

Climate and Society During the Late Bronze Age-Early Iron Age Transition in the Eastern Mediterranean

Doctor of Philosophy

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Abstract

During the 13th and 12th centuries BCE, the prosperous Late Bronze Age (LBA) came to an end across the eastern Mediterranean (EM). At this time, the EM saw the destruction and abandonment of important sites and the demise of once-powerful Empires and state systems. Following the events of the terminal LBA, the EM entered the Early Iron Age (EIA), which saw political fragmentation and cultural devolution. Proposed explanations for the end of the LBA are contentious and subject to debate. In recent decades, the climate change hypothesis, which proposes that climate change triggered the events of the LBA-EIA transition through widespread drought and food shortages, has become popular, with several EM palaeoclimate records identifying an onset of drier and cooler conditions at ca. 3.2 ka BP. However, this theory is subject to several limitations, and so this thesis has sought to provide a nuanced re-examination of the role of climate on the LBA-EIA transition.

This interdisciplinary thesis presents an examination of climate and society across the EM through the analysis of key palaeoclimate proxy data and archaeological evidence. Through the examination of a new highly resolved stable isotope record from Kocain Cave in Türkiye and existing palaeoclimate proxy records from the EM and surrounding areas, we can identify a shift to drier and cooler conditions in several proxy records around 3.2 ka BP, coinciding with the LBA-EIA transition. However, heterogeneity can be identified in climatic and socio-political conditions across the EM. Whilst climate changes may have contributed to the end of the Hittite Empire and Mycenaean Palatial System, there is no simple cause-and-effect relationship between climate and the LBA-EIA transition across the EM, as has been presented by the existing climate hypothesis. The climate hypothesis, therefore, requires significant amendments in order to address the heterogeneity of EM climate and society.

Declaration of Original Authorship

I confirm that this is my own work and that the use of all material from other sources has been properly and fully acknowledged.

Signed:

Lydia Bowler

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List of Acronyms, Chemical Symbols and Scientific Units

$\pm$	Represents the range of the error or uncertainty associated with a value
$\sim$	Approximation
‰	Per-mil (part per thousand)
σ	Sigma (standard deviation)
$^{\circ}\text{C}$	Degree Celsius
a.s.l	above sea level
BA	Bronze Age
BCE	Before the Common Era
BP	Before Present
C	Carbon
ca.	circa (meaning approximately)
Ca/Ca^{2+}	Calcium
CaCO_3	Calcium carbonate
cal	calibrated years
CO_2	Carbon dioxide
CE	Common Era
C-G	Cypro-Geometric
DEM	Digital Elevation Model
EA	East Atlantic Pattern

EIA	Early Iron Age
EM	Eastern Mediterranean
EMP	Eastern Mediterranean Pattern
ENSO	El Niño Southern Oscillation
GNIP	Global Network of Isotopes in Precipitation
ka	kilo annum (one thousand calendar years ago)
pCO ₂	Partial pressure of carbon dioxide
PCP	Prior Calcite Precipitation
PG	Protogeometric
IA	Iron Age
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
LA-ICP-MS	Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry
LB	Late Bronze
LBA	Late Bronze Age
LC	Late Cypriot
LH	Late Helladic
LIA	Little Ice Age
LM	Late Minoan
MedCLIVAR	Mediterranean Climate Variability and Predictability
MEDECC	Mediterranean Experts on Climate and Environmental Change

Mg	Magnesium
NA	North Atlantic
NAO	North Atlantic Oscillation
NCP	North Caspian Pattern
OWDA	Old World Drought Atlas
O	Oxygen
NOAA	National Oceanic and Atmospheric Administration
PDSI	Palmer Drought Sensitivity Index
PG	Protogeometric
SST	Sea Surface Temperature
Sr	Strontium
SRTM	Shuttle Radar Topography Mission
SubMyc	Submycenaean
SM	Subminoan
²³⁰ Th	Thorium
TSI	Total Solar Irradiance
²³⁸ U, ²³⁴ U	Uranium
USGS	United States Geological Survey
VPDB	Vienna Pee Dee Belemnite [geochemical standard]
VSMOW	Vienna Standard Mean Ocean Water [geochemical standard]
WMO	World Meteorological Organization
yr	Year

^{12}C , ^{13}C , ^{14}C Carbon isotopes

$\delta^{16}\text{O}$, $\delta^{18}\text{O}$ Oxygen isotopes

Chapter 1 - Introduction: Research Context

1.1. Introduction

In recent decades there has been significant interest in climate as an agent of societal change and “collapse”, with many studies attributing the fall of ancient societies to climate change events, as will be discussed further in this chapter (Butzer, 2012; Degroot et al. 2021; deMenocal, 2001; Weiss and Bradley, 2001; Weiss, 2017). For example, the apparent demise of ancient Maya and the fall of the Roman Empire have been linked to climate change (Hodell et al. 1995; Haug et al. 2003; Douglas et al. 2016; McCormick et al. 2012; Harper, 2017). Notably, the intensive focus on past climate and societal “collapse” is thought to reflect contemporary fears and concerns over human-induced climate change and the trajectory of modern life and its sustainability (Tainter, 1988; Ord, 2020; Centeno et al. 2023: 5). Modern-day climate change is seen as a significant threat in the public consciousness (Lenton, 2023). For example, the increasing frequency and severity of water scarcity and drought seen across the Mediterranean region, which is recognized as a major “climate change hot spot,” is likely to have significant impacts on agriculture through the degradation of agricultural land and the loss of fertile soils (Giorgi, 2006; Hoerling et al. 2012; IPCC, 2013; Zittis and Hadjinicolaou, 2017; Zittis et al. 2019; Tuel and Eltahir, 2020; MedECC, 2020). We must, therefore, learn how to adapt to increasingly harsh environmental conditions and their challenges.

It is generally believed that understanding the past will help guide modern societies toward sustainability for our present and future, providing historical hindsight of themes and patterns that have led to systemic failures in societies and insight into factors that promoted human resilience (Riede and Sheets, 2020; Burke et al. 2021; Centeno et al. 2023: 19; Douglas et al. 2016; Centeno et al. 2023: 5). The environmental sciences and archaeology can both provide valuable information on past climate and human societies. Palaeoclimatology can provide valuable information on longer-term natural climate variability and variations in the mean state of the climate system, whilst archaeology can inform us of societal responses and adaptations to the environment (Cook et al. 2016; Middleton, 2024). Interdisciplinarity is therefore required to understand past climate-societal interactions. An introduction to how we understand past climate and societal change is provided in 1.2.

Climate and the End of the Late Bronze Age in the Eastern Mediterranean (EM)

It is important to first state that in this thesis, the EM is defined as the eastern area of the Mediterranean Sea extending between Greece, Türkiye and the Levant. Due to an apparent approximate temporal correlation between the end of the Late Bronze Age (LBA) and a climate event at 3.2 ka BP across the EM, climate change has been hypothesized as a driver behind the Late Bronze Age-Early Iron Age transition (Drake, 2012; Kaniewski et al. 2013; Langgut et al. 2013; Kaniewski and Van Campo, 2017), as will be examined in this thesis.

This chapter will introduce how we understand past climate and society through palaeoclimatic and archaeological evidence before introducing the focus of this thesis which examines climate and the LBA-EIA transition across the EM (see 1.2.2). This chapter will also present the aims and objectives of this thesis (see 1.3) and outline its structure (see 1.4).

1.2. Understanding Past Climate and Societal Changes

Before introducing climate as a potential driver of the end of the LBA across the EM, it is important to first introduce how we understand past climate, societies, and “collapse.”

How Do We Reconstruct Past Climate Conditions?

Information on past climate variability (proxy data) is commonly preserved in a range of natural climate archives, including ice cores, marine and lake sediments, tree rings, and cave deposits (Hernández et al. 2020; Zittis et al. 2022). As will be discussed further in Chapter 2 (2.3), the value of proxy data to palaeoclimatic reconstruction is dependent on the chronological and temporal resolution of records, as resolution determines the degree of detail that can be obtained about past climatic conditions and their timing, including any abrupt events (Bradley, 2015). For example, we require highly resolved proxy records to investigate the incidence and magnitude of abrupt climate events such as drought and changes in climate variability over time, e.g., the duration and frequency of drier years (e.g., Manning et al. 2023). Critically, low-resolution proxy records are more likely to record longer-term changes in mean climate state, which can lead to different societal impacts (Ur, 2015; Jones et al. 2019). Additionally, if proxy chronologies are inaccurate, there is a potential danger of inadvertent temporal correlation of events that occurred at different times (Hodell et al. 2007: 238).

In recent decades, technological and methodological advances in palaeoclimate reconstructions have led to increased availability of highly resolved palaeoclimate proxy data, thus improving our understanding of past climate conditions (Caseldine and Turney, 2010;

Wong and Breecker, 2015; Wise and Jurkowski, 2024). Notably, the Holocene was previously characterized as a period of climatic stability, but this epoch was in fact, marked by a series of abrupt climate oscillations known as rapid climate change (RCC) events (Dansgaard et al. 1993; Alley et al. 1997; Bond et al. 1997; Mayewski et al. 2004; Wanner et al. 2011). A much discussed example of an RCC is the so-called 4.2 ka BP event, which has been regarded as one of the largest and best-documented abrupt climate events of the Holocene (Bini et al. 2019; Scroton et al. 2023; Weiss, 2017).

How Do We Understand Past Societies?

Archaeological evidence, which provides insight into the nature of past human societies and societal change, is drawn from fieldwork through excavation and surface survey, as well as examination of written records where we have them. Excavation involves the examination of buried deposits and features of archaeological sites and monuments at individual sites, whilst surface survey involves systematic walking over the ground surface of an area, recording, mapping and collecting artefacts to establish past activity. Excavation allows archaeologists to understand a site in greater detail and determine its stratigraphy and chronology, whilst surveys provide a broader reconstruction of the landscape of past societies including settlement patterns and insight into groups that may have only left behind a scarce archaeological record (Carver, 2009). Archaeologists and historians may also refer to literary and documentary texts (e.g., palace records and legal texts), which can provide additional insight into past culture and society. By examining archaeological evidence, it is possible to analyse important aspects of society and societal organization, such as demography and culture.

Throughout history, human civilizations, which can be understood as the cultural systems of a complex society, have been subject to profound change (Tainter, 1988: 41; Crumley, 2007; Daems, 2021: 1). Over the last 12,000 years the complexity of human societies has increased as smaller independent groups developed to larger interdependent, complex states (Tainter, 2000: 7; Tainter, 1988: 22). As summarized by Tainter (1999: 989) the complexity of societies “refers to the size of a society, the number of its parts and their distinctiveness, the variety of specialized roles, the number of distinct social personalities, and the number and effectiveness of mechanisms for integrating these into a functioning whole.” Complex societies such as states and empires are generally understood through characteristics including monumental architecture, political institutions, and economic specialization (Daems, 2021: 3).

It is also important to highlight that, traditionally, archaeological research has focussed on top-down perspectives of societies, focusing on the elite ruling class, with less consideration of ordinary people due to the high archaeological visibility of elites (Joyce et al. 2001; Middleton, 2017a: 18). However, it is important to recognize that smaller scale cooperative units such as households were important components of early cities and states which held them together (Halperin, 2017: 285; Yoffee, 2019: 2).

The Challenges of Establishing Relationships Between Climate and Society

Whilst the integration of palaeoclimatic and archaeological research is vital for our understanding of past climate and societal changes, consilience, which is the agreement between the different subjects, presents theoretical and practical challenges (Izdebski et al. 2016a). As summarized by Silva et al. (2022), within interdisciplinary research, there can often be a mismatch in expectations, misunderstandings and assumptions made regarding each other's theoretical perspectives and methodological approaches. Firstly, the spatial and temporal scale of analysis is a major factor contributing to the difficulty in establishing a link between climate and society (Izdebski et al. 2016a; Contreras, 2016; Burke et al. 2021). For example, palaeoclimatic reconstructions are generally undertaken at a regional scale and multi-decadal temporal resolution (although an increasing number of studies do provide sub-annual-decadal temporal resolution, including the new Ko-1 stalagmite record of this thesis) (Contreras, 2016: 9). In contrast, archaeological research often focuses on local diversity and decision making at local and annual-decadal scales and small geographical ranges (Izdebski et al. 2016a; Contreras, 2016: 9-10). Relating paleoenvironmental and archaeological data is also challenging due to the difficulty in establishing explanatory links between climate and societal changes due to the complex causal relationships between them, as will be discussed further in 1.2.2.1 (Contreras et al. 2018; Finné et al. 2019). Critically, chronological resolution is also a fundamental prerequisite of palaeoclimate and archaeological data when considering any synchronicity and causality between climate and societal changes, as the absence of a close temporal correlation can undermine any proposed causality (Manning et al. 2020; Degroot et al. 2022).

Palaeoclimatic and archaeological records also have their respective challenges and limitations, which limit our understanding of climate and society (see Chapters 2 and 3).

1.2.1. Societal “Collapse” and the End of the Late Bronze Age across the Eastern Mediterranean

Whilst popular, the concept of “collapse,” which has been applied to states, nations and societies, is subject to ambiguity as there are multiple definitions and disagreement over what it is and what it applies to (Butzer, 2012; Middleton, 2012: 260-261; Middleton, 2017a: 11; Centeno et al. 2023). Generally, “collapse” is understood by most archaeologists as “the fragmentation of states into smaller political entities; the partial abandonment or complete desertion of urban centres, along with the loss or depletion of their centralizing functions; the breakdown of regional economic systems; and the failure of civilizational ideologies” (Schwartz, 2006: 5-6). Societal “collapse” is largely inferred from visible changes in settlement pattern, destructions and abandonments and an overall simplification of social organization and the disintegration of political units (Middleton, 2012; Lawrence et al. 2021).

Societal “collapse” has often been viewed as a regression away from a more civilized culture and the catastrophic ending of a once-great and complex civilization (Middleton, 2012: 265; Tainter, 2023: 27; Scott, 2017: 186; Johnson, 2017: 58). For example, Diamond (2005: 3) suggests that “collapse” is a “drastic decrease in human population size and/or political/economic/social complexity over a considerable area, for an extended time.” Periods after collapse have also traditionally been characterized as so-called “Dark Ages” (e.g., the Greek Dark Ages) due to an apparent paucity of archaeological remains (Bell, 1971; Hawkins, 2009; Tainter, 1999: 988). As summarized by Middleton (2012: 265), “Dark Ages” are associated with few written texts, sites or material culture such as pottery and are traditionally characterized as unstable, more violent and less period (Middleton, 2012: 265). Following this view of “collapse,” a number of studies have focussed on what went wrong (Tainter, 2016: 30), with Diamond (2005) suggesting that “collapse” is an extreme form of decline and the worst thing that can happen to a complex society. As summarized by Tainter (2016), there has been an assumption in some “collapse” literature (e.g., Diamond, 2005; Graeber and Wengrow, 2021) that human societies have an inevitable tendency towards complexity, and thus once a complex society “collapses,” something has been lost. However, Tainter (1999: 991) suggests that complex societies are historical anomalies, emphasizing that throughout history, the common political unit was the small, autonomous and self-sufficient community. Morris (2019) and Scott (2017) also argue that most states were unstable entities that did not last long due to their brittleness and fragility. Additionally, Yoffee (2019: 2) suggests that the most centralized states are often the most fragile and, thus, are subject to disintegration and “collapse.” For example, Yoffee and Seri (2019) suggest that the instability of the Akkadian

Empire led to a return to more normal circumstances. Scott (2017: 209) asks the question, “Why deplore ‘collapse’ when the situation it depicts is most often the disaggregation of a complex, fragile, and typically oppressive state into smaller, decentralized fragments?”

In recent decades there has been a greater focus on human resilience and adaptability when considering societal changes, with “collapse” viewed as a necessary societal reorganization (e.g., McAnany and Yoffee, 2010; Butzer, 2012; Middleton, 2012: 259; Haldon and Rosen, 2018). Within resilience theory, which is drawn from ecology, resilience can be described as the capacity of a system to cope with and adapt to pressures (Gunderson and Holling, 2002; Walker and Salt, 2006; Allcock, 2017; Centeno et al. 2023: 18). The Adaptive Cycle model, which is a central concept of resilience theory, (see **Figure 1**) can allow us to visualize and contextualize transformations within human systems (Weiberg, 2012; Allcock, 2017). There are four phases within an adaptive cycle that systems can move through (Gunderson and Holling, 2002; Dearing, 2008; Rosen and Rivera-Collazo, 2012; Allcock, 2017; Haldon and Rosen, 2018):

- Exploitation (r)- This phase identifies a period of growth and accumulation. During this phase, there is increasing complexity, connectedness and conservatism of the system.
- Conservation (K)- This phase represents a period of maximum conservation and connectedness. This phase also exhibits the lowest flexibility, resilience, and potential for change, which limits the system’s ability to respond to points of stress.
- Release (Ω)- This is a phase of destabilization. During this phase, the system is opened to a number of possible responses. This phase culminates in the following phase.
- Re-organization (α)- This phase sees the stabilization and restructuring of a system. This phase is highly resilient, with the highest potential for innovation and adaptability.

As summarized by Allcock (2017), human systems will shift into a different cycle as a means of adaptation to tolerate a disturbance, stress factor, or constraint, and ultimately to grow resilience. Within resilience theory societal “collapse” is often equated with the end of the K-phase and the Ω phase of the adaptive cycle (Rosen and Rivera-Collaza, 2012; Middleton, 2020). By applying this theory to archaeology, “collapse” can be viewed as part of a normal long-term cyclical pattern, within an adaptive cycle (Middleton, 2012: 266; 2017a: 42).

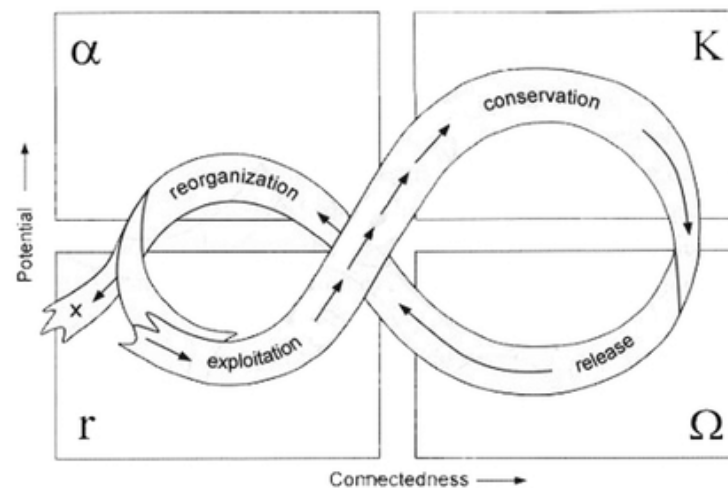


Figure 1. The adaptive cycle. Source: Figure 2-1 from *Panarchy* edited by Lance H. Gunderson and C.S. Holling. Copyright © 2002 Island Press. Reproduced by permission of Island Press, Washington, DC.

It is important to emphasize that “collapse” in the sense of the end of a social order and its people is rare, and so whilst crises existed and landscapes altered, rarely did societies end in an absolute sense (McAnany and Yoffee, 2010: 5-6; 11). As suggested by Centeno et al. (2023: 22), for many citizens, life went on. For example, Middleton (2020: 2) suggests that the changing nature of the Roman Republic and Empire was a clear example of civilizational transformation. Whilst the Roman Empire experienced the “collapse” of a political unit through the fall of the Western Empire, material culture and established traditions did not come to an abrupt end despite the economic and material repercussions of events around the “collapse.” Within archaeology, the concept of resilience is also used to understand the ways in which social groups and communities deal with economic, political, and environmental shocks (Haldon and Rosen, 2018). The more resilient a society is, the better it can sustain disturbances to the system (Middleton, 2017a: 43). As summarized by Izdebski et al. (2022), past human societies as a whole are thought to have been remarkably resilient in the face of severe challenges. Notably, resilience can vary between different segments of society as each subgroup of a complex society has its own set of vulnerabilities and will be affected differently as a result of its particular interaction with a stressor such as climate change (Rosen, 2007: 173; Izdebski et al. 2018). Whilst the “collapse” of political states is understood to affect elite members of society, for most members of a society (e.g., peasant farmers) life goes on as evidenced by continuity in local organizations, traditions, ethnic groups and diverse cultural systems (Renfrew, 1984; Yoffee and Cowgill, 1998; Tainter, 1999; 2016; Scott, 2017; Middleton, 2017a;

2020; Yoffee, 2019: 2; Centeno et al. 2023). For example, whilst the complex systems of ancient Maya collapsed, elements of Mayan society endured (Centeno et al. 2023: 9). Consideration of human agency and belief systems is therefore crucial for our understanding of human societies and “collapse” as the goals and motivations of different societal subgroups and individuals can differ (Izdebski et al. 2022; Rosen, 2007: 9). Significantly, whilst crisis periods are often detrimental for elites and rulers, societal crises also offer opportunities for others, usually non-elites (Middleton, 2020: viii).

To better address the agency of individuals and the wider complexity of societies from the bottom up, a number of archaeological studies have employed agent based modelling (ABM). ABM is used by archaeologists to understand the behaviour and actions of agents (e.g., individuals, settlements, villages) over a range of temporal and spatial settings (Romanowska et al. 2019). For further explanation of ABM, see Romanowska et al. (2019; 2021). Whilst agent based modelling is not undertaken in this research, as it is beyond the scope of this thesis, it may be considered for future research when examining the archaeology of the LBA-EIA (see Chapter 7).

