk into dairy products such as cheese and yoghurt (Thissen *et al.* 2010, 161-163). This is also an indication of the relevance of studying the actual forms of the pottery, as well as the deposits of proteins and lipids on and in them. We will not go into further detail on this here, due to the scope of this study.

Lake District. Currently, no studies have been done on the sites in this region that indicate the presence of dairy fatty acids or dairy proteins in Neolithic ceramics.

Aegean Anatolia. Currently, no studies have been done on the ceramics of sites in this region that indicate the presence of dairy fatty acids or proteins, although research is underway for the site of Ulucak. A small sample from this site did not provide evidence for dairy lipids so far (Çakırlar 2012b, 88).

Marmara Region. The six sites at which Evershed *et al.* found the highest percentages of milk fatty acids in potsherds are Aşaği Pinar, Toptepe, Yarımburgaz, Fikirtepe, Hoca Çeşme and Pendik. They are all located in north-western Anatolia, around the Sea of Marmara, and date to 6.500 - 5.000 BCE (table 1; Evershed *et al.* 2008, 529). Out of 703 pottery fragments from this region, 102 contained animal fat residues, 70% of which originated from dairy products (Evershed *et al.* 2008, 530; Spiteri *et al.* 2016, 13596). The samples of two of these sites, Fikirtepe and Pendik, can be dated to the second half of the 7th millennium with certainty, indicating that milk processing was practised at the earliest Neolithic settlements of the region (Spiteri *et al.* 2016, 13598; Thissen *et al.* 2010, 158). Another site in the Marmara Region at which dairy lipids were found is Barcın Höyük, dated to ca. 6.200 - 6.000 BCE. Out of 137 ceramic samples – 33 of which provided lipid residues – 18 samples contained dairy fatty acids (Thissen *et al.* 2010, 165-166).

Many of the aforementioned researchers substantiate their results with the archaeozoological proofs, such as animal bones and teeth, that are found at the same sites (Spiteri *et al.* 2016). In Central Anatolia, goats and sheep are the dominant domesticates, amounting to 87% of the animal economy, while in the Marmara Region, cattle take up a more important role (29%), correlating with the increased consumption of dairy products in this region (Arbuckle *et al.* 2014, 4). Evershed *et al.* further illustrate the importance of cattle in specialised milk production in the Marmara Region, noting a positive correlation between the sites with a high proportion of potsherds with dairy fat and the relative importance of cattle bones in the sites' archaeozoological assemblages (Evershed *et al.* 2008, 530). However, in recent archaeozoological studies, the importance of sheep and goats in the dairy production of Anatolia has also been emphasised (Çakırlar 2012a; Salque *et al.* 2012, 46-47; Spiteri *et al.* 2016, 13596). In the next subchapter, archaeozoological evidence will be reviewed to ascertain where and on what scale animals were held for their milk, which animals were mostly used and how different kinds of remains can be studied.

3.3 Archaeozoological remains and culling profiles

Archaeozoological research is one of the primary ways to determine consumption patterns in the past because the way people exploit their animals is revealed in the way they manage their herd (Vigne and Helmer 2007, 16). Culling profiles, which graphically present the animals' ages at death in an archaeological assemblage, can give strong indications of whether a herd was used for its meat or for its milk production, based on the age distributions of animals. The frequency distribution of the age at death, as well as the distribution of sex, creates an image of the way a herd was maintained and what for (Vigne 2008, 195).

3.3.1 Theory and method

In order to obtain culling profiles, researchers have to examine sufficiently large assemblages of skeletal remains from archaeological sites. Several skeletal elements can be used to create age distributions, such as the state of epiphyseal fusion of the long bones and skulls or the eruption and wear of mandibular teeth (Arbuckle *et al.* 2009, 131-132; Vigne and Helmer 2007, 17-18). The degree of epiphyseal fusion is the degree to which the extremities of the long bones or the parts of the skull have fused. This method can, however, only provide age ranges, since it only tells researchers if the animal died before or after a certain point in its growth process. Moreover, after a specific age, all bones have been fused and the degree of epiphyseal fusion provides little additional information past this point. The resulting age ranges make the data harder to use from a statistical point of view (Çakırlar 2012a, 7). A more accurate way to determine an animals' age at its death is by looking at the teeth in the assemblage. Preferred are teeth still attached to the jaw, although loose teeth can also provide some of the necessary information. The degree to which milk teeth and definitive teeth have erupted and replaced each other, as well as the degree of wear on the crowns of cheek teeth, can be used to determine the age of an animal with a higher degree of certainty and precision (Çakırlar 2012a, 7; Vigne and Helmer 2007, 17). Methods of determining the sex of an animal based on their skeletal remains depend on which bones one is researching. Depending on which species are studied, the presence, absence or configuration of elements such as horns or teeth can determine the sex of an animal. The ungulate species studied in relation to milk consumption in Neolithic Anatolia all display pronounced sexual dimorphism, making the task of estimating sex densities relatively easy (Çakırlar 2012a, 7).

In every consideration of organic remains, one must take into account several biases, such as the archaeological preservation of specific features, but also the biases in the collection and selection of the remains by researchers. When considering the preservation of skeletal remains, for instance, it is important to note that bones of younger animals are more porous, and therefore more prone to taphonomic loss, thus creating a bias in favour of older specimens (Arbuckle *et al.* 2009, 133; Çakırlar 2012a, 7). Another factor that might create a bias in any assemblage is the mobility of the archaeological occupants of the site from which it was collected. For instance, if the applied management strategy includes seasonal movement between sites, the resulting culling profiles will be truncated and only reflect a part of the entire system (Arbuckle *et al.* 2009, 135). These biases must be taken into account when assessing any sites' archaeozoological data.

The data are usually presented in the form of survivorship curves, which represent the frequency of animals surviving into old age, starting at 100% at the youngest age category and ending at 0% in the oldest (Arbuckle *et al.* 2009, 132). The resulting graphs can be interpreted using theoretical models that predict the culling patterns for certain specific uses of the animals. For goats and sheep, the most influential predictive model for this purpose, designed by Payne and expanded upon by Vigne and Helmer, consists of five profiles of herd management, which were aptly described by Arbuckle *et al.* (2009) (figure 8). The 'meat model' predicts that most young males will be slaughtered when they reach their optimal point in weight gain, between 18 and 30 months, while the 'tender meat' model predicts earlier culling of young males, between 6 and 12 months. In the 'fibre model' animals are kept to older ages, to maximise the time in which they provide wool. Finally, there are two 'milk models', the first of which was posited by Payne and which discusses *intensive* production of milk. In this model, lambs are culled at a very young age to maximise the amount of milk available for human consumption. This model is not undisputed, however, and especially in the context of this paper, it poses a significant problem, for it describes a system that hardly fits the Neolithic socioeconomic context discussed here. A better fit is the 'type B milk model', which describes the delayed slaughter of young males throughout their first year, limiting the risks in terms of herding strategies, and thereby also creating a longer period of time in which the meat from these lambs can be consumed (Arbuckle *et al.* 2009, 132-134).

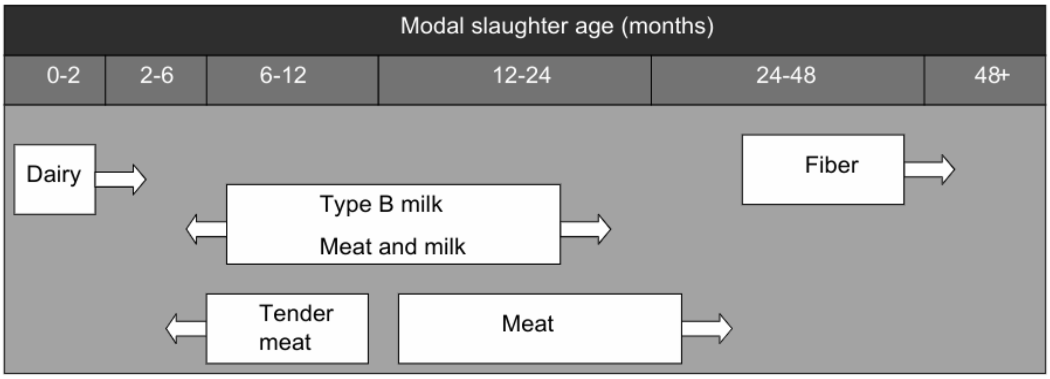

Figure 8. Visual representation of the theoretical model for culling patterns in relation to herd management for sheep and goats. After Arbuckle et al. 2009.

The theoretical models that describe systems of cattle exploitation are vitally different from those of goats and sheep. This is due to the behavioural and physical differences between sheep or goats and cattle, namely that Neolithic cows stopped lactating when their calves were removed. Unlike their modern-day relatives, Neolithic cattle used to have a milk release reflex which would be triggered by the presence of a calve (Vigne 2008, 197; Vigne and Helmer 2007, 26-28). The resulting difference in culling patterns stems from this fact since lambs and kids could be taken away and killed off at an earlier age than calves if people still wanted to be able to use the mother's milk. The lack of a slaughtering peak in newborn calves is one of the reasons why it is more difficult to demonstrate Neolithic dairying of cattle, since the later kill-off profiles may also indicate other forms of exploitation.

Finally, in the interpretation of culling profiles, attention must be given to the problem of equifinality. What is meant by this, is that any pattern in archaeology may be explained by an abundance of behaviours and factors. Mortality profiles that are similar to the milk models may therefore have been caused by completely different forms of exploitation. A redeeming factor is that while a host of circumstances may *mask* the evidence for milk production, the chance that false or artificial evidence for dairying is *created* is unlikely (Arbuckle *et al.* 2009, 133; Vigne and Helmer 2007, 16).

3.3.2 Culling profiles of Neolithic Anatolia

Using the data and conclusions of various studies, the following will discuss whether Neolithic herds in Anatolia were used for milk exploitation. Although there has not been an all-encompassing comparative study of culling profiles in Neolithic Anatolia to date, data from various sites will be reviewed, focusing mainly on the dates assigned to changes in culling practices and what this meant for the developments in Neolithic dairy consumption.

South-eastern Anatolia. Currently, there are no conclusive studies in this region that indicate the presence of archaeozoological proof of dairying.

Central Anatolia. Only a limited amount of zoological evidence can be found in this region for the use of dairy products, mostly due to a lack of published information on the subject. The main archaeozoological evidence comes from the sites of Çatalhöyük, Erbaba Höyük, Suberde and Köşk Höyük, where the faunal assemblages are dominated by sheep and goats, although cattle remains were also found (Arbuckle *et al.* 2009; Evershed *et al.* 2008; Spiteri *et al.* 2016, 13595-13596). Focusing on culling profiles of sheep, the culling of yearlings and older rams at the lower levels of Çatalhöyük East indicate a focus on meat production, although a combined meat/milk profile might also be suggested (figure 9; Arbuckle *et al*. 2009, 148). In the case of cattle, if they were also kept for milk, the herders probably had to share with the growing calves, while for sheep the

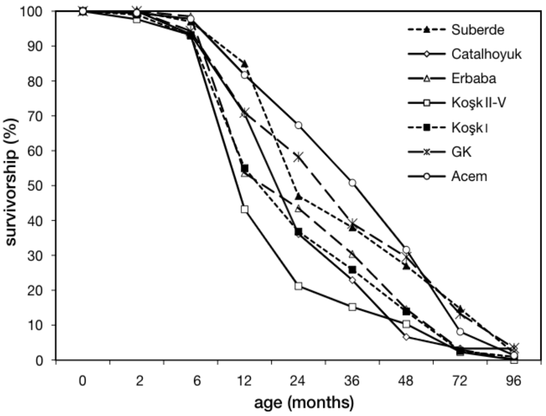

Figure 9. Survivorship curves based on mandibular tooth wear for sheep. Sites: Suberde, Çatalhöyük (levels pre-XII-IV), Erbaba Höyük, Köşk Höyük (Levels II-V and level I), Güvercinkayası, and Acemhöyük (levels II-III). After Arbuckle et al. 2009.