For further discussion of “collapse,” resilience and fragility see Tainter (1988), Yoffee and Cowgill (1988), McAnany and Yoffee (2010), Middleton (2012; 2017a; 2024), Yoffee (2019).

What Causes Societal “Collapse”?

As summarized by Tainter (2016: 27), a host of “collapse” theories have been presented through the years, but there is no consensus as to what causes societal “collapse” and transformation. For example, Tainter (1988) suggests that civilizations begin to fall once the benefits of their societal complexity are outweighed by the costs. Outside shocks such as natural hazards and climate variability have also been suggested to have led to “collapse” (e.g., McCoy and Heiken, 2000; Nur and Cline, 2000; Ord, 2020). As summarized by Tainter (2023: 32-33), “collapse” explanations wax and wane in popularity according to the issues of the day as “collapse” theories are influenced by contemporary issues.

Due to contemporary concerns over human-induced climate change and the increased availability of paleoenvironmental data, numerous interdisciplinary studies have come to focus significant attention on climate-induced societal “collapse” (Haldon and Rosen, 2018). As introduced in 1.1, a number of studies have asserted causal relationships between several short-term climate events and periods of societal change and transformation (e.g., Hodell et al. 1995; Cullen et al. 2000; deMenocal, 2001; Weiss and Bradley, 2001; Gill et al. 2007; Diamond,

2011). It is, however, important to highlight that whilst some scholars view evidence of climate change as the primary driver behind apparent episodes of societal “collapse,” several studies suggest that changing climate conditions may have been one of many causes of societal “collapse.”

1.2.1.1. The Late Bronze Age-Early Iron Age Transition

The end of the LBA in the EM has been commonly understood as an important period of human history that experienced widespread crisis and societal “collapse” (Ward and Joukowsky, 1992; Drews, 1993; Broodbank, 2013: 461; Killebrew, 2014: 598; Cline, 2014). However, it is important to highlight that this thesis will not use the term “collapse” to discuss the end of the LBA and the start of the EIA due to its ambiguity and contentious nature. This thesis instead employs the more neutral term “transition.” However, it is important to note that even this term is contentious for some scholars, as Ward-Perkins (2005) argues that the word “transition” may mask horrors experienced by people during historical events and changes.

Traditionally, the archaeology of the transition period has followed a top-down perspective on the archaeological record, focussing on the destruction and abandonment of LBA sites and the loss of major BA states and empires across the EM, which indicates significant instability and upheaval at the end of the LBA. As the climate hypothesis presents the LBA-EIA transition as a catastrophic “collapse,” it is important to summarize the main events and evidence that has supported this narrative, as presented below. For an introduction to opposing views, see 1.2.2.1.

The Late Bronze Age

During the LBA, the EM was home to several powerful and long-standing states and empires (see **Figure 2**), which operated within a culturally, politically and economically interconnected system, a so-called Club of the Great Powers (Middleton, 2021: 724; Killebrew, 2014: 595; Van De Mieroop 2016: 137). Due to the connectivity of this period, the LBA has been hailed as a “golden age” of internationalism and globalization (Cline, 2014: 58; Killebrew, 2014: 594). At this time, strong and centralised LBA polities and states were engaged in diplomacy and extensive systems of international trade (Knapp, 2013: 416). For example, trade in copper and tin was a key component of interactions across the region during the LBA (Powell et al. 2022; Fischer, 2023; Linkov et al. 2024). Additionally, Cypriot and Aegean pottery was widely exported throughout the Mediterranean in the LBA (Knapp, 2013: 417). However, it is

important to emphasize that several LBA states and empires were also rivals that sought to expand their territory at the expense of others in a highly competitive environment (Van De Mieroop, 2010: 253; Van De Mieroop, 2016: 151). Therefore, whilst the great powers relied on one another, they also frequently sought to harm each other (Van De Mieroop, 2010: 253). As a result, there was a precarious balance of power across the EM that was constantly at risk. Most significantly, between ca. 1325 and 1259 BCE, following the growing influence of the Hittite Empire, Egypt waged war against the Hittites (Grandet, 2022: 425-435). The long-held conflict between Egypt and Hatti ultimately culminated in the famous battle of Qadesh (ca. 1275 BCE) during the reigns of Ramesses II of Egypt and Muwattalli II of Hatti (Pfälzner, 2012: 771).



Figure 2. Map of major Late Bronze Age powers across the eastern Mediterranean and the Near East. Source: Author's original.

The End of the Late Bronze Age and the Transition to the Iron Age

Significantly, the end of the LBA witnessed the end of a highly connected world system of trade, diplomacy, and cultural exchange. During the 13th and 12th centuries of the LBA, the EM underwent a host of destructions and abandonment of important cities and palaces (e.g., Tiryns, Ugarit) (Knapp and Manning, 2016). Sites thought to present evidence of destruction can be seen in **Figure 3**. The end of the LBA and transition into the EIA also brought about the decline and demise of major LBA states and polities across Greece in the west through to Türkiye and the Levant in the east (Knapp, 2013: 447). For example, around ca. 1200 BCE, the Aegean witnessed the end of the Mycenaean palatial system, whilst Türkiye saw the dissolution of the Hittite Empire. The powerful New Kingdom of Egypt ended shortly after the retreat of Egypt from its LBA Levantine territory during the late 12th century BCE (Manolova, 2019: 1196). Whilst the Egyptian Empire lost its vast territory and was unable to ever regain the stability maintained throughout the Bronze Age, the Egyptian state did not experience a “collapse” (Sagona and Zimanksy, 2009: 291). With the end of LBA states and empires also came the end of centralised palatial economies and the international maritime trade network of the EM (Akkermans and Schwartz, 2003; Knapp, 2013: 475). For a summary of key events seen across the transition, see **Figure 4**.

Traditionally, the events of the so-called ‘crisis years’ were thought to have brought on a “Dark Age” at the start of the IA, as the scant and rather obscure archaeology of the EIA was understood to reflect a significantly different world order, one of political fragmentation and cultural devolution (Millek, 2021: 252; Harrison, 2009: 175). For example, the period between the Mycenaean palatial system and the later IA in Greece has traditionally been characterized as a “Dark Age” (Snodgrass, 1971; Desborough, 1972; Lemos, 2006). During the IA, the EM is understood to have seen the emergence of smaller states and a patchwork of polities across the region (Bryce, 2012; Harrison, 2021). Widespread contact between EM states and societies is also thought to be scarce in the IA, reflecting the loss of large-scale connectivity seen during the LBA (Hodos, 2020: 38). Following the end of the LBA, the EM also witnessed the emergence of new cultural forms reflective of a new Iron Age (Hodos, 2020: 38).

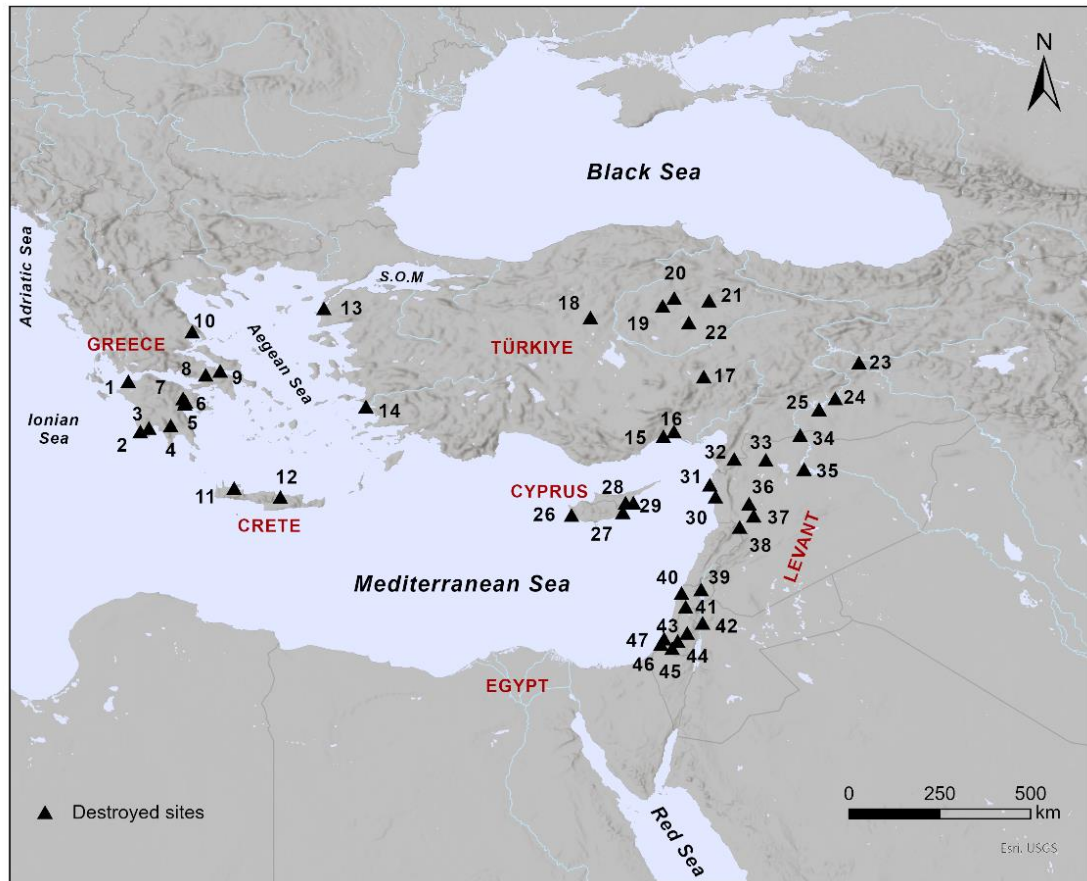


Figure 3. Map of allegedly destroyed sites across the EM as presented by Drews (1993: 9) and Cline (2014: 110-111). The locations of destroyed sites are shown by black triangles. 1) Teichos Dymaion 2) Pylos 3) Nichoria 4) The Menelaion 5) Tiryns 6) Midea 7) Mycenae 8) Thebes 9) Lefkandi 10) Iolkos 11) Kydonia 12) Knossos 13) Troy 14) Miletus 15) Mersin 16) Tarsus 17) Fraktin 18) Karaoğlan 19) Hattuša 20) Alaca Höyük 21) Maşat Höyük 22) Alishar Höyük 23) Norşuntepe 24) Tille Höyük 25) Lidar Höyük 26) Palaeokastro 27) Kition 28) Sinda 29) Enkomi 30) Tell Sukas 31) Ugarit 32) Alalakh 33) Aleppo 34) Carchemish 35) Emar 36) Hamath 37) Qatna 38) Qadesh 39) Hazor 40) Akko 41) Megiddo 42) Deir Alla 43) Bethel 44) Beth Shemesh 45) Lachish 46) Ashkelon 47) Ashdod. Source: Author's original.

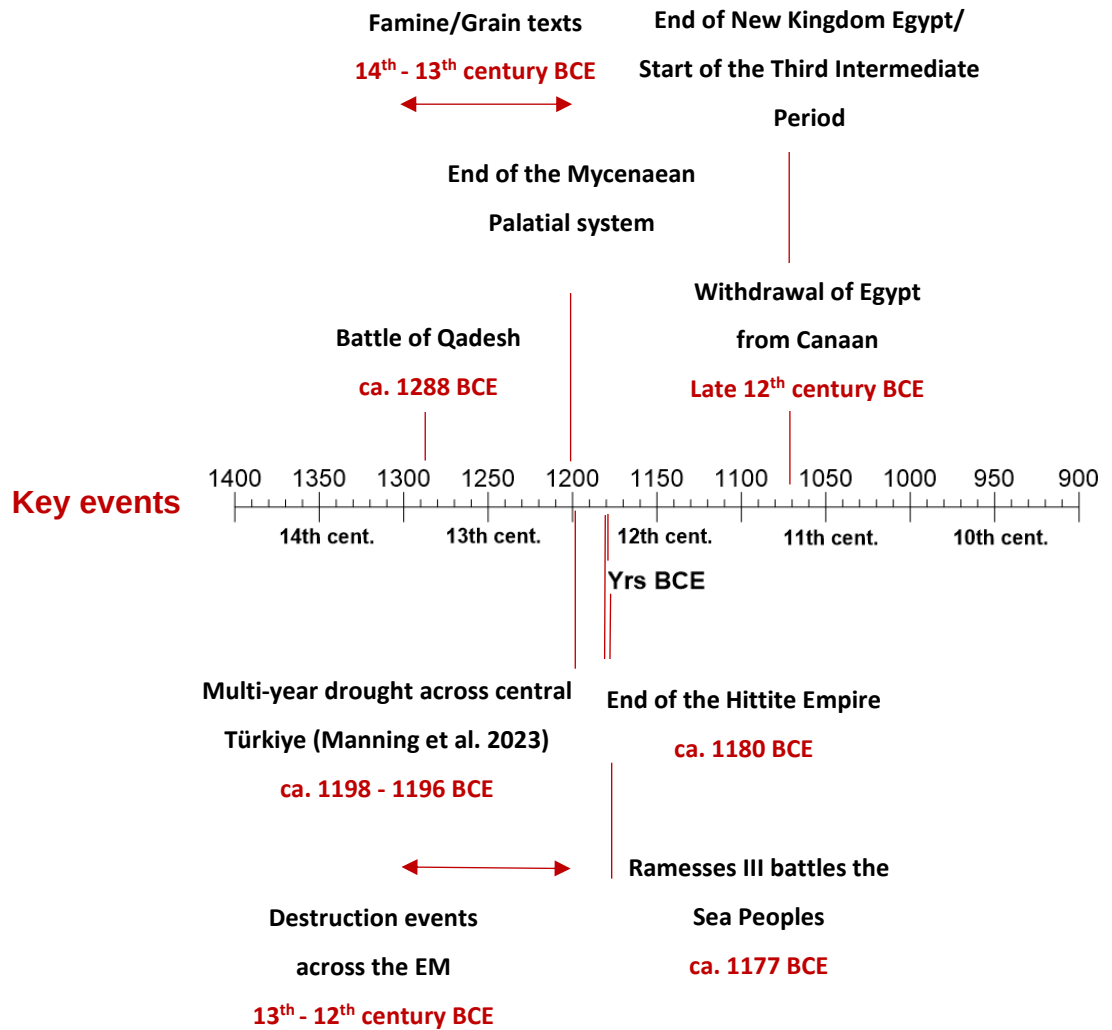


Figure 4. Timeline of key events of the Late Bronze Age-Early Iron Age transition across the eastern Mediterranean. Source: Author's original.

What Brought About the End of the Late Bronze Age across the Eastern Mediterranean?

The so-called “collapse” of the LBA across the EM has been the subject of intense scholarly debate throughout the years, as there is no consensus as to who or what led to the destruction and abandonment of major sites and palaces (Cline, 2014; Knapp and Manning, 2016). Several key hypotheses have been presented, including theories of migration and invasion (most notably the “Sea Peoples”), political competition, centre and periphery inequalities, poor palatial management, system collapse theories (e.g., centralized economies, excessive exploitation of resources), earthquakes, and climatic change (Sandars, 1987; Halstead, 1989, Shelmerdine, 1987; Tainter, 1988; Deger-Jalkotzy, 1995; Sherratt, 2001; Maran, 2009;

Schaeffer 1948; 1968; Nur and Cline, 2000; Carpenter, 1966; Weiss, 1982; Kaniewski et al. 2015). However, due to the complexity and ambiguity of the archaeological evidence, we should not expect to identify a coherent and agreed-upon overarching explanation that accounts for all changes seen during this period over different areas and even at different times across the late 13th and early 12th centuries BCE (Knapp and Manning, 2016: 100; Knapp, 2013: 447). Researchers, therefore, accept that a multitude of coalescing factors may have been responsible for the events of the LBA-EIA transition (Knapp and Manning, 2016: 99). Cline (2014), for example, suggests that the end of the LBA was caused by a “perfect storm” of catastrophic events which linked together. Even so, questions remain about the initial causes of this period of major societal transformation. In recent decades, the climate hypothesis has emerged as a popular theory that reflects current climate concerns. However, whilst the climate hypothesis has become popular, it is not without contention, as will be discussed in 1.2.2.1.

1.2.2. Climate and the Late Bronze Age-Early Iron Age Transition

Climate is often regarded as a significant force that acted on ancient cities, as societies rely upon the stable availability of food resources (Lawrence et al. 2016; Gaastra et al. 2021). Following the assumption that agricultural societies are vulnerable to years of too little rain and drought, several studies suggest that climate change induced subsistence crises result in food scarcity and societal “collapse” (Finné et al. 2017; Middleton, 2017a: 31; Degroot et al. 2021). Resulting societal “collapse” would suggest that societies were unable to respond to the rapidity, amplitude and duration of changing climatic conditions (Weiss and Bradley, 2001). For example, it has been argued that the end of the Akkadian Empire in Mesopotamia, which has been characterized as a societal “collapse,” was the result of an RCC climate event at ca. 4.2 ka BP (Weiss et al. 1993; Cullen et al. 2000; Weiss and Bradley, 2001; Weiss, 2017). Significantly, Weiss (2017) has suggested that a megadrought at 4.2 ka BP ended the productivity of the Khabur Plains, making dry-farming impossible which led to depopulation. However, it is important to emphasize that climate hypotheses are often subject to contentious debate. For example, a number of studies (e.g., Middleton, 2012; 2017a; Haldon et al. 2020; Degroot et al. 2021) have argued that climate change narratives are often environmentally deterministic, failing to recognize societal diversity, agency and resilience and ultimately, the complex interrelationship between climate and society.

As introduced in 1.1, it has also been argued that climate contributed to the end of the LBA across the EM (Drake, 2012; Langgut et al. 2013; Kaniewski et al. 2015). Whilst climate change

has become a popular causal explanation in recent years, the theory that climatic degradation contributed towards the events of the LBA-EIA across the EM is not new. The suggestion that climate change contributed to the events of the terminal LBA was first introduced over 50 years ago by Carpenter (1966), who suggested that a limited-term drought and consequent famine led to the end of the Mycenaean palatial system and the Hittite Empire. This theory was developed further by Weiss (1982), who postulated widespread drought and decline of palatial cultures across the EM. The theory of EM drought, however, could not be supported, with even Weiss (1982) himself recognizing that whilst the identified drought pattern could drive migration at the end of the LBA, there was no proof of this happening (Knapp and Manning, 2016). The climate hypothesis, therefore, fell out of favour.

Due to the rise in scholarship interest in past climate change and its influence on human societies, there has been a resurgence of interest in the role of climate on the LBA-EIA transition across the EM in recent decades. Several important studies have suggested that a drying/cooling event around ca. 3.2 ka BP coincided with the end of the LBA in the EM and thus contributed to the events of the transition (e.g., Kaniewski et al. 2015; Langguth et al. 2013; Drake, 2012). Kaniewski et al. (2010; 2013, 2015, 2019a; 2019b) hypothesize that a multi-century drought event around ~3.2 ka BP framed the end of the LBA, as presented in **Figure 5**. Langguth et al. (2013) also propose that the EM experienced a period of aridity at ~3.2-3.05 ka BP (~1250-1100 BCE) based on pollen analysis of a sediment core from the Sea of Galilee in Israel. Interestingly, recent research has seen Kaniewski et al. (2019b; 2020) revise their position on the climate hypothesis, now postulating that a cooling event at 3.2 ka BP was responsible for drier conditions across the EM, as opposed to a centuries-long drought. For a summary of apparent temperature cooling, see **Figure 6**. Kaniewski et al. (2020) do, however, note that cool, drier conditions may have been further amplified by drought. Evidence for this proposed cold and dry event is provided by pollen-based temperature and precipitation reconstructions from Larnaca Salt Lake and Tell Tweini (Kaniewski et al. 2019b; Kaniewski et al. 2020). Based on the analysis of several marine, lake and stalagmite proxy signals from the Adriatic, the Aegean and the Levant Drake (2012) also suggests that rapid sea surface temperature (SST) cooling during the LBA resulted in reduced precipitation into the more arid EIA (Jahns, 2005; Emeis et al. 2000; Rohling et al. 2002; Sangiorni et al. 2003; Bar-Matthews et al. 1998).