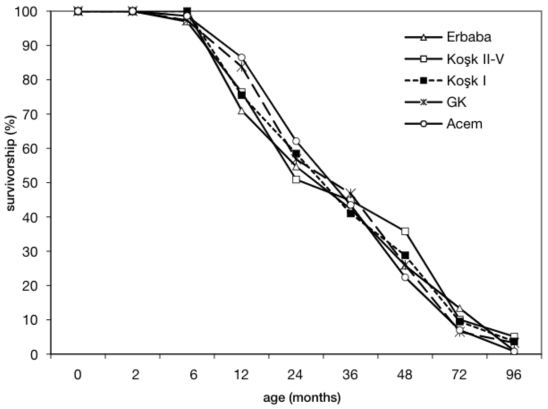

Figure 10. Survivorship curves based on mandibular tooth wear for goats. Sites: Erbaba Höyük, Köşk Höyük (Levels II-V and level I), Güvercinkayası, and Acemhöyük (levels II-III). After Arbuckle et al. 2009.

available milk was simply not the primary goal for the herders (Arbuckle *et al.* 2009, 139; Spiteri *et al.* 2016, 13596; Thissen *et al.* 2010, 162-163). During the later occupation of Çatalhöyük West (6.000 - 5.600 BCE), however, the importance of dairy processing seems to have increased significantly. Juvenile remains form a greater proportion of the assemblage from the site, suggesting management strategies were focused on tender meat and milk (Arbuckle *et al.* 2009, 148; Spiteri *et al.* 2016). At the site of Erbaba (late 7th millennium BCE), the exploitation of sheep can be assigned to both the meat model and the combination of milk and meat, mostly due to the presence of a significant number of young lambs and yearlings in the assemblage (Arbuckle *et al.* 2009, 141). On a regional scale, herd management strategies of both sheep and cattle changed significantly over time, with an apparent increase in the importance of dairy products in the Late Neolithic (Arbuckle *et al.* 2009, 149). Goats, on the other hand, show a more conservative pattern. On a regional scale, they appear to have been culled at older ages and were less prevalent in the assemblages, indicating small scale herding. Regional comparison in goat herding strategies shows that male goats were slaughtered as older kids, while females were culled at older ages, implying that their main use was for milk and fibre as proposed in the model for ‘type B milk’ (figure 10; Arbuckle *et al.* 2009, 149).

Lake District. In contrast to Central Anatolia, cattle, pigs, goats and sheep were all already domesticated and managed from the start of the Neolithic occupation. Bademağacı is one of the few sites, and certainly the best studied one, in this region in terms of archaeozoological evidence. The remains from Bademağacı (ca. 7.000 - 6.000 BCE) have been studied in order to ascertain animal management strategies. During the earliest phases of occupation, herding strategies for cattle seem to have been directed towards meat production. Although the sample size for cattle is small – making it difficult to argue firmly on any changes in patterns – there seems to be a shift in culling practice which favours milk production at the end of the 7th millennium (Çakırlar 2012b, 90-91; De Cupere *et al.* 2008, 385). This shift in culling practice is accompanied by an increased relative importance of cattle in the animal assemblage, indicating that dairying practices probably became more important (De Cupere *et al.* 2008, 386). Goats and sheep, on the other hand, were probably kept for their secondary products throughout the entire span of occupation at Bademağacı. This is mostly seen by the fact that a lot of the animals survived into maturity, which is indicative of the herders' reliance on secondary products such as wool and milk (Çakırlar 2012b, 90-91; De Cupere *et al.* 2008, 385). At the sites of Hacılar and Höyücek zoological evidence points to the possible use of sheep for dairy and textile production besides their role in meat production (Düring 2011, 166).

Aegean Anatolia. Archaeozoological research on faunal remains from Neolithic Ulucak Höyük (ca. 7.040 - 5.6600 BCE) reveals in great detail how the exploitation of animals changed over time at the site. In the earliest phases of settlement, sheep, goats and cattle seem to have been kept mainly for meat production, with fewer indications of intensive use of secondary products (Çakırlar 2012b, 92-93). For cattle, an increased reliance on milk seems to grow gradually over time, until a relatively sharp rise occurs in level IV (ca. 6.040-5.660 BCE), where the culling practices imply that milk production became a vital part of the cattle management strategy (Çakırlar 2012a, 13). For sheep and goats there also seems to be a clear turning point in herd management strategy near the transition from Level V to Level IV (ca. 6.040-5.660 BCE), when kill-off patterns clearly show a new focus on culling animals between 1 and 4 years old, indicating a far greater focus on milk products (Çakırlar 2012a, 18; Çakırlar 2012b, 89). Before then, caprine culling had focused on young males of up to 12 months, while females were kept alive as long as they could reproduce (Çakırlar 2012a, 18). To summarise, at the site of Ulucak the greatest change in herd management strategies, both for cattle or goats and sheep, occurred at the end of the 7th millennium, when culling profiles seem to indicate an increased reliance on dairy products (Çakırlar 2012a; Çakırlar 2012b; Çilingiroğlu and Çakırlar 2013, 24).

Marmara Region. Several sites in this region which date to the second half of the 7th millennium provide archaeozoological evidence for herd management: Ilıpınar (6.000 - 5.500 BCE), Menteşe (ca. 6.400 - 6.000 BCE) and Fikirtepe (6.500 - 5.500 BCE) (Çakırlar 2012b; Düring 2011, 197). As mentioned before, cattle is relatively prominent in this region, although goats and sheep are also well represented in the faunal assemblages. At Menteşe, more than 60% of the domestic food animals were cattle. Culling patterns provide a possible indication of dairy production, since young calves were commonly slaughtered, although this interpretation should be approached with caution since the sample size is very small (Çakırlar 2012b, 91). At Fikirtepe, cattle are present in similar frequencies, although the kill-off pattern at this site indicates a focus on meat exploitation, while dairy was probably of secondary importance. Culling data for goats and sheep at Fikirtepe, although not very clearly described, seems to indicate that exploitation for dairy products only happened on a small scale (Çakırlar 2012b, 91-92). At Ilıpınar, relatively few cattle remains were found. Culling of caprines at Ilıpınar mainly focused on animals of less than a year old, which is interpreted as a strong indication of meat exploitation. However, some individuals were kept into old age, possibly indicating some interest in their secondary products (Çakırlar 2012b, 91). It is interesting to note that the site of Barcın Höyük, where evidence for dairy lipids in ceramics was found, is within walking distance of Ilıpınar, thus indicating possible cultural connection or exchange (Çakırlar 2012b, 91; Thissen *et al.* 2010).

3.4 Summary of the results

Before continuing to the next chapter, which will discuss the relations between the 8.2 ka event and dairy consumption, a condensed overview of the evidence for dairy consumption will be given. The evidence will be presented per region and with special emphasis on chronology, insofar as this is possible. For a visual representation of this data, see appendix 1. In this discussion, the genetic evidence was left out. This is because these studies indicate that people in Neolithic Anatolia were not lactase persistent, and must therefore have found other ways to still be able to consume dairy products. Processing dairy products into cheese, yoghurt or other fermented products would certainly have provided ways for these Neolithic societies to benefit from the nutritional advantages of this foodstuff.

South-eastern Anatolia. No evidence has yet been found to indicate that the Neolithic populations of South-eastern Anatolia consumed dairy products to any significant degree.

Central Anatolia. At Çatalhöyük East (ca. 6.800 - 6.300 BCE) moderate amounts of dairy lipids were found in ceramics, while at Çatalhöyük West (ca. 6.000 - 5.800 BCE) lipid residues reveal that dairy was consumed in relatively greater amounts. Archaeozoological studies indicate a similar trend of increasing focus on dairy production towards the end of the Neolithic period, at the time of the shift from East to West. Other sites in the region reflect this change in zoological assemblages. Sheep and goats were the dominant food domesticates of the region.

Lake District. The archaeozoological evidence reveals that dairy was consumed in moderate amounts from the start of the occupation in the region, around 7.000 BCE. The evidence from Bademağacı reveals a shift at the end of the 7th millennium, however, indicating an increasing focus on cattle as opposed to sheep, and an increased interest in dairy exploitation. Lipid research, however, does not yet provide any evidence for dairy consumption in this region.

Aegean Anatolia. Archaeozoological research at the site of Ulucak shows a steady increase in dairy consumption throughout the 7th millennium BCE. At the end of the millennium, a sharp increase in the interest in dairy products is clearly visible. Lipid research has yet to provide any evidence for dairy consumption in the region, with research at Ulucak still ongoing at present.

Marmara Region. This region provides the greatest amount of evidence for dairy consumption from lipid residues. The sites that provide evidence for dairy consumption from ceramics are all dated between 6.500 - 5.500 BCE, but most lack precise chronologies. A recently excavated and researched site is that of Barcın Höyük, dated to ca. 6.200 - 6.000 BCE, where significant amounts of dairy lipid residues were also found. Archaeozoological research in the region provides limited results for dairy consumption, although the data do indicate that dairy consumption probably occurred to a moderate degree throughout the Neolithic.

4. Between synchronicity, causality and correlation

Based on the evidence provided in the previous chapters, this chapter aims to assess the correlation between the 8.2 ka event and the intensification of the consumption of dairy products in Neolithic Anatolia. Firstly, the synchronicity between the data presented in chapters 2 and 3 will be discussed. Then some theoretical context will be provided on the discussion of causality and correlation and a tentative theoretical framework for similar research is suggested.

4.1 Synchronicity

As has been made clear in the previous chapter, when it comes to genetic studies the evidence for adaptation to dairy consumption significantly postdates the 8.2 ka event. The relevant information gleaned from this, is that people will have had to process their dairy products to prepare them for consumption.

South-eastern Anatolia. One of the nearest sources of climate proxy data for this region is the pollen record from Lake Van, which reveals limited evidence for aridification during the 8.2 ka event based on the vegetation of this region. Evidence for intensification of dairy consumption at this time is lacking for this region. Both the archaeozoological and the lipid research fail to provide evidence for changes in consumption patterns. Based on the currently available evidence, a connection between dairy intensification and the climate event is ruled out.

Central Anatolia. The climatic impact of the 8.2 ka event, as reconstructed from the available climate proxies, was probably limited in this region. This is reflected in the archaeological records. At the best-studied site of Çatalhöyük, there are no great changes in habitation patterns or practices around the event (Asouti 2009, 4; Berger *et al.* 2016, 1851). The evidence presented in this thesis further substantiates this claim since the exploitation patterns of animals based on both archaeozoological and lipid residue studies do not indicate severe changes at the time of the climate event. Rather, the move between the East and West Mounds around the turn of the millennium seems to be a transitional point, so far as there *is* one when it comes to the intensification of dairy consumption. Still, the evidence for this intensification is not overwhelming and rather points to a slow but steady increase in dairy consumption throughout the 7th millennium BCE with a slight upsurge at the end of the millennium.