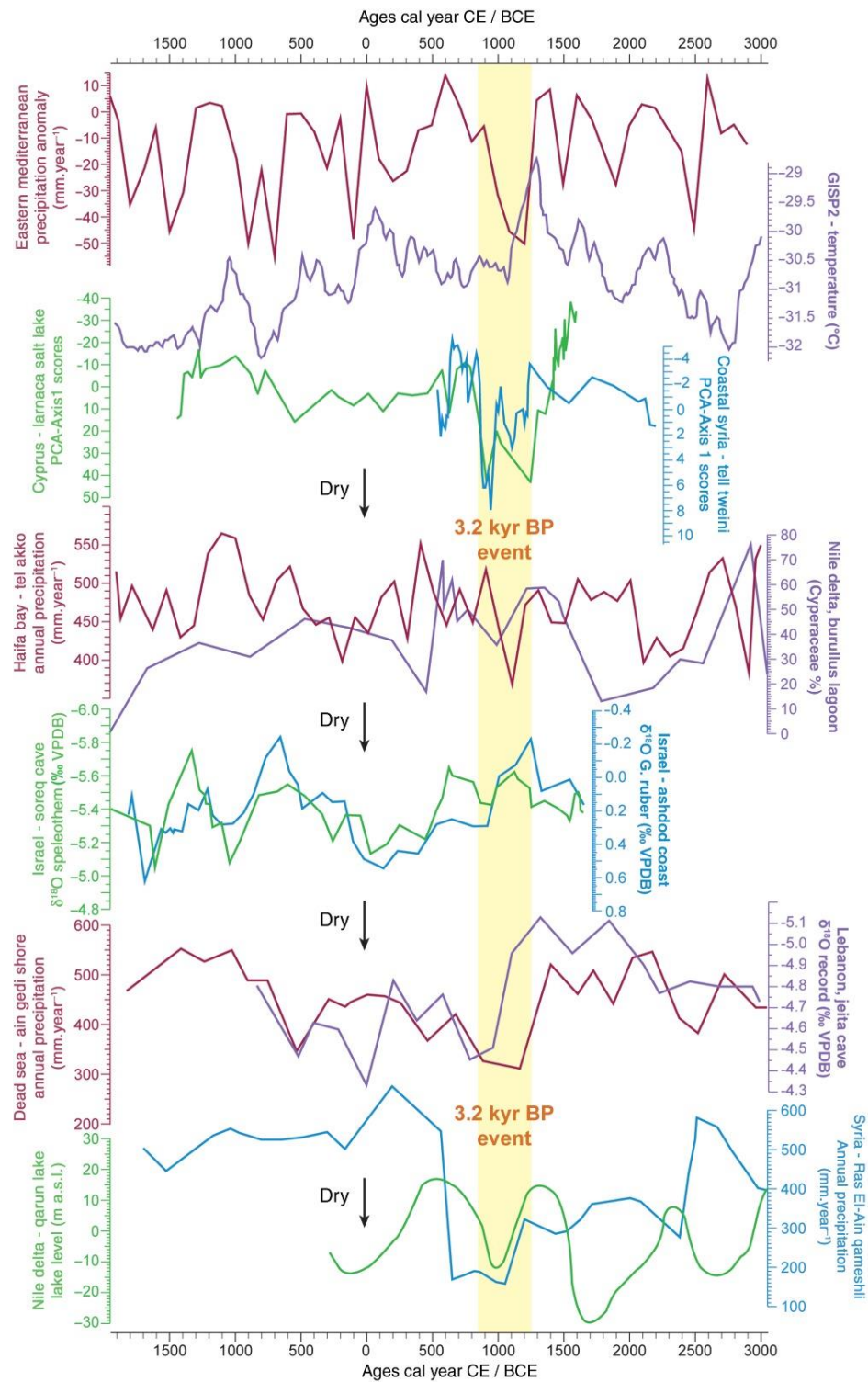


Figure 5. The 3.2 ka BP event at the end of the Late Bronze Age, as identified by Kaniewski et al. (2015) in several records across the eastern Mediterranean. The GISP2 ice core record from the North Atlantic is also presented. Source: Kaniewski et al. (2015), Figure 3. Copyright © 2015. Used with permission of John Wiley & Sons. Permission conveyed through Copyright Clearance Center Inc.

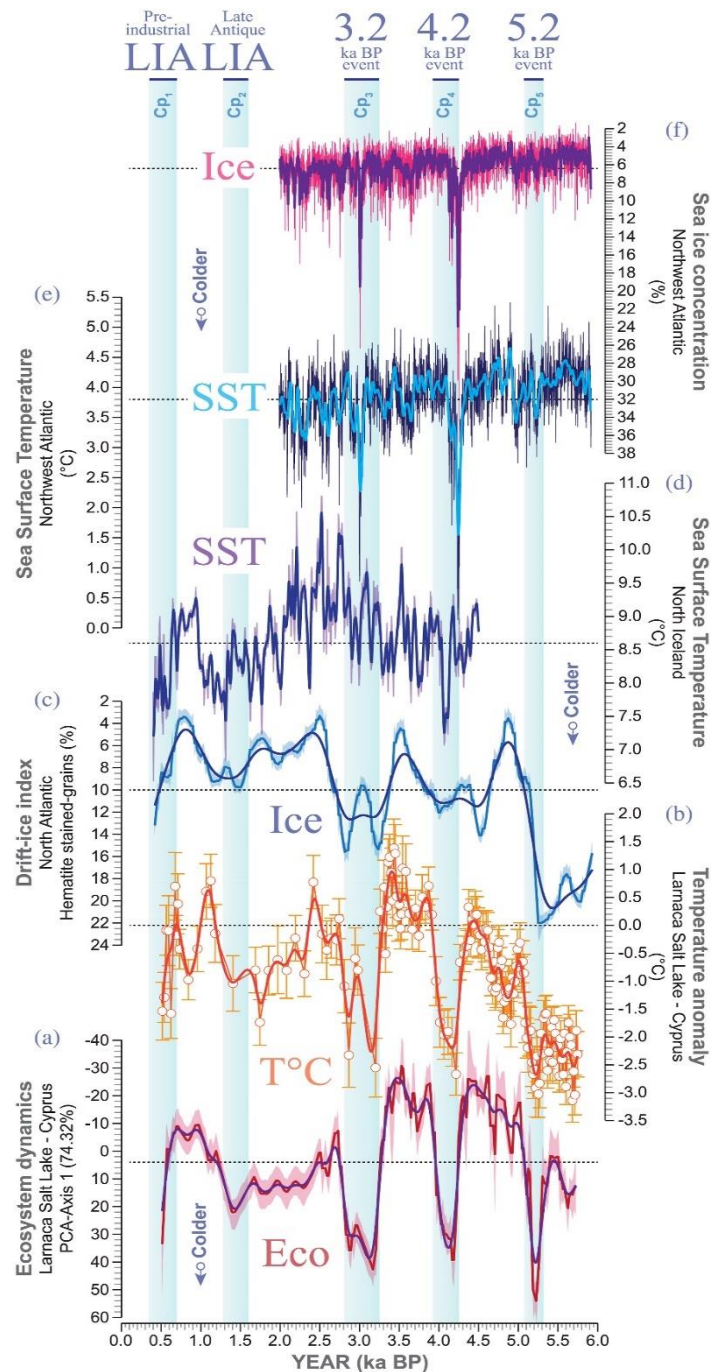


Figure 6. Temperature reconstructions of the North Atlantic and Cyprus presented by Kaniewski et al. (2020). (a) Ecosystem dynamics of Larnaca Salt Lake (b) Temperature anomalies of Larnaca Salt Lake, displayed with the standard deviations (c) Drift-ice index reconstructed from the North Atlantic (Bond et al. 2001) (d) SST from Northern Iceland (Sicre et al. 2008). (e) SST in the Northwest Atlantic (Klus et al. 2018) (f) Reconstructed sea-ice concentration in the Northwest Atlantic (Klus et al. 2018). Cold periods are shaded in blue and denoted by a number (Cp₁ to Cp₅). Source: Kaniewski et al. (2020), Figure 2. Copyright © 2020. Used with permission of John Wiley & Sons. Permission conveyed through Copyright Clearance Center Inc.

Famine and Food Shortages at the End of the Late Bronze Age

Following the assumption that increased aridity will negatively impact soil moisture, thus impacting crop productivity, many of the above-mentioned studies hypothesize that climatic pressure contributed to the demise of the LBA across the EM through food shortages and famine (Kaniewski et al. 2015; Langgut, 2013; Drake, 2012). Climate-induced food shortages and famine at the end of the LBA have traditionally been inferred from several Hittite, Akkadian and Ugaritic documents from the “crisis years” of the 13th-12th centuries BCE, which are commonly understood to refer to grain shortages and/or famine in the lands of Hatti and Ugarit. For example, KUB 21.38 is a Hittite letter sent by the Hittite queen Puduhepa to Ramesses II (1290-1224 BCE) asking the pharaoh to take over her dowry— horses, cattle, and sheep—because there is no grain in her lands (Knapp and Manning, 2016: 121). A summary of KUB 21.38 and other key texts can be found in **Table 1** (see Knapp and Manning, 2016: 120-122 for a more detailed written summary). Based on these texts, Bryce (2005) suggests that the Land of Hatti may have become more dependent on imported grain from Egypt and the Levant after the reign of Hattusili III (Middleton, 2017a). However, the relation of these grain texts to food shortages is not certain (Divon 2008, 103-4). Broodbank (2013: 461) suggests that these texts may refer to grain shipments, whilst Middleton (2022: 187) suggests that grain shortages may have been a common consequence of warfare and conflict. The dating and characterization of these texts are also questioned by some (Knapp and Manning, 2016; Broodbank, 2013; Miller, 2020). For example, Glatz (2020: 289) highlights that the correspondence between the Hittites, Carchemish, the vassal state of Ugarit and Egypt is not confined to the final years of the Hittites and the letters between the states do not necessarily relate to historical events. Furthermore, Glatz (2020: 289) suggests that dramatic predictions of ill fate were an essential feature of LBA diplomacy, used to hasten the delivery of goods.

An important recent study analyzing tree ring width and the stable isotope composition of Juniper trees in central Türkiye also suggests that the Hittite Empire experienced a period of severely dry conditions around approx. 1198-1996 BCE (Manning et al. 2023). Critically, this dry period, which coincides with the final years of the Hittite Empire of the LBA, is thought to reflect a major rare multi-year drought. As consecutive multi-year occurrences of extreme climatic events are thought to be able to push a population beyond adaptation and established resilience practices (e.g., Halstead and O’Shea, 1989; Halstead, 2014; Manning, 2018), it is suggested that the probable multi-year drought overwhelmed adaptive practices and agricultural systems of the Hittite LBA (Manning et al. 2023). Critically, Manning et al. (2023)

propose that this rare climatic episode was an important contributor to the demise of the Hittite Empire.

Table 1. Akkadian, Egyptian, Ugaritic and Hittite texts are understood to reflect famine and grain shortage. Source: Reproduced from Knapp and Manning (2016: 121), Table 2. Courtesy of the Archaeological Institute of America and the American Journal of Archaeology.

Text	Subject matter	Date	Find Location
KUB 21.38	royal letter to Ramesses II	13 th century BCE	Boğazköy, Türkiye
KUB 3.34	Hittite delegation to Egypt	13 th century BCE	Boğazköy, Türkiye
Kitchen 1982, 5.3	Merneptah—grain to Hatti	End of 13 th century BCE	Egypt
RS 94.2002+2003	Merneptah—grain to Ugarit	End of 13 th century BCE	House of Urtenu, Syria
No. 52055/1	Egyptian overseer— grain from southern Levant to Ugarit	13 th century BCE	Tel Aphek, Israel
RS 20.212	Royal letter- grain from Mukish to Ura	13 th century BE	Ugarit, Syria
RS 26.158	Letter- grain to Ura	?	Ugarit, Syria
RS 18.038	No grain left in Ugarit	?	Ugarit, Syria
RS 34.152	General famine (from Emar?)	?	House of Urtenu, Syria

1.2.2.1. Issues and Contention

Whilst popular, the role of climate as a causal factor behind the LBA-EIA transition is contentious due to issues around the quality of palaeoclimatic data and an oversimplification of the interrelationships between past climate and LBA-EIA society across the EM, as is discussed below.

Apparent synchronicity between the onset of arid and cool conditions around 3.2 ka BP and the end of the LBA across the EM has been taken by some to demonstrate a causal role of climate change on the events of the LBA-EIA transition. To confidently reconstruct past climate variability surrounding the LBA-EIA transition and understand the rapidity, magnitude and frequency of climatic changes, we require precisely and accurately dated and highly resolved palaeoclimate records. However, with the exception of a few highly resolved records (e.g., Jeita and Gordion), most EM proxy records possess rather weak chronologies and poor temporal resolution, as is discussed in Chapter 2. This is significant, as dating errors can contribute to the identification of an apparent climate event due to temporal misalignment (Baillie, 1991; Blaauw, 2012). Furthermore, it is important to emphasize whilst there is an assumption that temporal correlation between climate changes and societal changes demonstrates causality, temporal correlation alone does not prove causation (Coombes and Barber, 2005; Kintigh and Ingram, 2018). A chronological correlation may, for example, occur by random chance (Kintigh and Ingram, 2018). Causal arguments must also rely on multiple lines of supporting evidence to present a strongly contextualised argument for a link between climate and societal changes (deMenocal, 2001; Kintigh and Ingram, 2018). However, developing explanatory links between past climate and societal change and “collapse” is an enduring challenge. Notably, Contreras et al. (2018) state that studies that can demonstrate causality and move beyond correlation are rare.

Many archaeologists and historians argue that climate narratives have often oversimplified the role of climate in societal changes, underestimating the multitude of other factors that also affect human societies (McAnany and Yoffee, 2010; Butzer, 2012; Knapp and Manning, 2016; Izdebski et al. 2016a; Haldon et al. 2020). The climate hypothesis is also thought to present an oversimplistic narrative of widespread catastrophic societal “collapse” and disaster (Van De Mieroop, 2010: 237; Killebrew, 2014). In recent years, the catastrophic nature of the LBA-EIA transition has been questioned as archaeological research increasingly reveals a more complex picture of societal conditions of the LBA and EIA across the EM (e.g. see Manning et al. 2020; Middleton, 2021). For example, archaeological research increasingly recognizes that the apparent “collapse” of the LBA was not total (Middleton, 2021: 725; Broodbank, 2013: 469; Manning et al. 2020: 3; Middleton, 2021). Whilst destruction has played a critical role in understanding the end of the LBA as a host of LBA sites suffered destruction and abandonment across the EM, reassessment of destruction evidence in recent years suggests that there may have been a systematic exaggeration of how much destruction took place at ca. 1200 BCE (Millek, 2021). For example, Millek (2021) suggests that 52% of destruction events from the

Levant and Cyprus around ca. 1200 BCE did not take place for several reasons, based on misdating, incorrect assumptions, or insufficient evidence. Additionally, “Cities, states and empires faced different and specific challenges and had different fates. Some states came to an end, others did not. Some cities were destroyed, some abandoned, some rebuilt, some continued unscathed. Some non-state and ‘peripheral’ areas continued, thrived, whilst others seem largely devoid of people” (Middleton, 2021: 748). The end of the LBA is, in fact, thought to have been advantageous for some LBA-EIA societies, who were presented with the opportunity for new growth once free of controlling LBA powers (Cline, 2014: 174). For example, in some areas of the EM such as the Levant, the transition into the EIA aided the emergence of new civilizations, centres of power and cultural features (Killebrew, 2005: 21-22). A catastrophic view of the LBA-EIA transition evidently ignores the fate of non-state populations and regions and elements of survival and continuity (Middleton 2021).

Interrelationships and interactions between climate change and human societies are also highly complex and non-linear (Butzer, 2012; Palmisano et al. 2021). Significantly, the impacts of climate and environmental changes on societies are tied to social, economic and political circumstances, as well as societal attitudes (Middleton, 2020: 14). Environmental degradation is not inevitable and universal for human societies, as societies have always lived with and adapted to climatic and environmental variability (Butzer, 2012; Holmgren et al. 2016; Izdebski et al. 2022). For example, the archaeological-historical record contains multiple instances of human societies successfully adapting to low-frequency climate change (Manning et al. 2023; Butzer, 2012; Degroot et al. 2021). Arid conditions and drought events were common occurrences in the ancient EM, so periodic bad years would likely have been anticipated by ancient farmers and the wider society (Halstead, 1989; Weiberg and Finné, 2018). Ancient societies are, for example, known to have developed buffering mechanisms, including the cultivation of drought-resistant crops and the production of surplus during good yield years to counter the negative effects of climatic variability and subsequent risk of failed harvest (Halstead 1989; Marston, 2011; 2015; Kennett and Marwan 2015; Weiberg and Finné, 2018). Complex societies are also known to have offset problems with bad agricultural years by employing polyculture rather than monoculture to reduce the chance of total crop failure and storing surplus produce (Middleton, 2017a). Complex societies are, however, not indefinitely adaptive to climate variability (Weiberg and Finné, 2018; deMenocal, 2001). For example, persistent droughts and, thus, multiple bad agricultural years may overburden the adaptive capacity of a society (deMenocal, 2001; Izdebski et al. 2022). It is, therefore, important to accurately understand the magnitude and duration of any climate changes. However,

it is also important to emphasize that even substantial climate changes do not necessarily bring about a permanent transformation or breakdown of a system (Izdebski et al. 2022). Additionally, the response of societies to climate change is influenced by the perceptions of such changes and underlying beliefs, which affect the causal logic of a culture and the way it reacts to stressors that are specific to individual societies (Rosen, 2007: 173; Haldon and Rosen, 2018). Different segments of society also have different motivations when faced with environmental changes (Rosen, 2007: 173). For example, the motivations of the elites would have been significantly different from those of an everyday farmer. There is, however, no discussion of agency and belief systems within the existing climate hypothesis narrative. The climate hypothesis also evidently fails to recognize that the impact of environmental changes on societies can significantly vary (Izdebski et al. 2018; Rosen, 2007: 8).

Summary

As discussed in this chapter, attempting to link past climate change and societal changes through history is highly complex. The climate hypothesis has presented a grand explanatory framework with which to understand EM climate and society across the LBA-EIA transition. However, the climate narrative is undermined by the quality of existing palaeoclimate proxy data, its interpretation of the LBA-EIA archaeological record, which demonstrates an unfamiliarity with the depth and complexity of archaeological research, and the contested and transient nature of archaeological reasoning (Knapp and Manning, 2016: 101; Middleton, 2012). Consequently, the climate hypothesis presents an oversimplistic and rather deterministic view of LBA-EIA climate-human interaction.

The examination of past climate and LBA-EIA society evidently requires nuance, as the past does not necessarily reveal that societies inevitably succumbed to climate change (Degroot et al. 2021). It is therefore important to not only consider what made past societies vulnerable and fragile but also how adaptations worked and who for (Middleton, 2024: 38).

Given the limitations of the existing climate hypothesis, the role of climate on the LBA-EIA transition must be re-examined carefully. Due to modern climate change concerns, a re-examination of climate and the LBA-EIA transition is important, not only for our understanding of the LBA-EIA transition but also for how to understand past climate and societal changes more generally.

1.3. Aims, Objectives and Research Questions

To assess the likelihood that climate caused widespread and large-scale societal crises at the end of the LBA across the EM, this thesis aims to re-examine the role of climate on the LBA-EIA transition. To avoid the limitations of existing climate hypothesis studies this thesis will provide an interdisciplinary, expository and nuanced assessment of up-to-date palaeoclimate and archaeological evidence and theory. Critically, this thesis presents a multi-scalar examination of the palaeoclimate and archaeological data, considering climate and society across the EM region as presented by the climate hypothesis to identify any large-scale patterns in climate and societal changes and at a micro-regional scale to identify any complexities or nuances that may otherwise be missed or glossed over at the coarser regional scale of analysis.

In this thesis micro-regional analysis of climate and society is focussed on Türkiye due to the region's palaeoclimate and archaeological significance. As will be introduced in Chapter 2, Türkiye presents a complex climate influenced by several climate regimes, complex topography and distribution of water bodies. Whilst a number of palaeoclimate records (Sofular, Tecer, Eski Acigöl, Nar Gölü, Gordion, Van) cover the LBA-EIA period and the late Holocene, the majority of these records are poorly resolved, and so there are gaps in our understanding of climate from the region (Göktürk et al. 2011b; Kuzucuoğlu et al. 2011; Roberts et al. 2001; Dean et al. 2015; Manning et al. 2023; Wick et al. 2003). Therefore, it is important to produce a new highly resolved palaeoclimate record from the region, which will be presented and examined in Chapters 4 and 5. Additionally, as will be introduced in Chapter 3, Türkiye was an important region during the LBA, as it was home to one of the major powers of the period, the Hittite Empire. Significantly, the disintegration of the Hittite Empire at the end of the LBA is thought to have marked a major turning point in the history of Türkiye. Due to the subsistence and tax-based infrastructure of the Hittite Empire and apparent grain shortages at the end of the LBA, there has been the suggestion that climate change contributed to the end of the Hittites (e.g., Manning, 2023).

The objectives of this research are as follows:

- 1) To examine precipitation and temperature variability of the Late Bronze Age-Early Iron Age transition across the eastern Mediterranean.

This thesis examines several important proxy records across the EM and surrounding areas to understand the palaeoclimate conditions of the transition. Due to the scarcity of highly resolved records which cover the LBA-EIA transition period across Türkiye and the EM more

widely, this thesis presents a new highly resolved stalagmite proxy record from Kocain Cave in the southwest (37°13'N, 30°42'E, 730 m asl). For an introduction to speleothem science and the construction of the new Ko-1 record see Chapter 4.

This thesis also presents a synthesis of existing hydroclimate and temperature proxy records from across the EM and beyond to identify any major short-term changes and trends in rainfall and temperature variability.

Collectively the results of proxy examination (including the new Ko-1 results) will be discussed in order to assess the magnitude, timing, and spatial extension of any climatic changes and therefore identify whether changes reflect an abrupt climate event at 3.2 ka BP.

2) To examine Late Bronze Age and Early Iron Age archaeological evidence across the eastern Mediterranean

This thesis also presents an examination of key archaeological evidence across the EM to understand any societal changes and/or continuities across the LBA-EIA transition. To identify any variability and diversity in societal trajectories and cultural conditions across the EM, it is important to examine LBA-EIA archaeological evidence at a sub-regional level, with focus placed on the LBA-EIA across the different regions of Türkiye. Due to the regional focus of the climate hypothesis, the LBA-EIA archaeology of the western Aegean and the Levant will also be examined in this thesis and compared against the archaeology of Türkiye.

3) To integrate Late Bronze Age-Early Iron Age palaeoclimate and archaeological evidence

Finally, this thesis will integrate the results of palaeoclimatic and archaeological examination to determine whether any LBA-EIA societal changes seen across the EM region relate to climate change. By integrating the results of this examination, we can address the response of LBA-EIA societies to any climatic changes. For example, did EM societies make significant changes to agricultural production to cope with climate change, or did they continue using the same subsistence strategies across both the LBA and EIA periods? By comparing the palaeoclimatic and archaeological evidence we can therefore address the role of climate on the LBA-EIA transition and thus the coherence and validity of the existing climate hypothesis.