One of the factors that complicate this narrative is the fact that new forms of thin-walled, mineral tempered cooking pots are only introduced in Central Anatolia after ca. 6.500 BCE (Thissen *et al.* 2010). While archaeozoological evidence points mostly towards meat consumption, the consumption of dairy from sheep and cattle in modest amounts can not be excluded at any given time, and the use of goats for their milk during the entire 7th millennium is implied in their culling patterns (Arbuckle *et al.* 2009, 149). The evidence from lipid studies, on the other hand, provides a far clearer chronological transition, with a clear distinction between the East and West Mounds in terms of dairy processing (Evershed *et al.* 2008; Hendy *et al.* 2018). However, while this may point to an increase in dairy consumption, it may also indicate a change in ceramic technology. Before the introduction of the new pots, dairy may have been processed in perishable containers, thus leaving no traces for archaeologists to investigate. The increased presence of dairy lipids in pottery towards the end of the millennium may then only indicate the adaptation to cooking in ceramic vessels, as opposed to an increase in dairy consumption.

The absence of cultural or economic change in relation to the 8.2 ka event at Çatalhöyük is striking, since the contemporaneous site of Tell Sabi Abyad goes through a period of significant changes at the time of the event (Van der Plicht *et al.* 2011), and the two sites have quite similar environmental conditions and settlement complexity. For instance, both are located in regions that may be defined as marginal, with annual rainfall between 200-300 mm for the region of Sabi Abyad, and 350-400 mm in Central Anatolia (Özbaşaran 2011, 100; Van der Plicht *et al.* 2011, 230). Moreover, both sites were occupied for nearly two millennia, and display a settlement shift towards the end of the 7th millennium. Both of them have been studied in similar detail, especially in terms of their precise chronologies, which makes them prime candidates for the study of the impact of the 8.2 ka event. Why the outcome of these studies differs to the degree that is signified above is yet to be determined.

Lake District. The climatic data for this region signifies that the impact of the 8.2 ka event was probably limited. The lake records from the region provide no evidence for the event (Flohr *et al.* 2016, 26). On the other hand, records from the Aegean and Adriatic sea indicate that around the 8.2 ka event, surface temperatures were lower (Flohr *et al.* 2016, 26), although the precise effects thereof on the environment of the Lake District are not determined at this time. In the archaeozoological record of Bademağacı, a shift can be discerned at the end of the 7th millennium in favour of dairy production, although the sample size used to make this observation is rather small (Çakırlar 2012b, 90-91; De Cupere *et al.* 2008, 385). For the other sites, no specific studies on archaeozoological data have been performed to ascertain to which degree people relied on dairy production, although the use of sheep to this end may be surmised (Düring 2011, 166). As was mentioned above, there is currently no evidence from lipid residue research that indicated the consumption of dairy products in the Lake District.

All in all, the evidence for intensified consumption of dairy products at the time of the 8.2 ka event is scarce at the time of writing. There are several possible explanations for this. Firstly, the environmental conditions in the Lake District were very favourable for plant cultivation, which has been proven to be of paramount importance in the diet of the populations, and the landscape diversity of the Lake District provided a surplus of natural resources, as is reflected in the archaeological data that provides ample evidence for hunting of wild animals and foraging of wild plants and fruits (Düring 2011, 160, 166). This surplus may have limited the need for intensive dairy production, even at the time of the 8.2 ka event. Lastly, the region's chronology is not very detailed in terms of the archaeozoological record and in terms of radiocarbon dates available (Düring 2011, 162). This makes it difficult to discern the exact timing of possible changes in consumption patterns and compare them to the 8.2 ka event.

Aegean Anatolia. The climate proxy data for this region give far clearer indications for the effects of the 8.2 ka event than the other regions discussed above. It is therefore not unlikely that the event resulted in changes in (winter) temperatures, reduced rainfall and changes in vegetation in this region. While these effects may have been quite drastic, the fact that this is a coastal region may have reduced the severity of the impact (Flohr *et al.* 2016, 35).

Lipid residue analysis has, thus far, not yielded any evidence for dairy processing in this region. In terms of the archaeozoological record, the site of Ulucak provides the most detailed account: while consumption of dairy products probably occurred during the entire span of the occupation, an upsurge can be seen at the end of the 7th millennium. In relation to the 8.2 ka event, it is interesting to note that the main archaeozoological researcher at Ulucak, Canan Çakırlar, phrases and dates this trend as follows:

> "[T]he data suggests that the last occupational phase of Ulucak (ca. 6200 - 5700 BC) witnessed an intensification of all economic activities through optimising the exploitation of various seemingly unrelated resources from game in the landscape to milk from sheep." (Çakırlar 2012b, 89)

The given date of 6.200 - 5.700 BCE for the latest occupational phase of Ulucak is remarkable since the previously mentioned dates for it are 6.040 - 5.660 BCE. This change to 6.200 - 5.700, however, would mean these changes directly followed the 8.2 ka event. If this dating is correct, this would mean synchronicity between the climate event and changes in the populations' economic activities. However, since no further explanation is given for the change, this conclusion can not be drawn at this time. Moreover, since the rest of the archaeological record of the site of Ulucak seems to display no obvious changes at the time of the 8.2 ka event, it may be concluded that the effects of climate change were not of great influence on the populations of the region (Flohr *et al.* 2016, 35).

Marmara Region. The proxy data for the effects of the 8.2 ka event for this region are roughly the same as those for Aegean Anatolia, which means that the impact is estimated to be similar. Lipid residue analysis indicates that dairy consumption was prevalent during the Neolithic in this region, possibly as early as 6.500 BCE (Evershed *et al.* 2008; Spiteri *et al.* 2016, 13598; Thissen *et al.* 2010, 158). Archaeozoological evidence confirms this early date since the culling profiles of the sites of Menteşe (ca. 6.400 BCE) and Fikirtepe (ca. 6.500 BCE) provide evidence for dairy production (Çakırlar 2012b; Düring 2011, 197). In relation to the 8.2 ka event, however, these dates are too early, and no clear evidence is presented for changes in subsistence patterns at that time. This is further substantiated by the archaeological record of some of the sites in the region, such as Barcın Höyük, where there is no recorded cultural change during the event (Flohr *et al.* 2016, 35). For the Marmara Region in particular, though, it must be mentioned that the excavation history of many of its sites, principally the rescue excavations discussed in chapter 2, hampers our understanding of the sites' chronology, thus severely limiting the usefulness of their data in this discussion.