1.4.1. Research Questions

By examining LBA-EIA climate and society across the EM, this thesis will address the following key research questions:

- Did the eastern Mediterranean experience marked changes in hydroclimatic and temperature conditions surrounding the Late Bronze Age and Early Iron Age?
- Did the eastern Mediterranean experience an abrupt, synchronous and widespread climate event at ca. 3.2 ka BP?
- What were the impacts of climate change on Late Bronze Age and Early Iron Age societies of the eastern Mediterranean?
- Did climate change contribute to the end of the Late Bronze Age and the transition into the Iron Age across the eastern Mediterranean?
- How valid is the climate hypothesis in the light of new evidence?

1.4. Thesis Structure

Due to the interdisciplinary nature of this research, the structure of this thesis does not follow the traditional conventions of either palaeoclimatic or archaeological disciplines. The structure of this thesis instead reflects the inter-disciplinary nature of the research undertaken here.

Chapter 2

Chapter 2 of this thesis presents an introduction to the climate of Türkiye and the wider EM region, highlighting the complexity of EM climatic conditions and the challenges and limitations of palaeoclimatic reconstruction.

Chapter 3

Chapter 3 of this thesis presents an examination of the archaeology to understand the nature of LBA-EIA societies and identify any changes and continuities in societal features across the EM. Overall, this chapter provides a summary of LBA-EIA chronologies across the EM, key societal features (e.g., settlement organization, material culture) across the LBA-EIA and key issues associated with the archaeological evidence.

Chapter 4

Chapter 4 introduces the methods of this thesis, the examination of EM palaeoclimatic proxy records across the LBA-EIA transition through a new highly resolved stalagmite proxy record (Ko-1) constructed for this research and existing palaeoclimatic records. As this thesis constructs a new stalagmite record, Chapter 4 will introduce the basic principles of speleothem science before introducing the methodology of stable isotope analysis. This chapter will also present the criteria used to review existing hydroclimatic and temperature proxy records across the EM and surrounding areas.

Chapter 5

The results of the palaeoclimatic examination of this thesis are presented in Chapter 5, including the age-depth model and stable isotope results for Ko-1. This chapter will collate the results of both Ko-1 analysis and the synthesis of existing proxy records.

Chapter 6

The findings of this thesis are presented in Chapter 6. This chapter discusses all palaeoclimatic and archaeological data and theories presented throughout this research to consider the role of climate on the end of the LBA across the EM. The major results of this thesis will be considered against the existing climate narrative to examine its cogency and consider the future direction of research examining LBA-EIA climate and society across the EM region.

Chapter 7

The conclusions of this research are presented in Chapter 7, which provides a summary of this thesis and its contributions and implications. This chapter will also present the recommendations for future research.

Chapter 2 - Eastern Mediterranean Climate

2.1. Introduction

To understand past conditions during the LBA-EIA, we must understand modern climatic conditions in the EM. As this thesis provides a multi-scalar analysis of climate and society across Türkiye and the wider EM region, it is important to introduce modern climate conditions of the EM and modern climate conditions across the different regions of Türkiye. Understanding of modern climate conditions of the EM and Türkiye is important to comprehend climatic variability seen in proxy signals across the region and the potential mechanisms responsible for climate conditions, which can aid insight into how climate conditions changed in the past. This chapter will, therefore, explore present-day climate conditions of the EM and Türkiye. The interdisciplinary nature of this thesis also necessitates the introduction of the fundamental principles of palaeoclimate reconstruction. This introduction is crucial as it enables archaeologists to engage further with palaeoclimatic understanding. Finally, this chapter will also introduce existing palaeoclimatic proxy data which present arid conditions during the LBA-EIA transition, thus supporting the climate hypothesis. Critically, the limitations of existing proxy records will also be introduced.

2.2. Modern Climate Conditions across the Eastern Mediterranean

Because of its location between temperate northern Europe and arid North Africa, the EM is influenced by both mid-latitude and subtropical climate (Xoplaki, 2002; Giorgi and Lionello, 2008; Lionello et al. 2006; Lionello et al. 2012; Tuel and Eltahir, 2020). Climatic conditions in the EM are generally characterized by cool, wet winters and stable hot, dry summers (Köppen type Cs) (Bolle, 2003; Lionello et al. 2006; Tuel and Eltahit, 2020). During these seasons, the region is influenced by several large-scale climate mechanisms and teleconnection patterns, which make it very difficult to understand the interplay between these climatic modes. In winter, the northern reaches of the EM are influenced by the North Atlantic Oscillation (NAO), which is the dominant mode of North Atlantic atmospheric variability (Hurrell, 1995; Hurrell and van Loon, 1997; Hoerling et al. 2012). In its positive phase, the NAO is typically associated with below-average precipitation in the Mediterranean (Cook et al. 2016). EM winter is also affected by the North Caspian Pattern (NCP), which influences temperatures and precipitation, and the Siberian High-pressure system (Xoplaki, 2002; Lionello et al. 2006; Trigo et al. 2006; Kutiel and Benaroch 2002; Kutiel et al. 2002). Additionally, the East Atlantic pattern (EA), which

promotes a southerly air flow and increases in precipitation in coastal areas of Greece and western Türkiye, the Eastern Mediterranean Pattern (EMP) which can also contribute to increased precipitation over Greece, and the subtropical El Niño Southern Oscillation (ENSO) (Dükeloh and Jacobeit, 2003; Xoplaki et al. 2004; Finné et al. 2019; Hatzaki et al. 2007; 2009; Ulbrich et al. 2012; Yakir et al. 1996; Price et al. 1998) can also influence EM winter conditions. In summer, the region is influenced by the subtropical Azores High and the Indian and African monsoons (Raich et al. 2003; Rodwell and Hoskins, 1996; Ziv et al. 2004; Tyrlis et al. 2013).

Climatic conditions across the EM are also controlled by several physical and physio-geographical factors that strongly influence regional climate, such as topography and coastal features (Xoplaki et al. 2000; Xoplaki, 2002; Touchan et al. 2014; Krichak et al. 2010; Samuels et al. 2017). Mountain ranges across the EM (e.g., the Taurus and North Anatolian mountains) are important, as they influence the observed structure of weather systems and regional circulation due to thermal and orographic forcing (Fernández et al. 2003; Xoplaki et al. 2004). Due to the orographic effect for example, precipitation conditions can change dramatically moving inland from the coast as air masses meet steep mountain slopes, with enhancement of rainfall along coastlines on the windward side of mountain ranges and a rain shadow of warmer and drier conditions further inland, on the leeward side (Harding et al. 2009; MedCLIVAR, 2004). In addition to the significant role of topography, the Mediterranean Sea also influences EM climate as an important source of energy and moisture for cyclone development (Trigo et al. 1999). The existence of islands, peninsulas and several regional seas and basins additionally determine a complicated land-sea distribution (Lionello et al. 2006). Due to the multitude of climatic and physio-geographic factors that control and influence EM climate, spatial and temporal variability of temperature and precipitation is high across the region, even at relatively small spatial scales, as will be highlighted below (Lionello et al. 2006; Bolle, 2003).

Northern areas of the EM (e.g., northern Türkiye) are characterized by a relatively temperate climate due to their strong link with mid-latitude variability (Xoplaki, 2002; Lionello et al. 2012). Further south, areas such as the Levant generally experience hot and more arid climatic conditions due to the subtropical systems, including the South Asian and African Monsoons (Xoplaki, 2002; Lionello et al. 2012). North-south temperature and precipitation gradients are therefore particularly significant across the EM (Lelieveld et al. 2012). Mean temperatures across the region are highest in the south and decrease towards the north, with lowest values over the Black Sea region and mainland of Türkiye (Xoplaki, 2002). Enhanced precipitation

occurs in the north of the EM, in contrast to the more arid south where rainfall is scarce (Lionello et al. 2012). The spatial heterogeneity of both temperature and precipitation across the EM can be seen in **Figure 7** and **Figure 8** which show annual mean temperature and annual precipitation from 1970 to 2000.

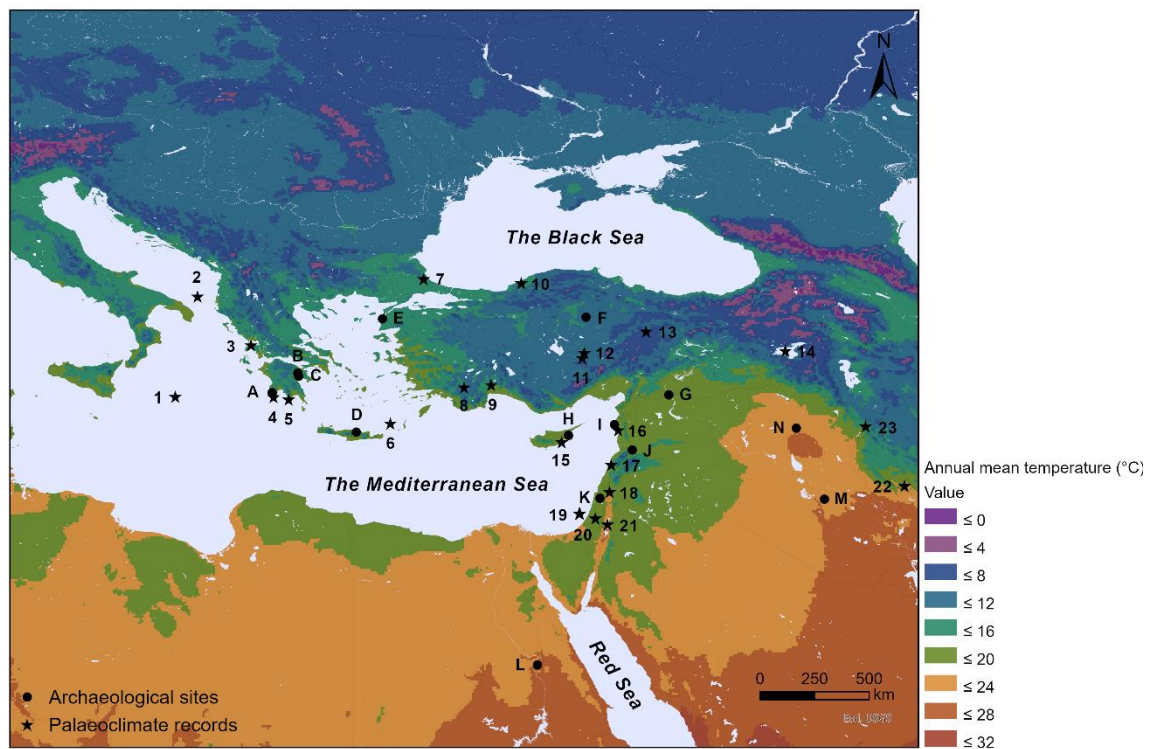


Figure 7. Map of modern annual mean air temperature (°C) across the eastern Mediterranean and surrounding areas. The location of key archaeological sites of the LBA-EIA transition are shown by black circles, whilst palaeoclimatic records discussed in this chapter are shown by stars. Key archaeological sites: A) Pylos B) Myceanae C) Tiryns D) Knossos E) Troy F) Hattusa G) Carchemish H) Enkomi I) Ugarit J) Qadesh K) Megiddo L) Thebes M) Babylon N) Assur. Palaeoclimate records: 1) RL11 2) AD91-17 3) Lake Voulkaria 4) Mavri Trypa 5) Alepotrypa 6) LC21 7) Uzuntarla Cave 8) Gölhisar Gölü 9) Kocain Cave 10) Sofular Cave 11) Nar Lake 12) Eski Acigöl 13) Tecer Lake 14) Lake Van 15) Larnaca Salt Lake 16) Tell Tweini 17) Jeita Cave 18) Sea of Galilee 19) GA-110 & GA-112 20) Soreq Cave 21) The Dead Sea 22) Lake Mirabad 23) Lake Zeribar. Source: Author's original. Data accessed from WorldClim Version2 (Fick and Hijmans, 2017).

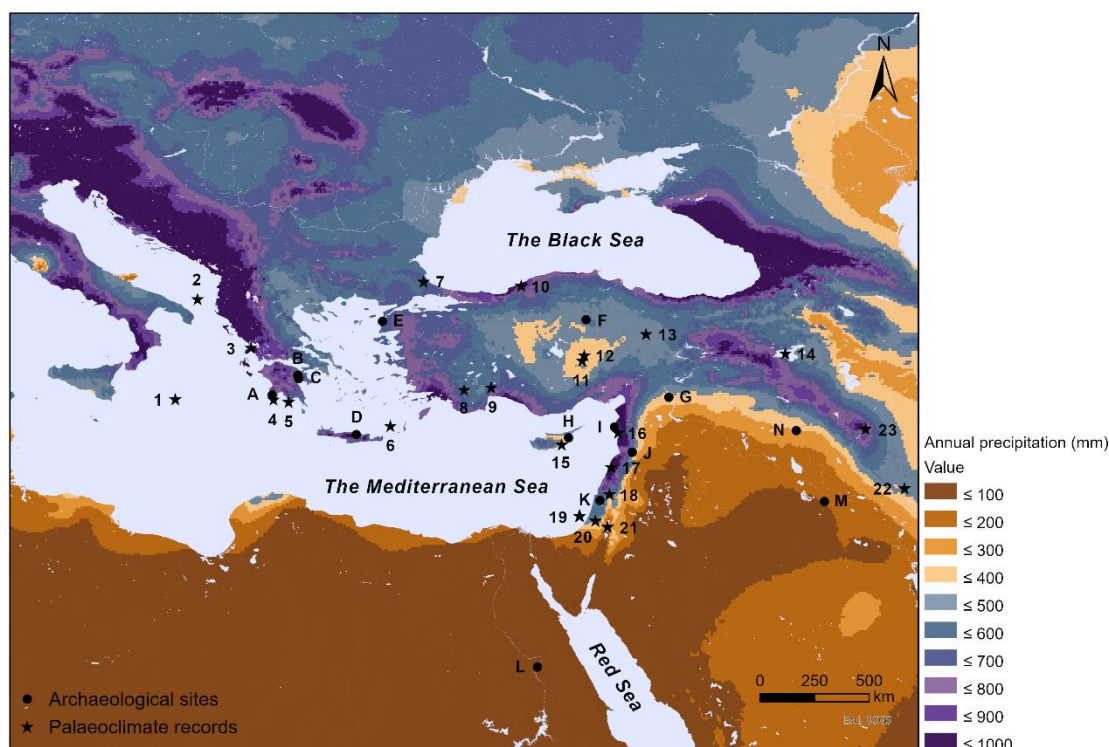


Figure 8. Map of modern annual precipitation (mm) across the eastern Mediterranean and surrounding areas. The location of key archaeological sites of the LBA-EIA transition are shown by black circles, whilst palaeoclimatic records discussed in this chapter are shown by stars. Key archaeological sites: A) Pylos B) Mycenae C) Tiryns D) Knossos E) Troy F) Hattusa G) Carchemish H) Enkomi I) Ugarit J) Qadesh K) Megiddo L) Thebes M) Babylon N) Assur. Palaeoclimate records: 1) RL11 2) AD91-17 3) Lake Voulkaria 4) Mavri Trypa 5) Alepotrypa 6) LC21 7) Uzuntarla Cave 8) Gölhisar Gölü 9) Kocain Cave 10) Sofular Cave 11) Nar Lake 12) Eski Acigöl 13) Tecer Lake 14) Lake Van 15) Larnaca Salt Lake 16) Tell Tweini 17) Jeita Cave 18) Sea of Galilee 19) GA-110 & GA-112 20) Soreq Cave 21) The Dead Sea 22) Lake Mirabad 23) Lake Zeribar. Source: Author's original. Data accessed from WorldClim Version2 (Fick and Hijmans, 2017).

Across the Mediterranean basin, precipitation occurs mainly in the winter months (Xoplaki, 2002). Cyclone activity is strongest during this season as the influence of mid-latitude variability is at its greatest (Brayshaw et al. 2010; Trigo et al. 2006). The NAO is thought to determine a robust signal on winter precipitation due to its control on the branch of North Atlantic (NA) storm tracks affecting the Mediterranean basin (Lionello et al. 2006; Trigo et al. 2006). In addition to the influence of mid-latitude variability, Yakir et al. (1996) and Price et al.

(1998) have also demonstrated connections between ENSO events and winter precipitation in the EM, as shown for winter rainfall in Israel (Alpert et al. 2006). For example, both Yakir et al. (1996) and Price et al. (1998) indicate an increase in precipitation during El Niño winters, whilst Price et al. (1998) also demonstrated that La Niña years were associated with below normal rainfall (Alpert et al. 2006).

In the summer months, the high-pressure belts of the subtropics begin to drift northwards, bringing warm and dry conditions to the EM (Xoplaki, 2002). During these months, the region is generally under the influence of the Azores High and the Indian and African Monsoons (Xoplaki, 2002; Giorgi and Lionello, 2008). Depressions, whilst not absent, are usually weak as anticyclonic conditions encourage subsidence and so air mass contrasts are reduced compared to winter (Xoplaki, 2002).

2.2.1. Climate Conditions across Türkiye

Owing to its position within the Mediterranean basin, Türkiye generally experiences a Mediterranean macroclimate, shaped by the seasonal alteration of air masses of polar and tropical origins (Tatli et al. 2004). Climatic conditions are diverse across the different geographical regions of Türkiye due to the additional influence of physio-geographical factors (Türkeş, 2020; Sensoy et al. 2008; Unal et al. 2012). Most significantly, the complex, irregular topography of the landscape (see **Figure 9**) strongly controls the distribution of temperature and precipitation (Türkeş, 2020; Sensoy et al. 2008; Deniz et al. 2011; Schemmel et al. 2013). Low lying coastal areas of Türkiye are separated from the central plateau by two large mountain chains, the North Anatolian mountains, which are situated parallel to the Black Sea coast (reaching up to 3492m in the east) and the Taurus mountains in the south (reaching up to 3000m) (Deniz et al. 2011; Unal et al. 2012). These two mountain ranges run towards the eastern region where the topography becomes more ragged and mountainous (mountains and isolated volcanic peaks such as Mt. Ararat rise to well over 5000 m) (Kadioğlu, 2000). Because of the influence of the mountains and prevailing pressure patterns moisture-bearing air masses from the coast are prevented from penetrating inland (Taha et al. 1981; Martyn, 1992; Kadioğlu, 2000; Türkeş, 1996). In addition to its complex topography, Türkiye is enclosed by the Black Sea in the north, the Marmara and Aegean seas in the west and the Mediterranean Sea in the south, which act as natural passages for frontal cyclones (Kadioğlu, 2000). The Black Sea also modifies the cool air masses arriving from the north (Türkeş, 1996; Trewartha, 1966; Göktürk, 2011).

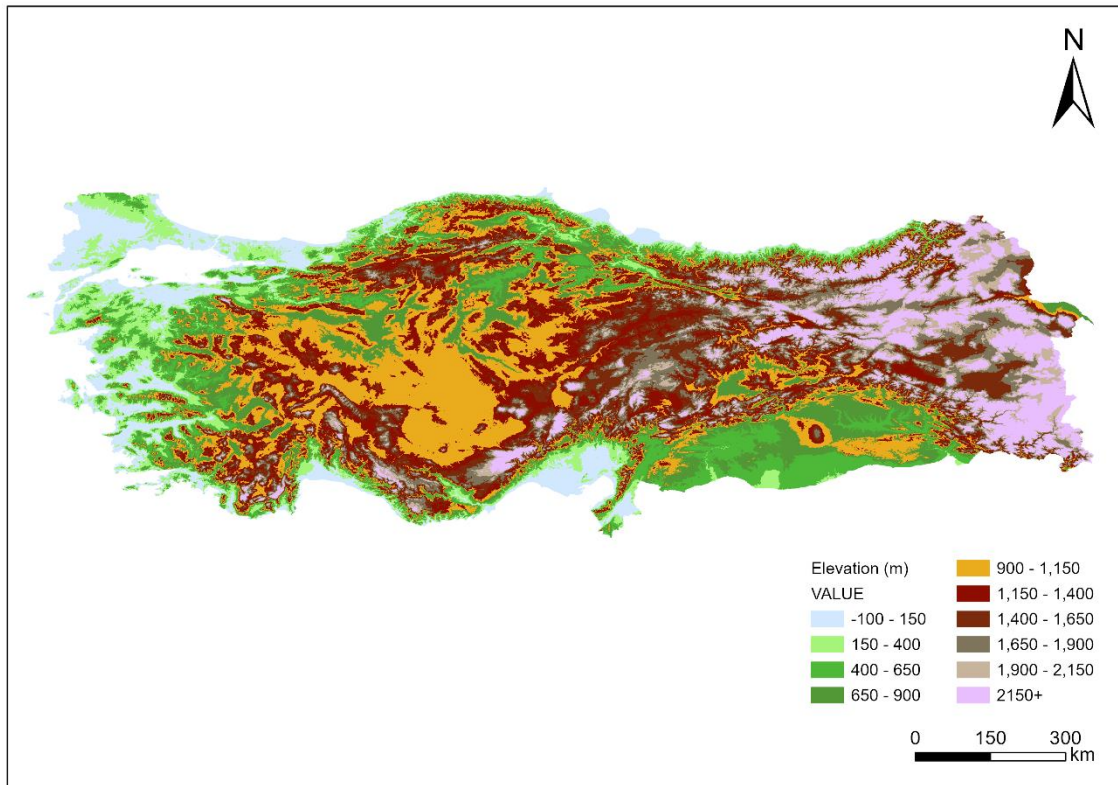


Figure 9. Digital Elevation Map (DEM) showing elevation across Türkiye. SRTM1 (30m resolution). Source: Author's original. DEM data accessed from USGS (<https://earthexplorer.usgs.gov>, 30 January 2023).

Across Türkiye, annual mean temperature varies from 3.6°C to 20.1°C (Deniz et al. 2011). The spatial distribution of annual mean temperatures (**Figure 10**) is mainly controlled by physiographic features such as elevation, orography and land-sea distribution (Türkeş, et al. 1995). Annual mean temperatures generally tend to drop from coastal areas towards interior regions and the eastern part of the country, where elevation increases rapidly (Türkeş, et al. 1995). Average minimum temperatures are, therefore, experienced in the eastern Türkiye due to the high altitudes in this region whilst average maximum temperatures occur in the south and along the Mediterranean coasts. During winter, the mean temperature is below 5°C so there is little evaporation (Sensoy et al. 2008). Temperature normally reaches a maximum in July and a minimum in January (Deniz et al. 2011).

Precipitation is relatively scarce in Türkiye averaging $\sim 630\text{mm yr}^{-1}$, with approx. 67% occurring during winter and spring (Sensoy, 2004). Precipitation across Türkiye presents a complicated spatial and temporal structure owing to the major influence of mountain ranges and

seasonality of atmospheric circulation (Unal et al. 2012; Sensoy et al. 2008; Türkeş et al. 2009). Mean annual precipitation totals decrease from the humid coastal belts to the semi-arid and continental interiors and the eastern margin of the Anatolian Peninsula, as can be seen in **Figure 11**. A steep gradient is also experienced over the Northern Türkiye and Taurus mountains (Türkeş, 1996; Türkeş and Erat, 2005). During the winter months, mid-latitude cyclones are responsible for most precipitation events and rainfall amounts over the different geographical regions (Türkeş, 2020). Whilst the passage of mid-latitude frontal depressions and Mediterranean cyclones in the winter months leads to high precipitation amounts in the coastal regions (alongside the contribution of orographic rainfall in the Black Sea region), central and eastern Türkiye experience continental conditions due to the modification of moisture-bearing air masses and cyclone trajectory by the local topography (Türkeş and Erat, 2005; Türkeş, 1996; Kutiel and Türkeş, 2005; Sarış et al. 2010). In these continental regions, peak precipitation occurs in late spring and early summer due to convective instability showers and thunderstorms (Deniz et al. 2011; Türkeş, 2020; Sensoy et al. 2008). Summer is mainly fair with long-lasting dry conditions as few frontal systems penetrate the region (Kadioğlu, 2000). Depressions that are seen during summer mainly affect the northern part of the Marmara region and over the Black Sea coast in the north (Tatli et al. 2004).

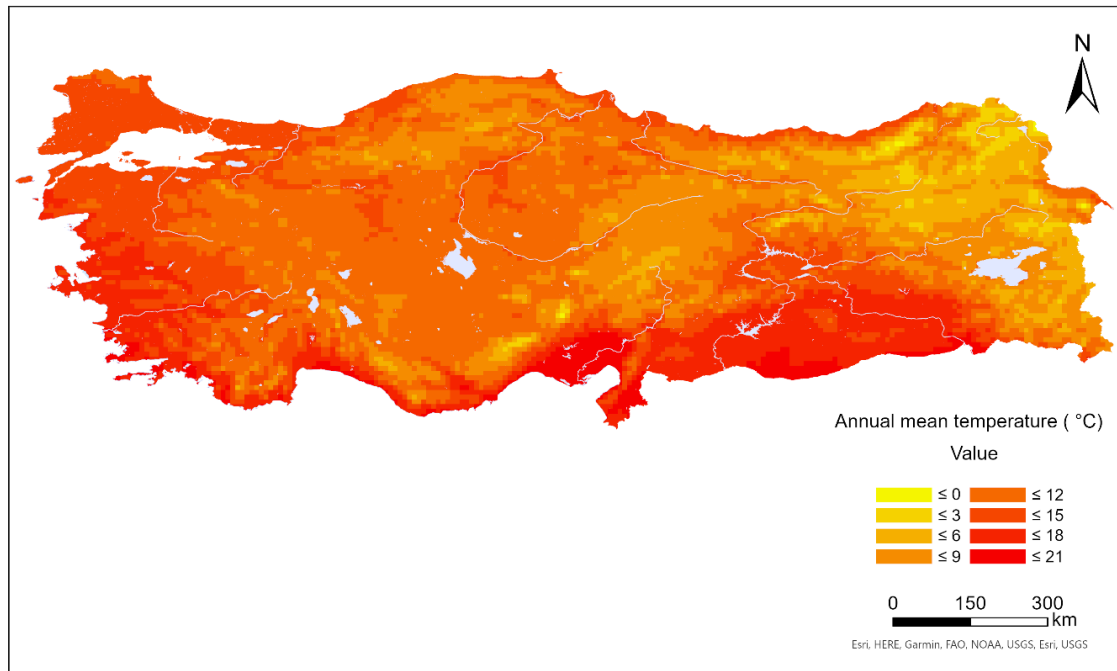


Figure 10. Annual mean temperature conditions across Türkiye from 1970-2000. Source: Author's original. Data accessed from WorldClim Version2 (Fick and Hijmans, 2017).

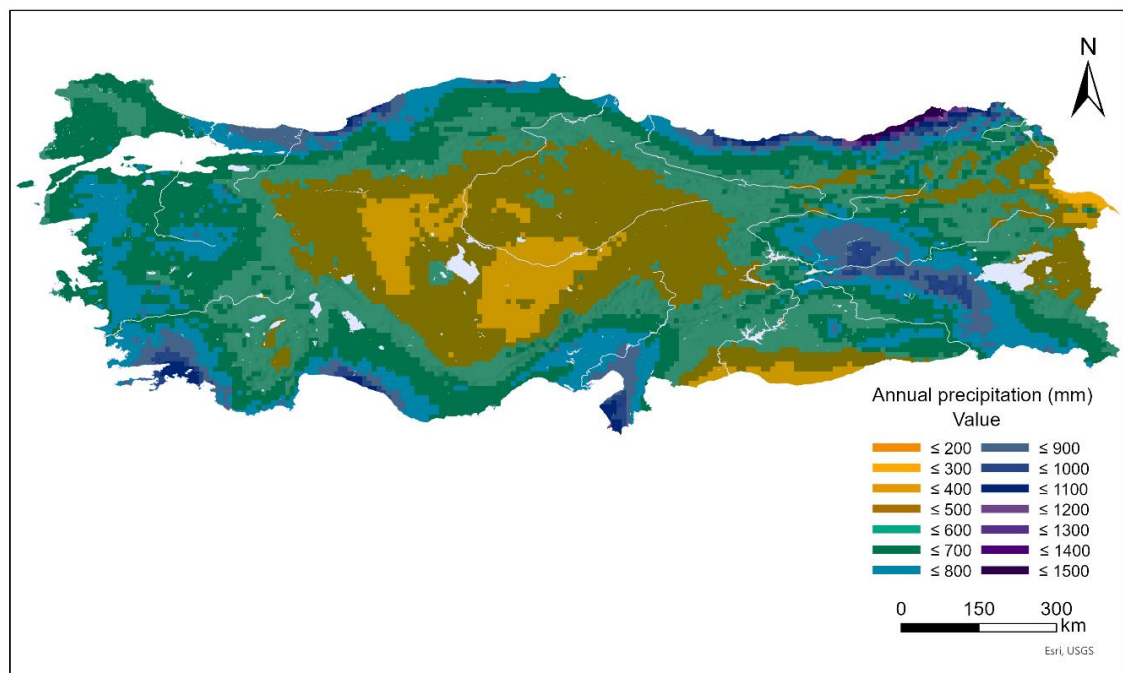


Figure 11. Annual precipitation conditions across Türkiye from 1970-2000. Source: Author's original. Data accessed from WorldClim Version2 (Fick and Hijmans, 2017).

2.2.2. Hydroclimate Conditions and Drought

As introduced in Chapter 1, the hydrological cycle, and its variability, is one of the most critical aspects of the Mediterranean region (e.g., Xoplaki et al. 2004). The variability of the Mediterranean wet season primarily influences the hydrological budget of the area including the water-stressed and drought-prone EM (Xoplaki et al. 2004; Xoplaki et al. 2018). Hydrological changes are particularly challenging for societies since precipitation variability impacts agriculture and food production (Xoplaki et al. 2018). For example, in central Türkiye rainfall is recognized as a limiting factor for agriculture (Marston, 2010: 457). Therefore, it is possible that only minor changes in rainfall in this region could have significant effects on agriculture.

Because of climate change, the Mediterranean region has witnessed a long-term drying trend over the last several decades and an increased frequency of drought (Hoerling et al. 2012; Mariotti, 2010). This aridification trend is reflected by a reduction in total precipitation and the duration of wet periods, alongside an increasing duration of dry periods (Mathbout et al. 2018; Lionello and Scarascia, 2020). Alongside the reduction of precipitation, the region has also seen increasing temperatures which in combination with reduced precipitation, vapour pressure deficits, land-surface feedbacks and anthropogenic causes has led to increasing intensity and frequency of droughts in the region (Lionello and Scarascia, 2020). For example, Türkiye has experienced a notable decrease in precipitation as well as an increase in minimum and maximum temperatures (Sen et al. 2012). Drought has also become a recurring phenomenon in Türkiye, with shifts from semi-humid (semi-dry) drought classes to semi-dry (dry) conditions in the Aegean, Mediterranean and Central Türkiye (Türkeş, 2003; Sen et al. 2012).

Giorgi and Lionello (2008) have suggested that the aridification of the Mediterranean is associated with increasing anticyclonic circulation over the region which causes a northward shift of the mid-latitude storm track. The behaviour of storm tracks, which is highly variable, is very important as it has a profound impact on Mediterranean hydroclimate, as the weather systems associated with storm tracks provide much of the annual rainfall in the region (Brayshaw et al. 2010). The northward migration of the NA storm tracks also appears to weaken and reduce the frequency of Mediterranean cyclones, which further contributes to a decline in wet season rainfall (Trigo et al. 2000). This winter change pattern is thought to be consistent with the positive phase of the NAO, which is associated with drier than normal weather across the basin (Giorgi and Lionello, 2008). As can be seen in **Figure 12**, negative precipitation anomalies in Türkiye appear to correspond well with positive phases of the NAO

(Sönmez et al. 2005). Turkish winters also generally experience drought conditions when the temporal pattern of the NAO is in its extreme high-index (positive) value (Türkeş, 2020). For example, severe droughts in some or most regions during at least 12 winters between 1943 and 2013 were closely related to the extremely high positive values of the NAO (Türkeş, 2020). As investigated by Rowell and Jones (2006) a summer drying signal may be caused by different mechanisms, including low spring soil moisture conditions, large land-sea contrasts in warming, positive summer soil moisture feedback and remote influences such as the strengthening of the Asian Monsoon (Giorgi and Lionello, 2008).

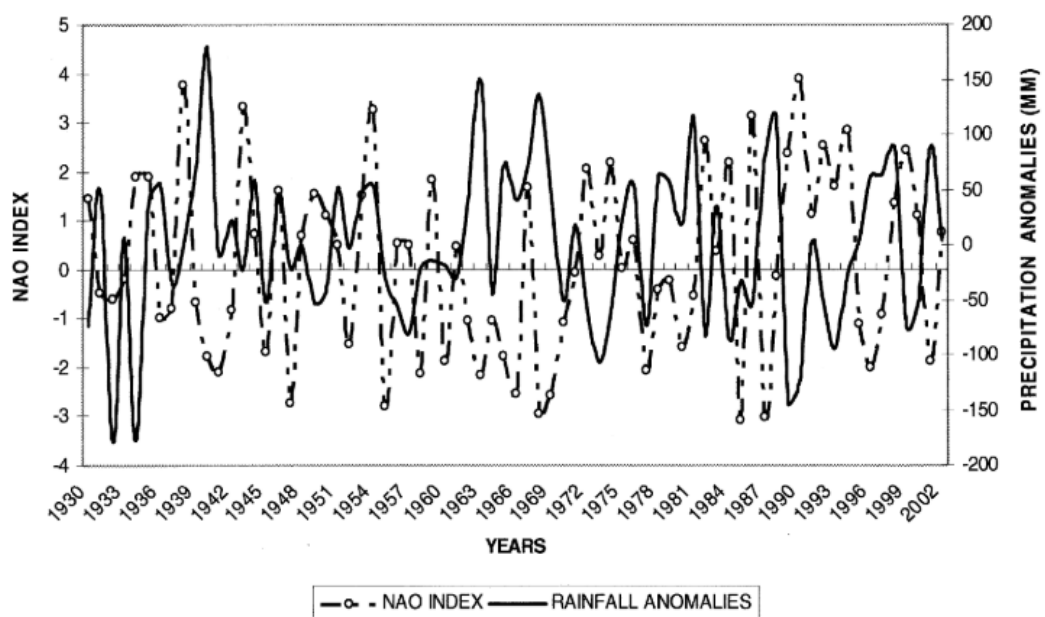


Figure 12. Long-term precipitation anomalies alongside the NAO index between the years 1930 and 2002 for Türkiye. Source: Sönmez et al. (2005), Figure 2. Copyright © 2005. Used with permission of Springer Nature BV. Permission conveyed through Copyright Clearance Center Inc.

2.3. Reconstructing Palaeoclimatic Conditions of the Eastern Mediterranean

Past climate information from the EM is stored in climate proxies, as introduced in Chapter 1, which provide indirect measurements of past climatic signals preserved in natural, terrestrial (speleothems and tree rings), lacustrine (lake records) and marine archives (Zittis et al. 2022). A diverse range of proxies are preserved within climate archives, including biological (e.g., pollen, diatoms, foraminifera, ostracods, dinocysts), geochemical (oxygen and carbon isotopes,

trace elements, organic biomarkers) and physical (e.g., sediment composition, magnetic properties) materials. Proxies are sensitive to multiple climate variables, including precipitation, soil moisture, air temperature and sea surface temperature (SST), and thus can provide us with multiple pieces of climatic information (Xoplaki et al. 2018; Abrantes et al. 2012).

In addition to providing measurements of past climate signals, palaeoclimate proxy data plays an important role in evaluating the ability of climate models to simulate past, present and future climate change (Haywood et al. 2019). Significantly, palaeoclimate proxy data can be used to constrain model performance and reduce model-related uncertainty thus aiding the production of more reliable climate estimates and projections (Braconnot et al. 2012; Tierney et al. 2020). Accurate modelling is important as climate modelling is fundamental for understanding climate behaviour and mechanisms of climate change across time.

The value of proxy data to palaeoclimatic reconstruction is dependent on the chronological and temporal resolution of records, as resolution determines the degree of detail that can be obtained about past climatic conditions and their timing, particularly abrupt events (Bradley, 2015). Accurate and precise dating is also fundamental, as without reliable estimates on the age of past climatic events, it is impossible to investigate any synchronicity between palaeoclimatic records (and archaeological events) (Bradley, 2015). The interpretation of palaeoclimatic data can also be ambiguous as there are no simple correlations between proxy signals and climatic variables. Additionally, proxy signals are often influenced by multiple environmental and climatic variables. The importance of a robust and precise chronology, temporal resolution, and accurate proxy interpretation is discussed below.

Chronology

To determine age estimates and construct chronologies, several dating methods can be used depending on the type of archive. Radiometric dating techniques (e.g., radiocarbon, uranium-thorium) measure the decay of radioactive isotopes over time, whilst incremental dating techniques measure the accumulation of material to organic tissue or sediment sequences through time (e.g., dendrochronology, varve chronology). Chronologies can also be based on other dating methods, such as tephrochronology, which uses tephra layers of well-known volcanic eruptions (e.g., the Minoan eruption at around 1620 BCE) as a stratigraphic marker horizon. Climate archives also contain annual layers which can be used to count back in time. For example, in regions of high seasonality trees produce annual tree ring layers, but the use of

this method is limited to later antiquity, with the exception of a new annual tree ring record from central Türkiye, which covers an interval of the Late Holocene, as will be discussed.

Each dating method presents its own distinct set of limitations, which must be considered. For example, several sources of error and uncertainty affecting ^{14}C dating exist, which may result in erroneous and/or imprecise dates (see Bradley, 2015 for more details). In lacustrine and marine records across the EM, for example, the accuracy of ^{14}C can be affected by both the hardwater effect and the reservoir effect (e.g., Finné et al. 2011). Any errors will be compounded by the uncertainty involved in translating radiocarbon years to calendar years, which depends on atmospheric ^{14}C levels, resulting in imprecise age determinations (e.g., Anchukaitis and Tierney, 2013). The precision of radiocarbon ages can also be limited by multiple “wiggles” in the calibration curve or plateaus, which can yield non-precise age ranges or multiple age ranges (Manning, 2006). The uncertainty associated with age determinations also varies across the different climate archives. For example, individual age-estimate errors from radiocarbon dating or U-Th dating of lake archives are typically in the order of tens to hundreds of years whilst typical U-Th chronological uncertainties of stalagmite records vary between 0.5 and 2% of the absolute age, depending on the uranium content and purity of the calcite (e.g., Jones et al. 2019). Even greater precision (annual, sub-annual) can be provided by dendrochronology, varve counting and the counting of annual stalagmite laminae (Frank et al. 2022; Zolitschka et al. 2015; Flohr et al. 2016).

The accuracy of proxy chronology also depends on the construction of an age-depth model which establishes the age-depth relationship of each proxy data point of a record through the input of dates. Many modelling approaches have been developed, including models that use linear interpolation between ^{14}C ages and those that employ Bayesian techniques such as OxCal and Bacon (Webb and Webb, 1988; Ramsey, 2008a; Blaauw and Christen, 2011). For a summary of age-depth models, including their limitations, see Lacourse and Gajewski (2020). Due to differences in the assumptions that underlie each model, chronologies from different age-depth models will differ, even for the same proxy record (Comas-Bru et al. 2020). It is, therefore, important to consider that different age-depth modelling approaches can provide very different outputs for the age given for a particular depth and the uncertainty associated with each age estimate (Bennett, 1994; Bennett and Fuller, 2002; Telford et al. 2004).

Temporal Resolution

The temporal resolution of a record is recognized as the time difference in years between two sample measurements. The smaller the time difference, the higher the resolution, which increases the reliability and robustness of the climate reconstruction (Schmittner, 2018). The temporal resolution of records varies across archives, ranging from seasonal (e.g., tree rings) to multi-decadal and centennial (e.g., lake and marine sediments) (Luterbacher et al. 2012; Bradley, 2015; Xoplaki et al. 2018).

Proxy Quality

Whilst proxy records can provide a wealth of information about past climatic conditions, interpreting proxy signals is often difficult as proxies can reflect multiple and even interacting climatic parameters (Zittis et al. 2022). Additionally, proxy signals can be modified or obscured by non-climate-related processes and subjected to noise. For example, in lake records, it is possible for detritus from the terrestrial environment to be washed in and consequently contaminate and modify isotopic signals (Leng and Marshall, 2004).

2.3.1. Past Hydroclimate Conditions and Drought in the Mediterranean

Drier conditions and drought events are also understood to have been common features of the Mediterranean's past, as can be identified in both documentary evidence and palaeoclimate evidence. For example, the writings of both Plato and Aristotle appear to acknowledge dry, arid conditions in the ancient EM (Laws VI; Meteorology II), whilst episodes of drought are also thought to be referenced in the Bible (e.g., the story of Joseph, Genesis 41:27). Palaeoclimatic reconstructions in the EM also identify substantial hydroclimatic variability and periods of drought throughout the Holocene (e.g., Roberts et al. 2011; Finné et al. 2019; Izdebski et al. 2016b; Xoplaki et al. 2018; Jacobson et al., 2021). A noteworthy study by Cook et al. (2016) looks at 900 years of Mediterranean drought variability through the use of the Old World Drought Atlas (OWDA), which is a tree ring-based reconstruction of summer season Palmer Drought Sensitivity Index (PDSI) (Cook et al. 2015). PDSI is a normalized indicator of soil moisture availability (negative values indicate drought), integrating changes in moisture supply (precipitation) and demand (evapotranspiration) on timescales of typically 12-18 months (Palmer, 1965; Jones et al. 2019). The OWDA demonstrates that almost a third of Mediterranean areas were under summer drought conditions from 1100-2012 CE (Cook et al. 2016). Additionally, through the OWDA, Cook et al. (2016) identify a significant tendency across the EM towards anti-phased hydroclimate variability between the southern Levant (e.g.,

Israel, Jordan, southern Syria and Lebanon) and a region that encompasses Greece, Türkiye and the Black Sea (Cook et al. 2016; Jones et al. 2019). This anti-phasing in hydroclimatic conditions can be seen in **Figure 13**, where negative PDSI values for the Levant indicate drought conditions that are not seen in Greece, Türkiye and the Black Sea. Significantly, this north-south dipole is persistent across centuries and bears a strong resemblance to the hydroclimatic pattern expected from variability in the NAO (Cook et al. 2016; Jones et al. 2019). Therefore, as has been proposed for modern drying, it is possible that changes in the NAO may have led to drier conditions in the EM's past.