Of the regions discussed here, the evidence for intensified dairy consumption predates the 8.2 ka event by nearly three centuries in the Marmara Region and postdates it nearly two centuries in Central Anatolia and Aegean Anatolia. For the other two regions, there was insufficient data to attest for dairy consumption. With the currently available data, no synchronicity can be surmised between the 8.2 ka event and the intensification of dairy consumption in Neolithic Anatolia.

The evidence from the Marmara Region might be connected to the mega 8.2 ka event. This is a tentative connection though because several reasons support it or detract from it. Firstly, the given dates for the mega 8.2 ka event are ca. 6.400 - 5.900 BCE, which is slightly later than the proposed date of 6.500 BCE from the evidence in the Marmara Region. However, this argument may be mitigated by the insufficiently detailed chronologies for many sites in the region, as well as the poorly documented diachronic trends in ceramic and archaeozoological evidence. Secondly, the climatic impact of the mega 8.2 ka event is stipulated to have been quite severe in the Marmara Region (Düring 2016, 139). The impact may have been a factor in increasing dairy consumption. More research is needed, however, to confirm the link between the intensity of dairy consumption in the Marmara Region and the impact of the mega 8.2 ka event.

4.2 The fallacy of causality and the assumptions in correlation

Even though this thesis seems to show little synchronicity between the 8.2 ka event and the intensification of dairy consumption, a theoretical discussion on the implications of synchronicity between climate and cultural change and its limitations is in order. A mere overview of synchronous events is not sufficient, because this will inevitably lead to climatic determinism. This is problematic for various reasons: the cultural responses to climatic changes and the timing and intensity of human responses vary wildly, correlations are difficult to make because of chronological uncertainties, and other factors – such as economic and political disturbances – may have had a part in causing societies to change as well (Kuzucuoğlu 2015). Moreover, climate anomalies, instead of leading to completely new forms of behaviour, may simply result in increased expression of previously made innovations that were already present prior to the climate event (Nieuwenhuyse and Biehl 2016, 3). This could mean that changes that were already ongoing at the time were merely increased in speed or scope.

This discussion will start by analysing the limitations of the data and what this means for the current state of research. It will expand upon the various theoretical frameworks that are dominant in the field of archaeology and will end by reviewing to which degree correlation – let alone causality – can be surmised from currently available archaeological and climatic records.

4.2.1 Difficulties in dating

At present, the large majority of Neolithic sites in Anatolia – and the entire Near East for that matter – remain poorly dated (Nieuwenhuyse *et al.* 2016, 68). Based on these chronologies, archaeologists have been correlating climate change and cultural change for decades, often linking cultural shifts or societal downfalls with some climatic disaster (Düring 2016, 136). This is problematic since synchronicity by definition requires precise dating. The lack thereof, however, has not stopped scores of researchers in proposing correlations nonetheless. Due to the lack of absolute dating frameworks on a global scale, it is easy for researchers to match chronologies of climate and cultural change, by simply moving chronologies up or down a few centuries to match their research question (Nieuwenhuyse *et al.* 2016, 68; Nieuwenhuyse and Biehl 2016, 4). At the same time, climate proxy data on a regional scale are still scarce, yet the rapid development of the field of paleo-climatic sciences over the past decades has created a huge influx of accurate data on a global scale. Both of these elements create methodological difficulties that relate to scale: spatially, climate records do not yet provide the detail necessary to link regional archaeological and climate proxy data, and diachronically the resolution of archaeological dating can often not keep up with that of climate records (Nieuwenhuyse and Biehl 2016, 2-4).

4.2.2 Theoretical paradigms

Apart from the actual data at their disposal, researchers also rely on theoretical paradigms that determine the direction of their interpretations (Van de Noort 2011, 1042). Three important paradigms will be discussed here in chronological order of conception.

The Culture-Historical paradigm, which was – and in many parts of the world still is – the dominant paradigm in archaeology, looks for long-term cultural change in the archaeological record, with one nearly static cultural entity following the other. This way of looking at cultural change, defining it as great shifts in material culture between essentially stable periods, makes it rather easy to find synchronicity and even causality with climate change: all one has to do is match up the dates (Nieuwenhuyse and Biehl 2016, 4). Recent fieldwork, however, has made clear that in the Near East cultural innovations were made continually, thus negating the strict cultural boundaries on which Culture-History bases its theory (Nieuwenhuyse *et al.* 2016, 68-69). Moreover, the aforementioned problems with precise chronologies make the conclusions set by this paradigm rather unreliable.

Not wholly dissimilar to this conception of culture, the New (or Processual) Archaeology of the 1960s and 1970s tried to implicate a holistic view of archaeological culture, focusing on the systems that influence human behaviour. This ‘systems theory’ treated cultural systems as relatively stable, changing under the influence of outside systems such as climate and environmental change (Van de Noort 2011, 1042). The main critique of this method is that it did not leave room for any human agency and/or change, thus turning innovation into adaptation (Düring 2016, 137; Nieuwenhuyse and Biehl 2016, 4). In the theme of the current study, Processual Archaeology's theory posits that synchronicity may be equated to causality since the cultural system is disrupted by the climatic system. This kind of reasoning leads to climatic determinism.

In response to Processual Archaeology, in the 1980s archaeologists of the Post-Processual movement regarded cultural systems as essentially *dynamic*, stating that human agency was the principal driver for societal change (Düring 2016, 137; Van de Noort 2011, 1042). Within this paradigm, finding synchronicity between climate change and cultural change is essentially meaningless, since cultural change happens continually and originates in human agency (Düring 2016, 137). While the influence of climate change on human behaviour is not denied, the danger in this view of archaeology is that climate change is essentially rendered invisible in the resulting narrative (Van de Noort 2011, 1042-1043).