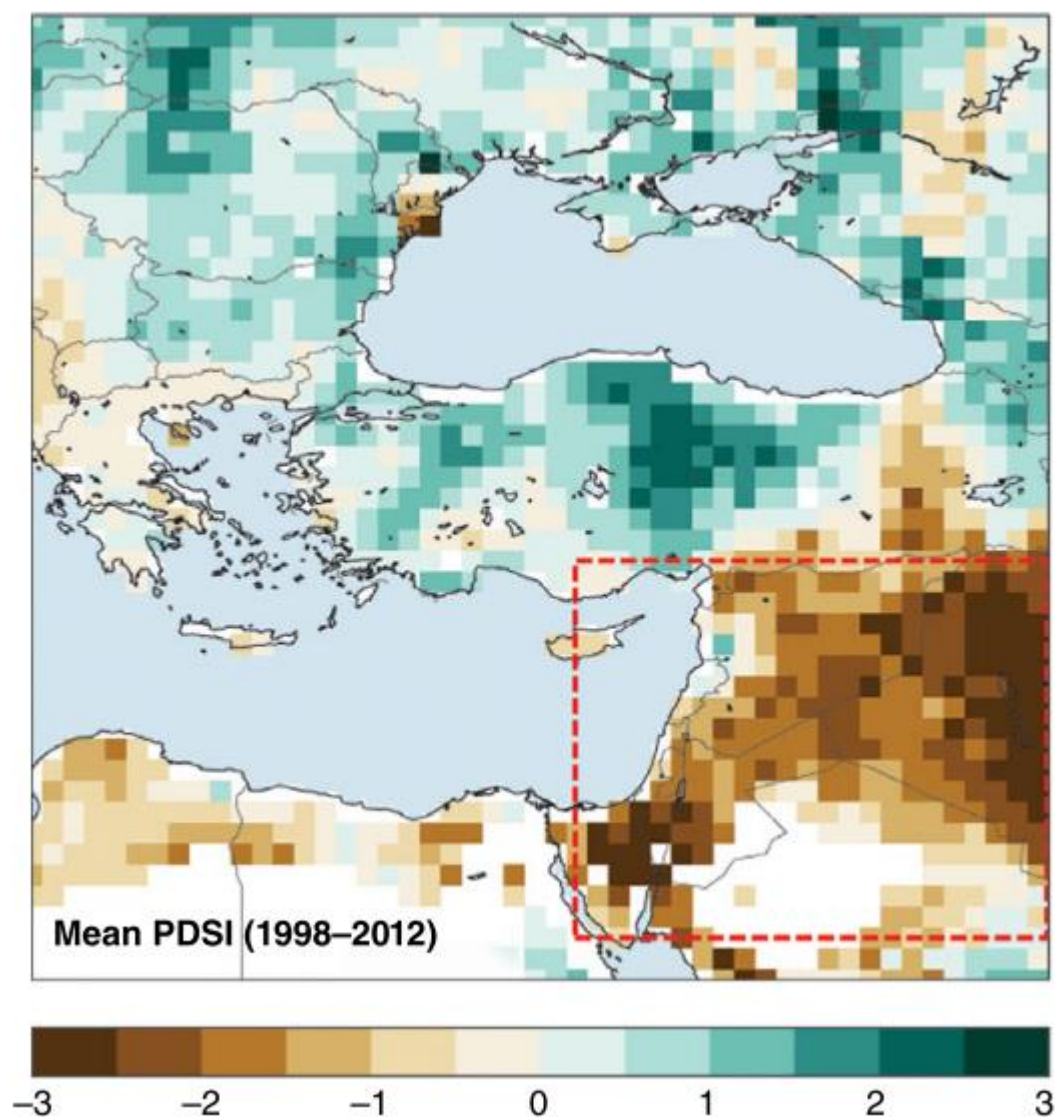


Figure 13. Spatial patterns in the Old World Drought Atlas (Cook et al. 2016) of mean Palmer Drought Severity Index (PDSI) values through the last 600 years. The scale bar indicates PDSI

values, with negative values indicating drought conditions. Source: Jones et al. (2019), Figure 5, [20,000 years of societal vulnerability and adaptation to climate change in southwest Asia](#), licensed under [CC BY-NC 4.0](#).

2.4. Late Bronze Age-Early Iron Age Climate Conditions across the Eastern Mediterranean

Whilst the climate hypothesis was first proposed several decades ago (Carpenter, 1966; Weiss, 1982), the theory of climatically induced societal challenges at the end of the LBA and transition into the EIA has only become prominent over the last few decades, following the development of a dense network of EM palaeoclimatic records which appear to record a shift towards increasingly arid conditions during the transition (e.g., Kaniewski et al. 2013; 2015; 2019a; 2019b; 2020; Langgut et al. 2013; 2015; Bar-Matthews et al. 1998; Finné et al. 2017; Kuzucuoğlu et al. 2011; Roberts et al. 2001; Manning et al. 2023).

Following the identification of a 3.5-2.5 ka BP RRC event by Mayewski et al. (2004), Kaniewski et al. (2008) suggested that this RCC event appears to have coincided with the end of the LBA across the EM. The recognition of an apparent temporal correlation prompted the resurgence of research interest in climate and the LBA-EIA transition. Kaniewski et al. (2010) sought to identify a shift in climate variability towards the end of the LBA in the EM, examining alluvial deposits from Tell Tweini in coastal Syria. Through pollen analysis of the Tell Tweini sediment core TW-1, Kaniewski et al. (2010) identified an abrupt and severe drought between 3.1-2.8 ka BP (1175-850 BCE), interrupted by a wetter phase between 2.95-2.9 ka BP (1000-950 BCE) which they suggest may have acted as a triggering factor behind the LBA-EIA transition. Further palynological analysis was also undertaken on core B22 at Larnaca Salt Lake in Cyprus, which appears to identify drying of the landscape from around 3.15 ka BP (1200 BCE) (Kaniewski et al. 2013). The findings of these two lake records, alongside comparison with other proxy records from the EM, led Kaniewski et al. (2010; 2013, 2015, 2019a; Kaniewski and Van Campo, 2017) to hypothesize that a multi-century drought event around ~3.2 ka BP (~1250 BCE) framed the end of the LBA. Interestingly, recent research has seen Kaniewski et al. (2019b; 2020) revise their position on the climate hypothesis, now postulating that a cooling event at 3.2 ka BP (~1250 BCE) was responsible for drier conditions across the EM as opposed to a centuries-long drought. Kaniewski et al. (2020) do, however, note that cool, drier conditions may have been further amplified by drought. Evidence for this proposed cold and dry event is provided by pollen-based temperature and precipitation reconstructions from

Larnaca Salt Lake and Tell Tweini (Kaniewski et al. 2020; Kaniewski et al. 2019b). The Larnaca lake record, for example, is thought to present a significant cooling of approx. 2.6 ± 0.5 °C at 3.2 ka BP (1250 BCE) and 2.3 ± 0.6 °C around 2.9 ka BP (950 BCE), alongside a reduction in winter and spring precipitation of approx. 38 ± 2.1 mm (Kaniewski et al. 2019b; 2020). Kaniewski et al. (2020) suggest that cooler conditions from ca. 3.2 ka BP seen in the Larnaca record are correlated with lower temperatures in the Atlantic, supported by an apparent increase in the North Atlantic drift-ice index, a reduction in SST and expansion of sea ice in the Northwest Atlantic around this time (Bond et al. 2001; Klus et al. 2018). The Tell Tweini record also suggests a dramatic cooling of approx. 7°C from 3.05 ka BP (1100 BCE) with a fall in temperature greater than what was seen during the Little Ice Age, as suggested by Kaniewski et al. (2019b). In addition to the work led by Kaniewski et al. (2010; 2013; 2015; 2019a; 2019b; 2020), independent research undertaken by Drake (2012) and Langgut et al. (2013) has also proposed that LBA societies faced significant climatic pressures due to the onset of drier and cooler conditions. Based on the analysis of marine, lake and stalagmite proxy signals from the Adriatic, the Aegean and the Levant Drake (2012) suggests that rapid SST cooling during the LBA resulted in reduced precipitation into the more arid EIA (Jahns, 2005; Emeis et al. 2000; Rohling et al. 2002; Sangiorni et al. 2003; Bar-Matthews et al. 1998). Langgut et al. (2013) also propose that the terminal LBA experienced a period of aridity at ~3.2-3.05 ka BP (~1250-1100 BCE) based on pollen analysis of a sediment core from the Sea of Galilee in Israel. More specifically, during the terminal LBA Langgut et al. (2013) identify a significant reduction in Mediterranean tree values which denotes a reduction in precipitation, in addition to shrinkage of Mediterranean forest/maquis.

Several key proxy-based EM palaeoclimate studies cover the LBA-EIA transition and have been discussed in relation to this period. These records, which appear to suggest increasingly arid conditions, have thus been used to further support the climate narrative. These records also appear to demonstrate a seasonality bias. Significantly, changes in seasonality (e.g., a change in rainfall patterns) have implications on rain-fed agriculture in the EM. Changes in rainfall variability can affect the length of the crop growing season, which refers to the number of days plant growth takes place (Habte et al. 2023). For example, a delayed onset or early cessation of a rainy season and dry spells during crop growing periods can shorten the crop growing period, which can result in lower crop yield, affecting food security (Mugalavai et al. 2008; Bahiru et al. 2020; Habte et al. 2023).

As this thesis presents a microregional focus on past climate conditions and societal dynamics of Türkiye, particular attention is paid to proxy records from this region. Several proxy records referred to in this chapter can be seen in **Figure 14**.

2.4.1. The Aegean

Stalagmite records from Mavri Trypa and Alepotrypa Caves in the Peloponnese both appear to indicate drier conditions around ~3.2 ka BP (1250 BCE), as reflected by more positive $\delta^{18}\text{O}$ values (Finné et al. 2017; Boyd, 2015). This short dry phase at ~3.2 ka BP (~1250 BCE) in the Mavri record is followed by a long-term trend of increasing arid conditions from approx. 3.15 ka BP (1200 BCE) until around 2.9 ka BP (950 BCE), when there was a hiatus in the growth of the stalagmite. This hiatus is thought to reflect the drying out of the aquifer due to arid conditions (Finné et al. 2017).

2.4.2. Türkiye

Several proxy records from lake, speleothem and tree archives have been understood to reflect changes in hydrological conditions across ancient Türkiye towards the end of the LBA.

Northern Türkiye

In the Black Sea region of northern Türkiye, the high-resolution stalagmite record So-1 from Sofular Cave appears to present dry conditions surrounding the end of the LBA and Hittite empire (Göktürk et al. 2011). The $\delta^{13}\text{C}$ curve of Sofular Cave also appears to present more arid conditions around the LBA-EIA, reflecting a long-lasting drying trend from ~3.5 ka BP (~1550 BCE), which extends beyond the first millennium BCE (Göktürk et al. 2011).

Central Türkiye

Around 3.25-3.05 ka BP (1300-1100 BCE), a period of intense aridification and lake desiccation is identified in the Tecer Lake record, as inferred from a hiatus in sedimentation (Kuzucuoğlu et al. 2011). A reduction in arboreal pollen and an inferred arid interval in $\delta^{18}\text{O}$ can also be identified around 3.1-2.7 ka BP (1150-750 BCE) in the Eski Acigöl record, with maximum salinity levels reached from approx. 3 ka BP (1050 BCE) (Roberts et al. 2001). At Nar Gölü, a period of high dolomite (>20%) can be identified around 3.15-2.5 ka BP (1200-1600 BCE), which appears to suggest that conditions were drier than the millennial average. Drier conditions during this time are also inferred from the absence of varved sediments (Dean et al. 2015). Roberts et al. (2016) additionally state that this period represents the most arid conditions during the last 14

ka at Nar. A new annually resolved tree ring record from Gordion in central Türkiye identifies dry conditions around 3.18 ka to 3.14 ka BP (1232-1192 BCE) (Manning et al. 2023). A particularly severe continuous dry period between ca. 3.158-3.146 ka BP (1198 to 1196 BCE) is also identified by the Gordion tree ring record (Manning et al. 2023).

Southern Türkiye

In southeast Türkiye, the $\delta^{18}\text{O}$ signature of Lake Van appears to present a period of colder, drier conditions with intermediate detrital input and high salinity and low lake level between 3.5-3.3 ka BP (1500-1350 BCE) (Barlas Şimşek and Çağatay, 2018).

2.4.3. The Levant

Across the Levant, which in this thesis is defined as modern-day Syria, Lebanon, Jordan, Israel Palestine and Cyprus, LBA-EIA palaeoclimatic conditions are predominantly understood from southern Levantine proxy records, which appear to suggest that arid conditions surrounded the transition period. In addition to the Sea of Galilee record of Langgut et al. (2013), drier and warmer conditions around 3.2 ka BP (1250 BCE). have also been proposed by Litt et al. (2012) as understood from a reduction in Mediterranean biome pollen from the Dead Sea. Litt et al. (2012) further suggest that it is highly likely that an extensive drought led to the destruction of Mediterranean woodland on the Judean Hills. In further support of LBA aridity, Neugebauer et al. (2015) propose that the Dead Sea experienced a significant dry period from 3.5-3.3 ka BP (1550-1350 BCE), as indicated by a decline in lake level of ~45m (Migowski et al. 2006). A dry period has also been identified from 3 ka BP (1050 BCE), but this is less pronounced as it appears to have had a less significant impact on sedimentation (Neugebauer et al. 2015). Across the LBA-EIA period, a trend of increasing aridity is also exhibited by an increase in $\delta^{18}\text{O}$ values in the stalagmite record from Soreq Cave from approx. 3.15 ka BP (1200 BCE), with the driest conditions seen from approx. 3.05 ka BP (1100 BCE) (Bar-Matthews et al. 1998). Proxy signals from marine cores GA-110 and GA-112 (located off the Levantine coast) and Jeita Cave in Lebanon also appear to indicate a shift towards drier conditions centuries later (from approx. 3 ka BP onwards). Therefore, whilst Kaniewski et al. (2015) state that aridification can be identified from ~3.2 ka BP (~1250 BCE) in the marine cores, dry conditions are not reflected by the $\delta^{18}\text{O}$ signal of planktonic foraminifera (*G. ruber*) prior to the LBA demise. Instead, it appears that humid conditions prevail from 3.5-3 ka BP (1550-1050 BCE), followed by arid conditions in the EIA from 3 ka BP to 2 ka BP (1050-50 BCE) (Schilman et al. 2001). The Jeita record, which is one of the best-dated EM proxy records, has also been referenced by

Kaniewski et al. (2015) in support of drier conditions from around ~3.2 ka BP (~1250 BCE). However, Cheng et al. (2015) identify a relative wet period in the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ around this time, followed by a significant drought period at approx. 2.8 ka BP (850 BCE), as can be seen in **Figure 14**.

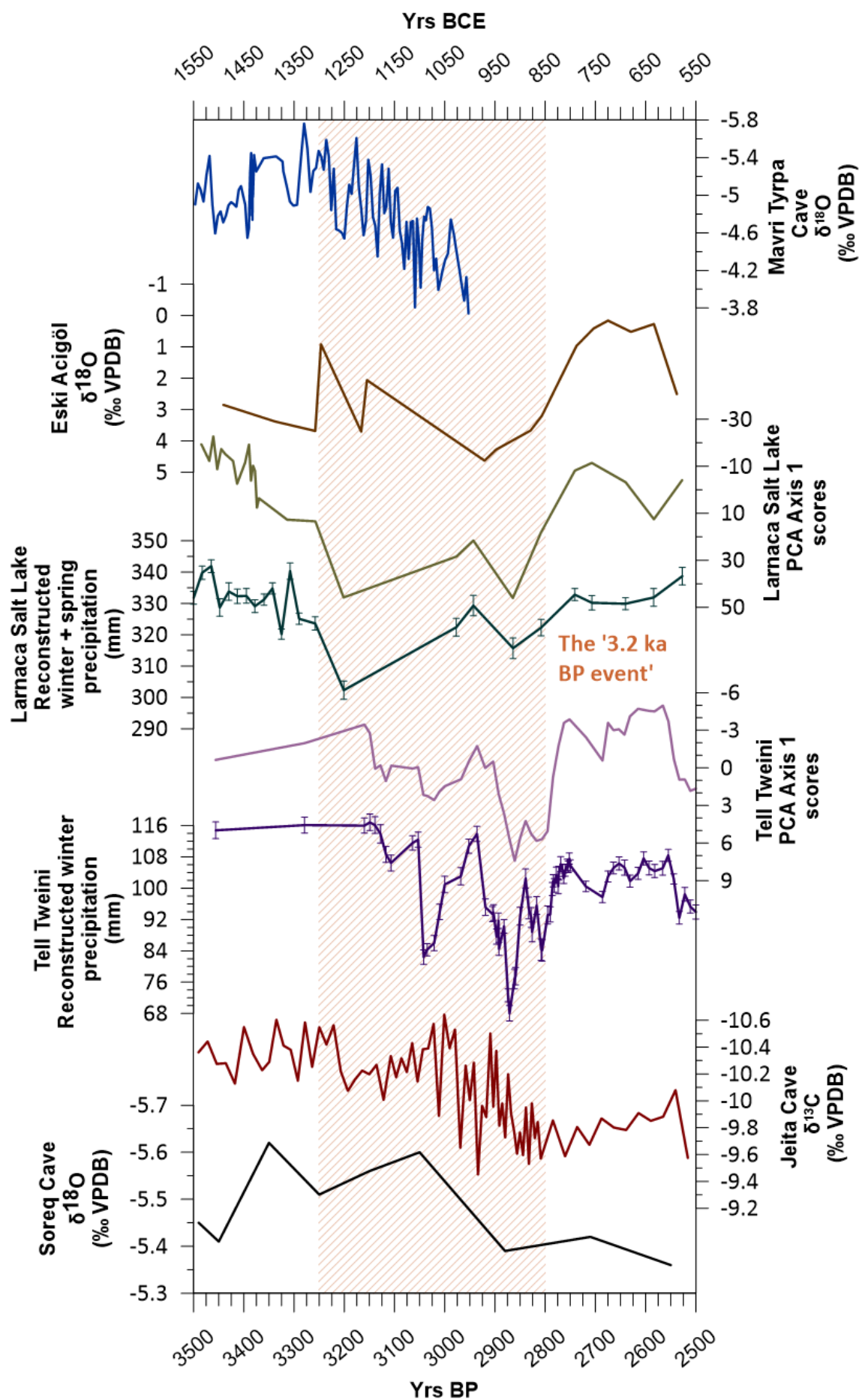


Figure 14. Summary plots of accessible proxy data from the Aegean, Türkiye and the Levant as introduced in this chapter. From top to bottom: Mavri Trypa (Finné et al. 2017), Larnaca Salt Lake (Kaniewski et al. 2013; 2020); Tell Tweini (Kaniewski et al. 2013; 2019b), Jeita Cave (Cheng et al. 2013); Soreq (Bar-Matthews et al. 1998). The orange shaded bar indicates the 3.2 ka BP event. Source: Author's original.

2.4.4. Limitations of the Existing Palaeoclimatic Proxy Data

As stated by Haywood et al. (2019), in a perfect world palaeoclimatic proxy data would provide accurate estimates of past environmental conditions for every point on Earth throughout history. In reality, palaeoclimate reconstruction is difficult, with proxy records associated with numerous limitations and uncertainties.

The reliability of the existing climate hypothesis is notably undermined by the quality of existing palaeoclimatic data and subsequent interpretations and conclusions, which will be critically examined below. To determine whether there is any synchronicity between climatic changes in the palaeoclimatic record and events of the LBA-EIA transition, a robust and reliable chronology is imperative. Unfortunately, as highlighted by Finné et al. (2011) and Knapp and Manning (2016), the chronological and temporal resolution of many published EM palaeoclimatic records is generally poor.

Chronology

Firstly, several of the existing palaeoclimate records across the EM have been dated using few ^{14}C dates and so the dating density is generally rather insufficient. Most critically, in some records, the LBA and EIA periods are not covered by a single absolute date. The chronology of the LBA-EIA for these records is instead interpolated from a void between the nearest absolute dates in age-depth models. For example, the chronology for the LBA in the Sea of Galilee record is interpolated between radiocarbon dates ETH-48430 (~3.9 ka BP) and ETH-48434 (~2.1 ka BP). As there are no absolute dates covering the LBA-EIA transition period, there is significant uncertainty as to whether the shift towards aridity did occur around ~3.2-3.05 ka BP (~1250-1100 BCE), as posed by Langgut et al. (2013), or instead occurred earlier or later.

Secondly, several records covering the LBA-EIA transition present radiocarbon ages, which are either inaccurate or suffer from significant imprecision and uncertainty resulting from errors

(e.g., the reservoir effect and hardwater effect in lacustrine and marine cores) or from calibration issues (e.g., ^{14}C plateau). Whilst advances in Bayesian age-depth modelling have made it possible to quantify errors and output more precise calibrated ages, radiocarbon chronology and its potential and limitations for a given calendar interval largely depends on the shape of the radiocarbon calibration curve (Manning, 2006). Although the generalized timing surrounding the end of LBA civilizations across the EM is the subject of active debate, a simplified date of 1200 BCE (3150 BP) is often provided (Manning, 2006). It is, however, inherently challenging to date the period around 1200 BCE (3150 BP) as the shape and wiggles of the calibration curve around ca. 1300-1100 BCE (3250-3050 BP) effectively acts as a plateau. As can be seen in **Figure 15**, the calibration of the ^{14}C date Beta-229048 from the Tell Tweini record (Kanievski et al. 2010) provides highly imprecise age ranges of 1260-1123 BCE (68.3% probability) and 1376-1049 BCE (95.4% probability). Additionally, as exemplified by the Sea of Galilee record, an inappropriate choice of age-depth model can provide inaccurate chronologies. As demonstrated by Knapp and Manning (2016: 114-116) the original OxCal (v 4.2.2) age-depth model presented by Langgut et al. (2013) seen in **Figure 16** for the Sea of Galilee record is inappropriate. Through reassessment of the original model, which uses U-Sequence deposition (assuming a constant accumulation rate of sediment), it appears that there is a poor overall model agreement (OxCal $A_{\text{model}}=41$) as the index value is below the threshold value of 60. This overall poor agreement is unsurprising as a third of radiocarbon dates offer poor agreement with the model. In contrast, a P_Sequence model (assuming random deposition), as shown in **Figure 17**, presents good overall model agreement (OxCal $A_{\text{model}}=77$). Whilst the original model places the arid LBA signal at approximately ca. 1250-1150 BCE, the Knapp and Manning (2016: 115) model places this signal at 1450-1033 BCE (68.2% probability) and 1665-765 BCE (95.4% probability).