A potential solution to overcome the theoretical blindspots mentioned in the theories above would be a pact between the Processual and Post-Processual methodologies, where climatological and environmental factors are rigorously studied, but the influence of human agency and cultural differences are taken into account as well. In this multidisciplinary approach, it is theoretically impossible to propose direct causality between climate change and cultural change, because cultural change is brought about by a multitude of factors and influences. Correlation, on the other hand, is not ruled out: climate change may have affected human behaviour, even though it was one factor amongst many (Van de Noort 2011, 1044). A multidisciplinary approach is needed to reconstruct social responses to climate change (Nieuwenhuyse and Biehl 2016, 5; Van de Noort 2011, 1043).

5. Conclusion

The main question this thesis set out to answer is: can the intensification of dairy consumption in Anatolia be correlated to the 8.2 ka event? The focal point was to provide an overview of available data. This data was then used to see if there is synchronicity between the increase in dairy consumption and the effects of the 8.2 ka event and what this would mean from a theoretical perspective. In order to answer the main research question, several matters had to be investigated first.

The effects of the 8.2 ka event on the Anatolian regions, so far as there were any effects, were rather diverse. For instance, in Central and South-eastern Anatolia, the effects were probably rather limited, since proxy data fail to indicate environmental changes. The climate proxy data in the Aegean and Marmara Region give a clearer indication of the effects of the event, namely a decrease in average temperatures and a drop in precipitation, although the severity of these effects is not clear. The effects on the Lake District are unclear at the time of writing, but possibly similar to the previous regions. Overall, detailed regional climate proxy data for the 8.2 ka event are very scarce, which means that it is difficult to draw any definite conclusions from them.

Evidence for dairy consumption is easier to find, although the temporal resolution for many assemblages, both ceramic and archaeozoological, is rather low. Throughout Neolithic Anatolia, various sites provide indications of the occurrence of dairy consumption, albeit in differing degrees. Firstly, it must be indicated that in most regions and time periods, dairy consumption on a small scale can not be ruled out. Physical evidence for it, however, first appears in lipid residue research, where a limited amount of evidence points towards moderate dairy consumption in Central Anatolia (ca. 6.800 BCE), while the earliest indication of intensive processing and consumption is found in the Marmara Region (ca. 6.500 BCE). In the Lake District and Aegean Anatolia, archaeozoological research provides evidence for consumption of milk throughout the occupational history, although evidence for an *increase* in dairy consumption is dated to the end of the 7th millennium BCE. This trend is also visible at Çatalhöyük in Central Anatolia around the turn of the millennium, which also corresponds with the move from the East to the West Mound. Based on the dates presented for the intensification of dairy consumption and those of the 8.2 ka event, it can be surmised that there is no synchronicity between the two (see appendix 1). This lack of synchronicity should not be taken at face value, however, since knowledge of the local effects of the 8.2 ka event is currently limited and the temporal resolution of evidence for dairy consumption is too low at this time.

In order to deduce any definite correlation between the effects of the 8.2 ka event and the intensification of dairy consumption in Anatolia, archaeologists mostly need far more detailed data. One of the most prominent difficulties in researching this topic, especially on the scale that is attempted in this thesis, is the lack of sufficiently detailed chronologies, both on an intersite and an intrasite level. The 8.2 ka event lasts only 160 years, which means correlating any possibly synchronous event requires highly detailed archaeological data. A second problem in comparing human behavioural changes with the climate event is the lack of well-defined regional proxy data; since the 8.2 ka event did not impact the whole of Anatolia to the same extent and in the same way, more detailed climatic data for all regions are needed to determine the effects on a specific region. A third obstacle, and possibly the most important one, is that currently other factors that were in play have not been researched in sufficient detail; researchers therefore simply cannot determine that a climatic shift was the foremost reason for a change in subsistence patterns, while there may have been other social, ritual, political or economic factors in play.

This means that, at the time of writing, it is difficult to give any definitive answers. However, while synchronicity between the 8.2 ka event and dairy consumption seems to be excluded in all regions discussed here, it is possible that the intensification of dairy consumption, at least in the Marmara Region, might sooner be linked with the mega 8.2 ka event, which started earlier and lasted longer (ca. 6.400 - 5.900 BCE).

While the present literature study provides insight into the topics of the research question, it could not answer it to a satisfactory degree. This is mostly due to the overall lack of detailed data concerning these topics. As far as possible within its scope, this study provided a critical overview of the effects of the 8.2 ka event and dairy consumption in Neolithic Anatolia per region, while also discussing the theoretical obstacles of the research fields involved.

Future research can hopefully provide researchers with increasingly detailed and extensive chronologies, climate proxy data and interdisciplinary frameworks, so that questions about the role of climate change in cultural developments may be answered in more satisfying ways. Before that time, however, researchers should be cautious in proposing synchronicity and correlation – let alone causality – between climatological and cultural change.

Abstract

The objective of this thesis is to assess whether there is a correlation between the intensification of dairy consumption in Neolithic Anatolia and the effects of the 8.2 ka event. The 8.2 ka event is a global cooling event that happened at approximately 8.200 years BP (ca. 6.300 BCE) which mostly affected the Northern Hemisphere. The proxy data for the event indicate that its effects on the Anatolian regions were diverse: the Aegean and Marmara Regions probably experienced the greatest impact, namely lower average temperature and decreased precipitation. The other regions were either not greatly affected, or are insufficiently studied to be able to do more than speculate. Evidence for dairy consumption was gathered from several sources, of which lipid residue analysis and archaeozoological research provided most of the evidence. Based on this, it may be surmised that there is no synchronicity between the 8.2 ka event and significant increases in dairy consumption in or at any of the regions or sites discussed. Based on a theoretical discussion about the (im-)possibility of determining causality or correlation between archaeological and climatic data, it is concluded that causality is impossible to prove, while correlation is meaningless without extensive research into other factors at play. Future research should provide more detailed chronologies, proxy data and information on how other (socio-economic and cultural) factors influenced the archaeological record.