It is important also to state here that substantial weaknesses are also associated with archaeological chronologies of the LBA-EIA (see Chapter 3), which further challenges reliable comparisons between the palaeoclimatic data and archaeology.

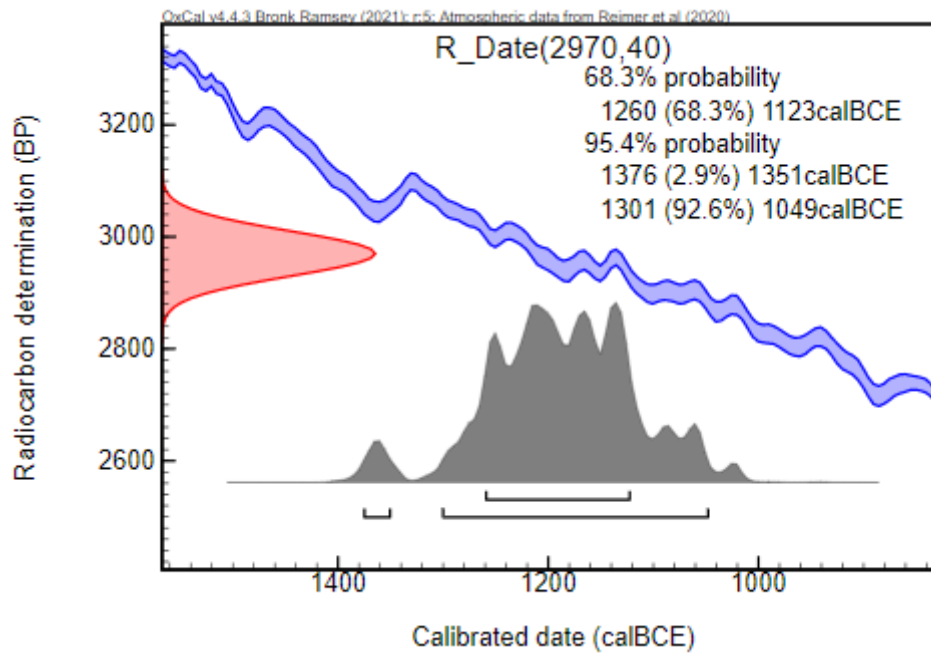


Figure 15. Calibration of Beta-229048 from Tell Tweini (Kaniewski et al. 2010) using IntCal20 in OxCal v 4.4. Source: Author's original.

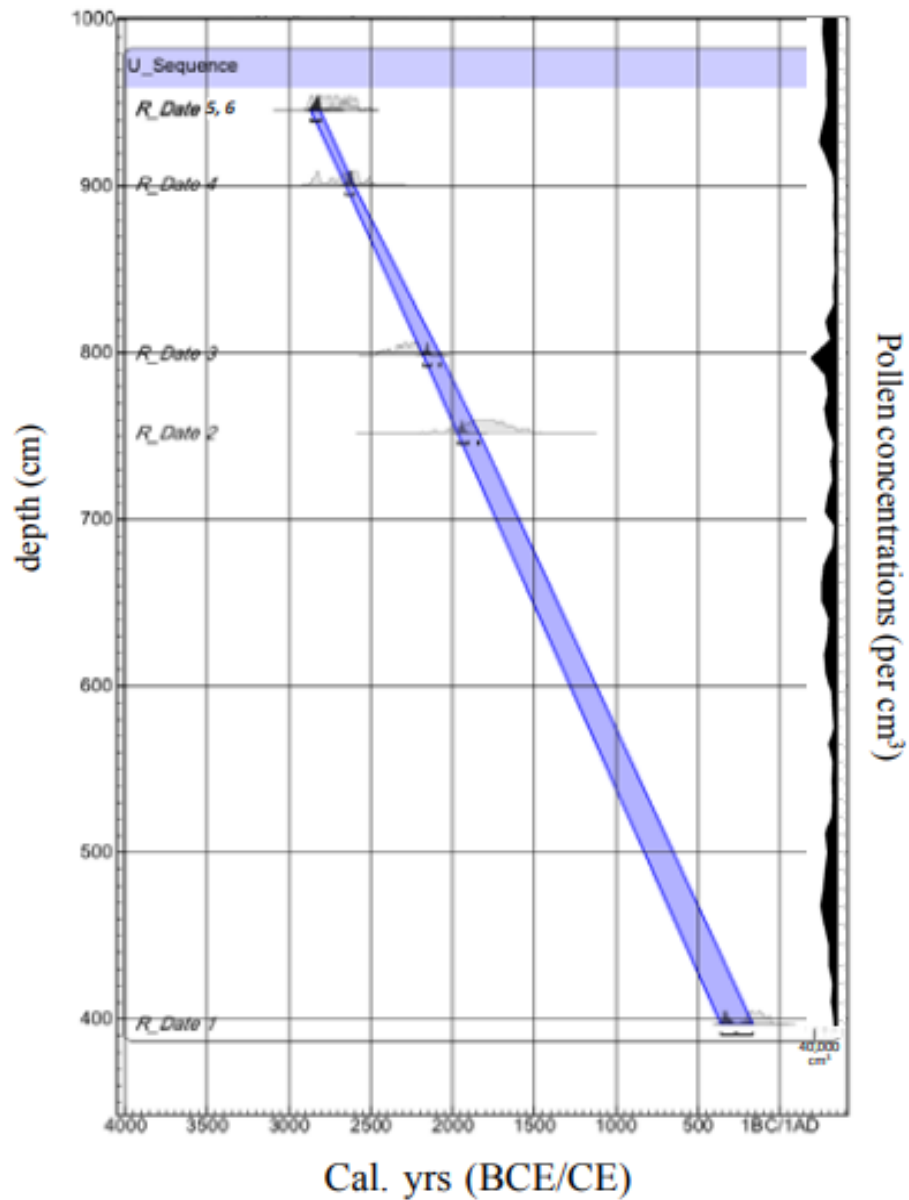


Figure 16. Original Langgut et al. (2013) Bayesian age-depth model of the 5.5.m core section using a U_Sequence in OxCal. Source: Langgut et al. (2013) *Climate and the Late Bronze Collapse: New Evidence from the Southern Levant. Tel Aviv*, Figure 2. Copyright © 1974 Institute of Archaeology of Tel Aviv University, reprinted by permission of Informa UK Limited, trading as Taylor & Francis Group, www.tandfonline.com on behalf of 1974 Institute of Archaeology of Tel Aviv University).

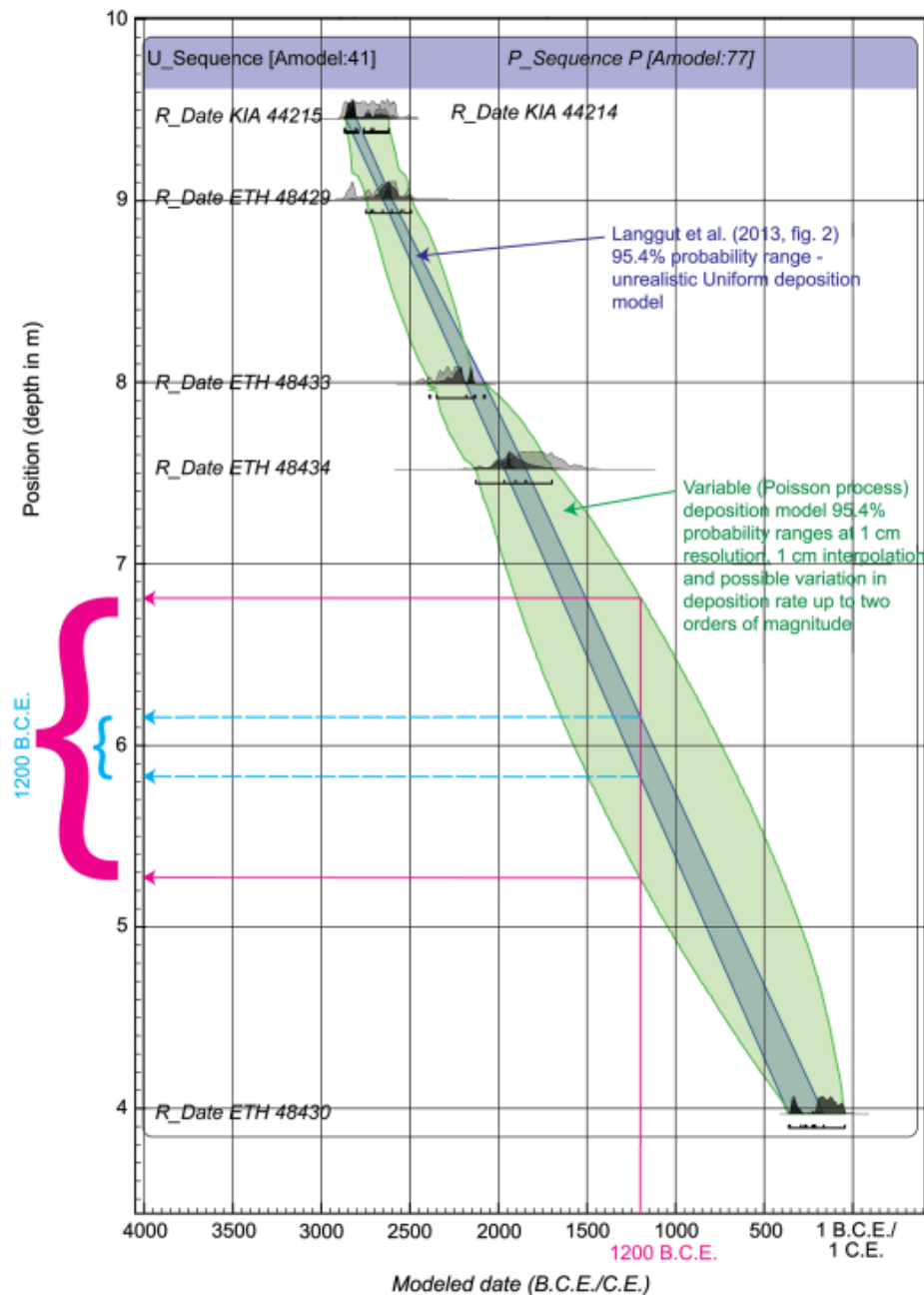


Figure 17. Age-Depth model for the six radiocarbon dates stated to be on short-lived samples from the Sea of Galilee core of Langgut et al. (2013) as produced by Knapp and Manning (2019: 114-116). Source: Knapp and Manning (2016: 114-116), Figure 6. Courtesy of the Archaeological Institute of America and the American Journal of Archaeology.

Temporal Resolution

Many of the discussed proxy records are also poorly resolved between 3.5-2.5 ka BP (1550-550 BCE) and, more specifically, during the LBA and EIA. SST reconstructions from the EM covering

the LBA-EIA (e.g., Schilman et al. 2001; Rohling et al. 2002), for example, possess low temporal resolutions ranging from 50 to 100+ yrs, whilst the Dead Sea pollen record of Litt et al. (2012) provides a multi-century resolution (~150-200 yrs). Insufficient temporal resolution makes palaeoclimatic inference difficult, as only highly resolved records can capture the precise timing of a climatic event and any short-lived events (Finné et al. 2019; Caseldine and Turney, 2010).

Spatial Coverage

Palaeoclimatic reconstruction of LBA-EIA conditions across the EM is also limited by the spatial coverage of existing proxy records. As presented in section 2.2, modern climate data demonstrates a high degree of climatic heterogeneity across the EM and so a dense network of precisely dated and highly resolved palaeoclimate proxy records is required to adequately reconstruct this variability. However, as many EM proxy records are either poorly dated or poorly resolved, there is a scarcity and uneven distribution of records across the region (see Appendix A2 and Chapter 4). Significantly, there are also very few EM temperature records that cover the late Holocene and the LBA-EIA (Zittis et al. 2022).

2.5. Chapter Summary

This chapter can be summarized by the following key points:

- The climate of the EM is highly complex due to the influence of mid-latitude and subtropical climate regimes, its varied topography and complicated coastal features. Due to the range of climatic and physio-geographic factors controlling and influencing EM climate, spatial and temporal variability of temperature and precipitation is high across the region.
- Climatic conditions are diverse across Türkiye due to the irregular topography of the landscape, which controls the varied distribution of temperature and precipitation.
- Aridity and drought events were common features in the EM's past, as can be identified in documentary evidence and palaeoclimate evidence.
- Several existing palaeoclimate proxy records from the EM present a shift towards increasingly arid conditions during the LBA-EIA transition.

- The Tell Tweini and Larnaca proxy records from the Levant also suggest a shift towards cooler conditions across the LBA-EIA transition (Kaniewski et al. (2019b; 2020).
- However, many existing EM proxy records are of low chronological and temporal resolution, which makes it difficult to determine the precise timing and duration and accurately determine any synchronicity in climate changes across proxy records.
- The poor quality of existing EM palaeoclimate data appears to undermine the existing climate hypothesis, and so a critical re-examination of existing EM proxy records, which cover the LBA-EIA transition period, should be undertaken, alongside the provision of new high-resolution proxy records as posed in Chapter 1.

Chapter 3 - Late Bronze Age and Early Iron Age Society in Türkiye and the Wider Eastern Mediterranean Region

3.1. Introduction

Through the examination of archaeological evidence, we can attempt to understand LBA-EIA societies across the EM in an effort to determine their vulnerability and resilience. As this thesis follows a multi-scalar level of analysis of climate and society across Türkiye and the wider EM region, this chapter will examine LBA-EIA archaeological evidence across the different regions of Türkiye and the archaeology of the western Aegean and the Levant to understand conditions at a regional level. By presenting a multi-scalar analysis of the archaeological evidence, we can attempt to not only understand conditions generally and identify any large-scale patterns but also identify any complexities and/or diverse societal trajectories.

To understand LBA and EIA societal and economy across Türkiye and the wider EM region, this chapter will:

- 1) Introduce the chronology of the LBA and EIA periods across Türkiye and the wider eastern Mediterranean region.

To understand the timing and rates of change affecting the end of the LBA and any possible interrelationships between environmental change and societal response, the chronology of the LBA-EIA across Türkiye and the EM must be examined.

- 2) Examine LBA-EIA archaeological evidence to understand society and economy in Türkiye and the wider eastern Mediterranean region.

To understand the human responses of LBA societies to any climate changes across Türkiye and the wider EM, this chapter will examine key societal features between the LBA and EIA, such as settlement patterns and material culture (e.g., ceramic assemblages found at key sites). Through the examination of societal features during the LBA and the transition into the IA, it is possible to identify any socio-cultural changes and/or continuities across the transition period in the EM. Due to the climate

focus of this thesis, it is also important to examine the agricultural practices of the LBA-EIA to inform our understanding of agricultural risk and resilience during the LBA and EIA periods. Significantly, if aridity posed a threat to food production systems, societies would have needed to modify production practices or find mitigating techniques to continue production in a changing landscape (Gaastra et al. 2021). Therefore, agricultural conditions of the LBA and EIA will be examined in this chapter, as understood from documentary evidence and archaeobotanical and zooarchaeological data.

- 3) Present a summary of key issues affecting our understanding of LBA-EIA societies across Türkiye and the wider eastern Mediterranean region.

Whilst archaeologists have made significant progress in understanding the societal conditions of the LBA-EIA across Türkiye and the EM, several key issues plague interpretations that must be highlighted. This chapter will, therefore, also present the issues surrounding LBA-EIA archaeology of the EM which impede our understanding of LBA-EIA societies across Türkiye and the EM.

3.2. Late Bronze Age-Early Iron Age Chronology across the Eastern Mediterranean

As the establishment of a reliable and precise temporal correlation between climate change and societal changes relies on robust chronologies, the chronology of the LBA and EIA periods across the EM and their uncertainties will be presented here. As introduced below, LBA-EIA chronologies of the EM are based on a combination of relative dating and absolute dating methods.

3.2.1. Relative Chronology

Traditionally, the most common method of archaeological dating relies on establishing relative chronologies through the temporal ordering of objects and events relative to each other (Manning, 2012: 12). The relative sequencing of deposits and artefacts can be established using methods of stratigraphy, typology and seriation. By applying these methods, archaeologists can establish relative site chronologies and local chronological sequences. Larger regional chronologies and chronological frameworks have also been constructed from the comparison and collation of sequences across sites and areas. Relative chronologies are, however, associated with several limitations (Manning, 2012). For example, the location of an object within a site or relative to other objects may not reflect its chronological age. It is also

important to highlight its interdisciplinary weakness, given the nature of this thesis, in that relative chronologies are complex and designated by different technical terms and abbreviations (e.g., LH IIC). Whilst familiar to archaeologists, relative chronologies often hinder engagement with other disciplines as these terms are only known to those in the field (Manning, 2012: 18). Most significantly, relative dating methods can only establish a chronological order that is not anchored in time and is chronologically imprecise.

3.2.2. Absolute Chronology

To know how old sequences, sites and artefacts are more specifically and to determine when events occurred, we must establish chronologies associated with absolute calendar years (yrs BCE/CE) (Manning, 2012: 18). Importantly, absolute chronologies can provide us with dates that are independent of historic sources, ceramic sequences and pseudo-historical cultural assumptions that have been taken as fact (Manning, 2006; Yakar, 2002: 557; Genz and Mielke, 2011: 18). To derive absolute dates, chronologies can be constructed through either archaeological-historical dating or radiometric dating.

Archaeological-Historical Dating

Traditionally, archaeologists have sought to link the exports or imports of objects across neighbouring areas using ancient historical records to determine approximate calendrical years. For example, the chronology of the Aegean BA is in part derived from the comparison of artefacts and stylistic associations of the Aegean world with the approximate historical dating of Egypt and the Near East (Manning, 2012). Approximate historical chronologies exist for Egypt and the Near East as written and inscribed records have provided a list of successive kings and officials and their reigns and years in office. Calendar dates can be attributed to such lists, for example, through an astronomical event etc. recorded in ancient texts.

Whilst historical records may reliably record the number of years in a reign, each king's list must still be linked to our own calendar. Historical dating can also be misleading if any linkage comprises a single object or stylistic association (Manning, 2012). Additionally, regular revisions of historical chronologies and king lists are required due to new emerging finds that require regular revision of historical chronologies and king lists (Manning et al. 2020: 6; see Schneider, 2010 for a summary of recent work undertaken on the chronology of the New Kingdom and Third Intermediate Period). For example, the re-excavation of the Tomb of Horemheb has supported a reduction in the duration of the pharaoh Horemheb's reign (van Dijk, 2008; Schneider, 2010; Wiener, 2014). Due to archaeo-historical linkages between

neighbouring areas of the EM, Egyptian chronological revisions can, therefore, also lead to revisions of Aegean and Levantine LBA-EIA chronologies (see Wiener, 2010; 2014).

Additionally, dates that can be established rarely provide more than a general chronological framework (Genz and Mielke, 2011: 16; Yakar, 2011: 77).

Radiometric Dating

Two radiometric dating methods are commonly applied in archaeology: Dendrochronology and Radiocarbon dating, which are summarized below.

Dendrochronology

Dendrochronology, otherwise known as tree ring dating, uses the annual growth increments of trees to provide a precise estimate calendar age of a wood sample. Within archaeology, tree ring dating may be used, for example, to date a specific wood sample or establish the temporal history of a building (Manning, 2023). The most fundamental concept of dendrochronology is crossdating, the process by which the exact year is assigned to every tree ring (Douglass, 1941; Black et al. 2016; Frank et al. 2022: 29-30). Crossdating involves matching patterns of wide and narrow rings from the same tree and between different trees from different locations matched across trees (Douglass, 1941; Sheppard, 2010). Critically, since the production of tree ring dating relies on the similarity between ring patterns, dates are independent of other dating evidence and history.

Whilst dendrochronology contributes much to LBA-EIA chronology in the EM (e.g., see 3.2.3), this dating method is also associated with several limitations. For example, dendrochronology dates only the rings in the wood sample, which is not necessarily the year the timber used in buildings was felled, when a building was constructed or how long the building was used (Mielke, 2006; Genz and Mielke, 2011: 17). Additionally, timbers used to construct LBA-EIA buildings may have been recycled from earlier structures (Schoop, 2008; Kealhofer et al. 2019). For example, the reuse of timber at Kilise Tepe was suggested by Postgate as the likely reason for the earlier-than-expected dendro dates at the site (see Kuniholm et al. 2007: 622).