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List of tables, figures and appendices

Tables

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Appendices

Appendix 1: Overview of evidence for dairy consumption

The following table gives a visual overview of the dates at which dairy consumption is accounted for, and when an intensification in its use takes place. The regions are indicated at the top of the table. Intensification is relative; relative to an earlier time or other sites in the region. The colours do not indicate any absolute amounts.

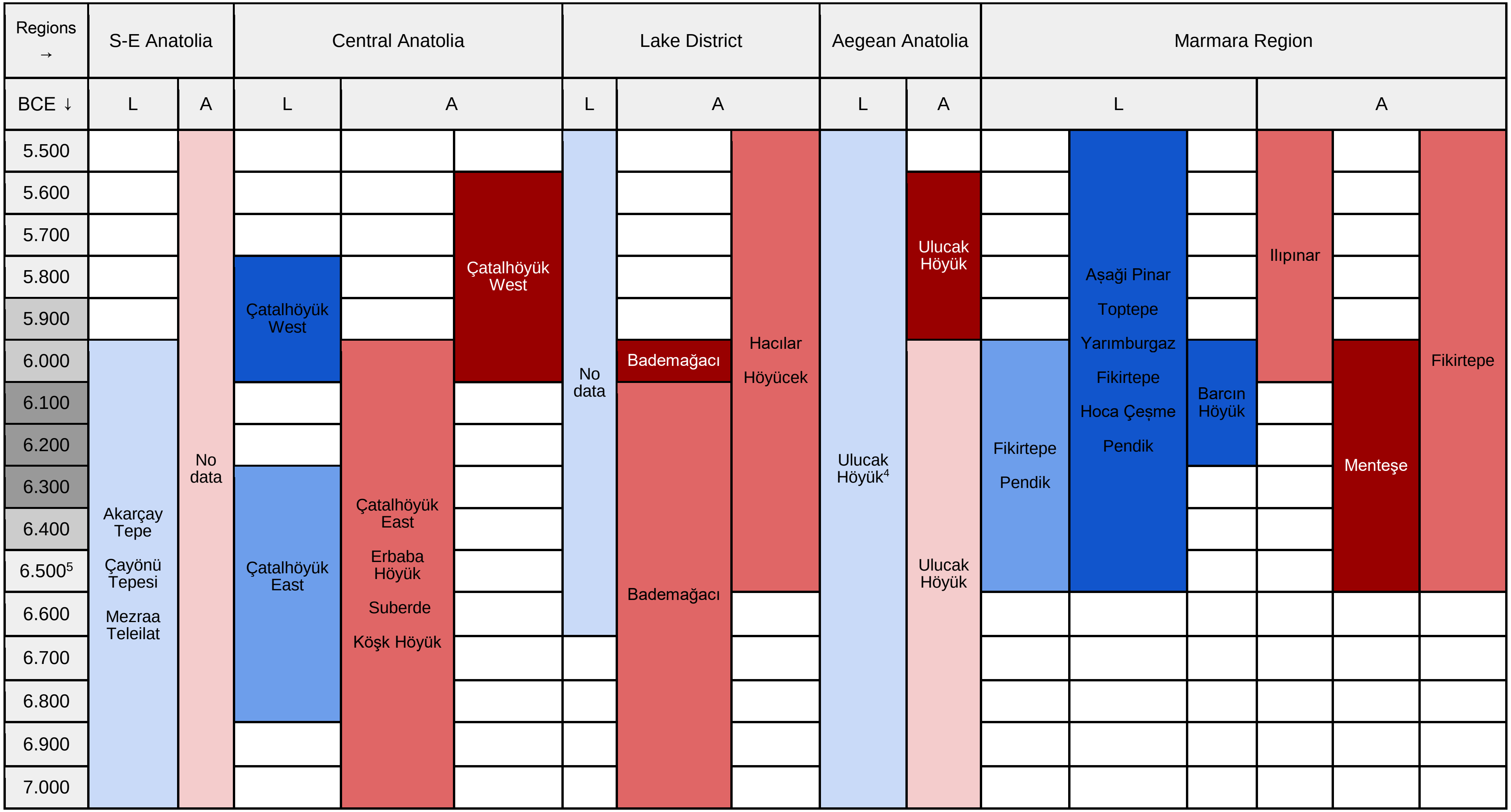
Key:

L = Lipids
no currently available evidence moderate use intensified use

A = Archaeozoological remains
no currently available evidence moderate use intensified use

8.2 ka event

Mega 8.2 ka event



Regions →	S-E Anatolia		Central Anatolia			Lake District			Aegean Anatolia		Marmara Region					
BCE ↓	L	A	L	A		L	A		L	A	L			A		
5.500		No data				No data		Hacılar Höyücek	Ulucak Höyük[4]			Aşaği Pinar Toptepe Yarımburgaz Fikirtepe Hoca Çeşme Pendik		Ilıpınar		Fikirtepe
5.600					Çatalhöyük West					Ulucak Höyük						
5.700																
5.800			Çatalhöyük West													
5.900																
6.000	Akarçay Tepe Çayönü Tepesi Mezraa Teleilat			Çatalhöyük East Erbaba Höyük Suberde Köşk Höyük			Bademağacı			Ulucak Höyük	Fikirtepe Pendik		Barcın Höyük		Menteşe	
6.100							Bademağacı									
6.200																
6.300			Çatalhöyük East													
6.400																
6.500[5]																
6.600																
6.700																
6.800																
6.900																
7.000																

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[4] Research underway (Çakırlar 2012b, 88)

[5] New pottery techniques introduced in Central Anatolia (Thissen et al. 2010)