Radiocarbon Dating

As stated by Manning (2006: 53), radiocarbon has become an essential element in establishing prehistoric chronologies. Radiocarbon dating is based on the measurement of the concentration or the decay rate of the radioactive isotope ^{14}C (van der Plicht and Bruins, 2001). Radiocarbon dates can be obtained by measuring $^{14}\text{C}/^{12}\text{C}$ ratios of materials containing carbon

such as wood, plant remains, and animal bones (Ramsey, 2008b). Short-lived plant remains (e.g., seeds, cereal grains), which have a secure relationship to the archaeological context or research question, are generally considered the best dated materials as these remains typically have a relatively short growth period. Whilst wood and charcoal are commonly sampled materials dated from archaeological contexts care should be exercised in the selection of wood or charcoal to avoid the old wood effect (Taylor and Bar-Yosef, 2014; Schiffer, 1986). The old wood effect occurs when the age of the sample is older than the age of the archaeological context in which it was found, resulting in erroneous dates (Schiffer, 1986; Bowman, 1990; van der Plicht and Bruins, 2001). For example, the death of a tree may have occurred years before it yielded material used at archaeological sites (Schiffer, 1986). The delayed use and re-use of wood in other built structures, e.g., if old wood is employed in a building after being removed from an earlier one, can also contribute to the old wood effect (Bowman, 1990; Taylor and Bar-Yosef, 2014: 66). To determine calendar age estimates radiocarbon dates must be calibrated, as the proportion of atmospheric radiocarbon varies over space and time (Ramsey et al. 2006). For a more comprehensive introduction to radiocarbon dating, see Ramsey (2008b).

As summarized by Bayliss (2009), increasingly accurate chronologies can be produced by ^{14}C dating. For example, chronologies can be provided to a resolution of less than a century, within the span of a human lifetime, and sometimes down to a generation or a few decades. Radiocarbon dating has also been found to be an effective tool in developing absolute chronologies that are independent of any archaeological context and separate from any long-standing cultural assumptions and bias and/or debated historical information (Manning, 2006: 53). However, radiocarbon dating is challenging. As summarized by Bayliss (2009), radiocarbon dating requires rigorous attention to detail and demands high accuracy in the selection and measurement of samples. ^{14}C laboratories and archaeologists can both make mistakes that lead to erroneous radiocarbon dates (van der Plicht and Bruins, 2001). Laboratories can contribute to erroneous dates through the dating methodology and accuracy, whilst archaeologists may cause dating errors through poor sampling procedures and poor interpretation (van der Plicht and Bruins, 2001; Renfrew and Bahn, 2020: 144). Confidence in this dating method can also vary amongst archaeologists, who may lack familiarity with radiometric dating methods (Webster, 2015: 24). Critically, the potential and limitation of radiocarbon chronology for the LBA-EIA transition period is also dependent upon the shape of the radiocarbon calibration curve, which determines the dating probabilities of radiocarbon ages (Manning, 2006: 54). Radiocarbon ages which intersect with periods with plateaux or

multiple wiggles including similar radiocarbon ages can either yield multiple possible calendar age ranges or very wide age ranges which do not offer precision (Manning, 2006: 54). Significantly, the radiocarbon calibration curve features a small plateau and multiple wiggles around the LBA-EIA transition period (ca. 1300-1100 BCE) as well as a plateau known as the “Hallstatt Plateau” of the IA between ca. 750-400 cal BCE), which also affects LBA-EIA chronology. As can be seen in **Figure 18**, the calibration of a high precision radiocarbon age of 2950 ± 20 yrs BP using Oxcal v4.4.4 and the IntCal20 calibration curve will provide an age range of approx. 80 yrs at 1σ or >150 yrs at 2σ . This is significant as the disintegration of the Hittite Empire, the end of the Late Cypriot IIC (LC IIC) period in Cyprus, the end of the Late Helladic IIIB in the Aegean and the beginning of the so-called ‘crisis years’ of the 12th century BCE all coincide with this plateau (Manning, 2006).

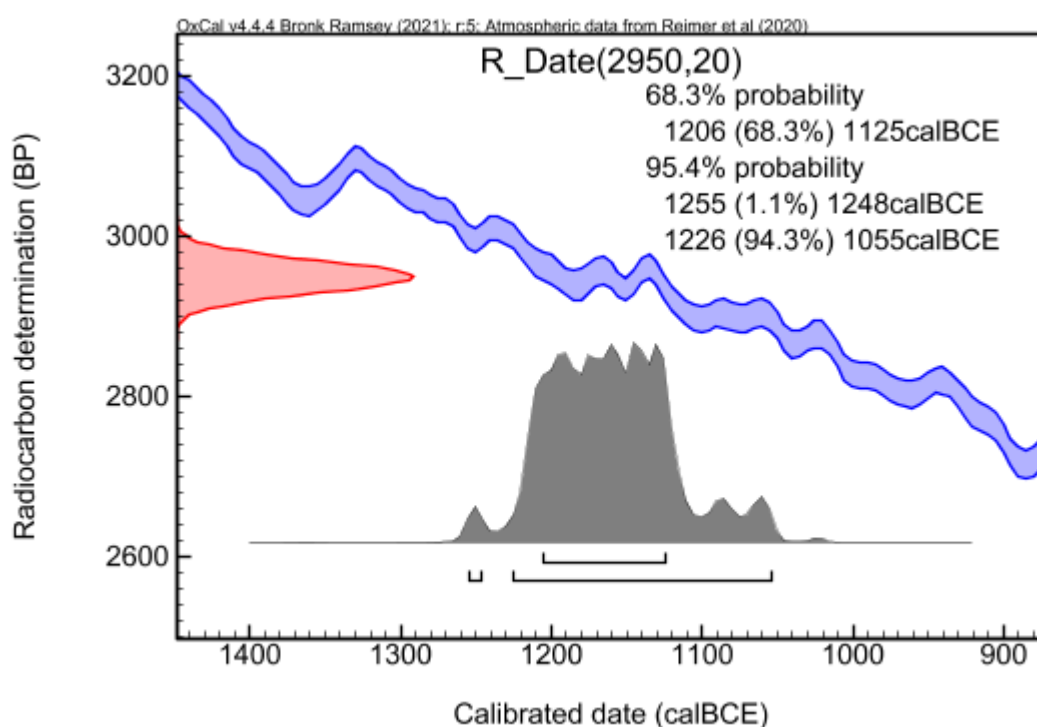


Figure 18. Example calibration of a radiocarbon age (2950 ± 20 BP) using the IntCal20 calibration curve (Reimer et al. 2020). Source: Author’s original.

Bayesian Chronological Modelling

Often, archaeologists have been able to tie relative and absolute chronologies together, notably through Bayesian statistics, which seeks to establish absolute dates of greater precision and reliability (Dickinson, 2019: 46). Critically, ^{14}C dates are not dates, they are measurements of an isotope ratio (Ramsey, 2009). To determine absolute dates ^{14}C measurements must be calibrated using Bayesian statistics (Ramsey, 2009). Bayesian modelling has become a common and best practice in the last few decades (Bayliss, 2009; Wood, 2015). To constrain the calibration of ^{14}C dates, relative dating understood from stratigraphic sequences and contexts can be entered into a model as informative prior information (Bayliss, 2009). As stated by Bayliss (2015: 680), the benefit of Bayesian modelling is that the model output, with its combined chronology, should be more reliable than its individual components (relative chronological information and individual radiocarbon dates). However, model output is fundamentally affected by the quality of data. Critically, a model can look robust even if radiocarbon dates are systematically incorrect (Wood, 2015). Different model parameters (*a priori* information) can produce different date outputs, even if the same material is used. For example, the modelling of Tel Rehov has produced dates supporting both the Low and High Chronology (see section 3.2.5) based on varied *a priori* information (Hodos, 2020: 13). Additionally, if the order of dated samples incorporated into the model is wrong the estimated chronology of the model will be incorrect, as the stratigraphic information of a model has considerable effects on output (Bayliss, 2009). It is therefore recommended that users who are new to Bayesian modelling collaborate with or seek advice from experienced model users or program developers (Wood, 2015).

In sum, a variety of archaeological dating methods exist, which are often used in tandem with one another through cross-dating to circumvent the limitations of each method.

3.2.3. The Chronology of the Late Bronze Age and Early Iron Age in Türkiye

As there is a paucity of absolute dates from stratified archaeological contexts at LBA sites, the chronological framework for LBA Türkiye is largely based on reconstructed political history, historical events and pottery typology (Bryce, 1998: 408-15; Beckman, 2000; Genz and Mielke, 2011: 14-16; Yakar, 2011). Hittite kings and historical events are arranged in a relative sequence, with the reigns of each king calculated approximately using generation counts, where one generation covers an interval of 20-30 years (Genz and Mielke, 2011: 16). The chronology of the Hittites is also partly established through historical synchronisms to

Mesopotamian king lists and events and to a lesser extent Egypt, where chronologies are better established (Beal, 2011: 597). Whilst Hittite pottery is generally a rather imprecise chronological indicator due to its general homogeneity and slow evolution of vessels, ceramics from well-dated contexts from Hittite sites (e.g., Hattuša, Kuşaklı) also contribute to our understanding of LBA chronology (Yakar, 2011: 77; Schoop 2006: 221; Schoop and Seeher 2006; Müller-Karpe 2006). Whilst Türkiye provides optimal conditions for dendrochronological dating, the list of dendro dates from Hittite sites is limited and ultimately does not contribute greatly to the dating of the Hittite Empire (Mielke, 2006). Radiocarbon estimates have also contributed to the chronology of several Hittite sites such as Hattuša (Schoop and Seeher 2006).

Notably, there is no overall chronological scheme for the EIA in Türkiye that combines dated historical events (as historical records are sparse or absent in the EIA) with changes in archaeological material, and so our understanding of EIA chronology is reliant on radiocarbon and dendrochronological determinations (Summers, 2008). For example, radiocarbon determinations from the site of Gordion have contributed to the chronology of the transition into the EIA (e.g., see Kealhofer et al. 2019).

For a summary of the relative and absolute chronology of the LBA and EIA across Türkiye see **Table 2**.

Table 2. Chronology of Late Bronze Age and Early Iron Age in Türkiye as presented in Yakar (2011: 83, Table 4.10), Kealhofer et al. (2019, Table 1) and Schachner (2019: 1115, Table 5.2.1.).

Period	Site phase			Calendar Age (BCE)
	Hattuša	Gordion	Kaman	
Late Bronze Age	Late Empire	YHSS 8-9	IIIa	ca. 1400- 1200/1180/1150
Early Iron Age	EIA	YHSS 7	IId 1-3	ca. 1200- 950/900
	Büyükkaya stage	YHSS 7A		

3.2.4. The Chronology of the Aegean Late Bronze Age and Early Iron Age

It is important to first state that different chronological sequences exist across the western Aegean, including sequences for the Greek mainland and Crete. Generally, the relative periodization of the LBA and the EIA has been established through site stratigraphy, pottery and tomb seriation without much issue, but establishing a reliable absolute chronology remains difficult (Jung, 2012: 171; Dickinson, 2019: 47). Establishing an absolute chronology across this transition period is challenging due to the lack of archaeological contexts that can be *directly* related to events carrying absolute dates mentioned in Egyptian/Near Eastern historical sources, or to well-dated Egyptian/Near Eastern leaders (Toffolo et al. 2013). Additionally, there is a relative scarcity of absolute dates across the western Aegean, which is insufficient to establish an absolute chronological sequence (Toffolo et al. 2013). Due to the scarcity of absolute dates, synchronisms have been established with Near Eastern chronology, though there are questions over the reliability of these apparent synchronisms (Dickinson, 2019: 47-48). Significantly, there is a contentious debate over the beginning of the Aegean Iron Age (Toffolo et al. 2013; Wardle et al. 2014; Fantalkin et al. 2015). Whilst Aegean chronological frameworks are traditionally based on a conventional “low” chronology, following synchronisms with the EM and Egypt, a number of scholars have proposed a “high” chronological framework. Notably, the “high” chronology raises the conventional chronology of the Aegean IA by 50-100 years, based on radiocarbon dates from elsewhere in the Mediterranean (Macedonia, Italy, Spain and Tunisia) (Wardle et al. 2014; van der Plicht et al 2009; Guidi, 2018; Hodos, 2020: 14). A series of radiocarbon dates from the sites of Sindos in the northern Aegean and Zagora on the island of Andros also support a higher Aegean EIA chronology, thus challenging the traditional Greek chronology (Gimatzidis and Weninger, 2020; Alagich et al. 2024). For a comparison of Aegean periodization according to the “low” and “high” chronological frameworks, see **Figure 19**. Notably, some scholars suggest that the “high” chronology is founded on unreliable contexts and problematic selection and interpretation of the data (Fantalkin et al. 2015: 26). As there is no fully revised system provided for the “high” chronology, some scholars believe it is safest to adhere to the conventional “low” chronology (e.g., Dickinson, 2019: 50), whilst those in support of the higher chronology propose the revision of Aegean IA chronology (e.g., Gimatzidis, 2024).

For a summary of the relative and absolute chronology of the Aegean LBA and EIA following the convention “low” chronology, see **Table 3**. As can be seen in **Table 3**, the transitional

chronology between the LBA and EIA is organized into several sub-periods, in order to appreciate the various transformative processes of this period (Eder and Lemos, 2019).

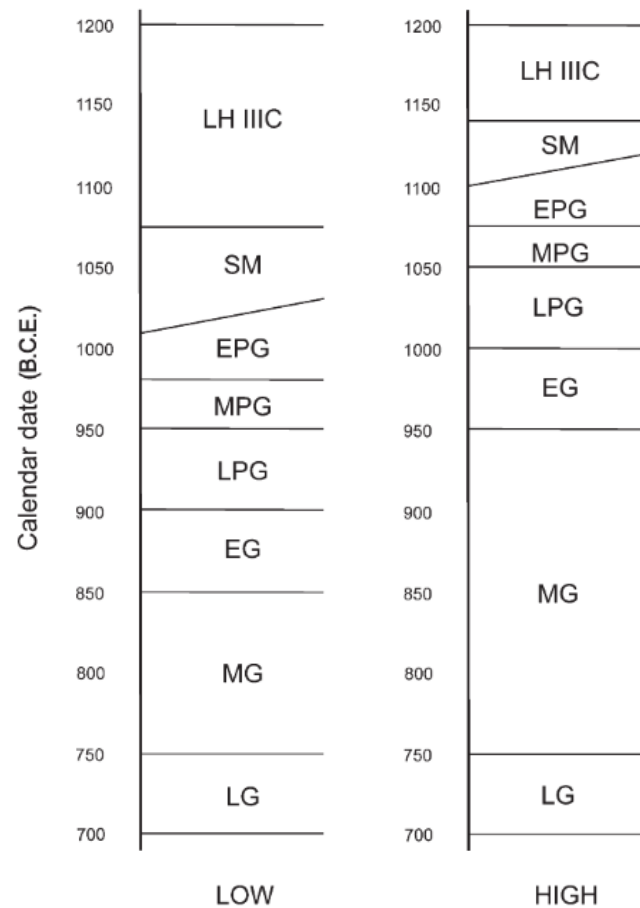


Figure 19. Relative periodization of the Aegean Iron Age according to the High and Low Chronologies. Source: Fantalkin et al. (2015), Figure 1. Copyright © 2015. Used with permission of University of Chicago Press. Permission conveyed through Copyright Clearance Center Inc.

Table 3. The relative and absolute chronology of the end of the Aegean LBA and start of the IA following the conventional “low chronology,” as cited in Dickinson (2019) and Middleton (2020). Abbreviations: The Late Helladic (LH), Submycenaean (SubMyc), Protogeometric (PGM), Late Minoan (LM), Subminoan (SM).

Period		Phase		Calendar Age (BCE)
		Mainland Greece	Crete	
Late Bronze Age	Palatial	LH IIIA1	LM IIIA1	1400-1200
		LH IIIA2	LM IIIA2	
		LH IIIB1	LM IIIB	
		LH IIIB2		
	Postpalatial	LH IIIC- early	LM IIIC	1200-1070/1025
		LH IIIC- middle		
		LH IIIC- late		
		SubMyc		
Early Iron Age		PG- early	SM	1025-700
		PG- middle		
		PG- late		

3.2.5. The Chronology of the Levantine Late Bronze Age and Early Iron Age

The chronology of the Levant across the Bronze and Iron Age periods is complex and the subject of contention. Notably, the chronology of the mainland Levant differs from Cypriot chronology due to different archaeological stances. Whilst Levantine archaeology defines the beginning of the Iron Age around the onset of the ‘crisis years’, Cyprus has traditionally followed Greek archaeology whereby the BA continues until the new order is firmly in place,

which can make correlations between Cypriot chronology and the rest of the Levant difficult (Sharon 2014: 59). For example, the LC IIIA and LC IIIB periods of the LBA in Cyprus are contemporaneous with the beginning of Iron I on the mainland.

The Levantine Mainland

The subdivision of the Late Bronze Age across the Levantine coast is generally based on imported Mycenaean pottery and is tied to the activities and policies of the Egyptian New Kingdom, as well as local conditions and processes (Sharon, 2014: 57-58; Panitz-Cohen, 2014: 541). In the southern Levant, the LBA-EIA transition period witnessed the end of LBA pottery imports from the Aegean and Cyprus, the end of Egyptian influence and the appearance of Philistine wares (Myc IIIC) (Sharon, 2014). Due to the disappearance of inscribed artefacts, scarcity of written sources, and the end of the well-defined sequence of historical rulers from New Kingdom Egypt at the end of the LBA, dating the transition into the IA is complex across the Levant and is therefore subject to contentious debate (Gilboa, 2014: 626; Manning et al. 2020: 6). Traditionally the chronology of IA across the northern and southern Levant has been based on correlations between the material record and events and phenomena cited in historical and literary sources such as the Hebrew bible (Gilboa and Sharon, 2001; Mazar, 2005). However, some scholars have questioned the reliability of biblical history, suggesting that correlations could be conjecture (Gilboa and Sharon, 2001). Challenging the traditional high chronology, Finkelstein (1996) has proposed a low chronology through a revision of the Philistine ceramic sequence, which lowers Levantine IA chronology by approx. 50-80 yrs. Significantly, contention over the chronological framework of the IA not only presents implications for the EIA across the mainland Levant but also for Aegean and Cypriot chronologies (Gilboa and Sharon, 2003). Most Levantine archaeologists do, however, appear to follow the traditional high chronology (Mazar, 2005; Bruins, 2011; Sharon, 2014). As the above chronological suggestions remain unanchored to absolute dates and continue to be subjective, establishing an independent chronology of the LBA-EIA Levant is important (Hodos, 2020: 13; Gilboa and Sharon, 2003: 8). As summarized by Harrison (2021), radiocarbon dating across southern Levantine sites such as Megiddo has contributed to the issues surrounding IA chronology (Toffolo et al. 2014). In contrast, it is important to highlight that radiocarbon dates are relatively scarce for the Northern Levant (Harrison, 2021).

For a summary of the relative and absolute chronology of the LBA and EIA across the Levantine coast see **Table 4**.

Table 4. The relative and absolute chronology of the LBA and EIA Levantine coast following the chronology cited in Panitz-Cohen (2014). Abbreviations: Late Bronze (LB), and Iron Age (IA).

Period	Phase	Calendar Age (BCE)	Egyptian chronology	
Late Bronze Age	LB IIA	1479- 1375	New Kingdom	Late 18 th Dynasty (Amarna Period)
	LB IIB	1300-1190		19 th Dynasty
	IA IA/ LB III	1190-1140		20 th Dynasty (Ramesses III-Ramesses VI)
Early Iron Age	IA IB/ Early Iron I	1140-1050	Third Intermediate Period	21 st Dynasty

Cyprus

Across Cyprus, LBA-EIA periodization is largely based on pottery typologies. For example, LBA has been defined by the appearance of White Slip, Base Ring and Monochrome vessels (Steel, 2014: 573). The LBA is also subdivided into the following phases, LC IA-B, LB IIA-C and LC IIIA, whilst the EIA has been subdivided into the phases LC IIIB and Cypro-Geometric I (Steel, 2014: 573; Knapp, 2013: 27). Absolute dates for the LBA and EIA have also been established through correlations with the chronologies of Egypt and the Near East (Merrillees, 1992) and radiocarbon dates (Knapp, 2013). A summary of the relative and absolute chronology of the LBA-EIA across Cyprus can be seen in **Table 5**.

Table 5. The relative and absolute chronology of the Cypriot LBA and EIA following chronology cited in Knapp (2013: 27). As stated by Knapp (2013: 28) absolute ages are based on radiocarbon dates calibrated using the IntCal09 radiocarbon calibration curve (Reimer et al. 2009). Abbreviations: Late Cypriot (LC), Cypro-Geometric (C-G), Protohistoric Bronze Age (ProBA).

Period	Phase	Calendar Age (BCE)
Late Bronze Age (ProBA)	LC IIA-IIC early	1450-1300
	LC IIC late-LC IIIA	1300-1125/1100
Early Iron Age	LC IIIB	1125/1100-1050
	C-G I	1050-1000

3.2.6. Dating the Transition

As introduced in Chapter 1, the end of the BA and the beginning of the IA is generally marked by the destruction and the abandonment of urban sites, the emergence of alternative settlement patterns and changes in the material culture. As highlighted in 3.2.3-3.2.5, LBA-EIA chronologies of the EM have traditionally been constructed through relative sequences and historical dates and events. However, in the last few decades, there has been an increased focus on providing absolute chronologies that are independent of cultural-historical viewpoints and assumptions (Gilboa and Sharon, 2003; Wood, 2015). Significantly, there has been a major focus on radiocarbon dating to establish how old sequences, sites and artefacts are across the LBA-EIA in calendar years, though the number of high-quality LBA-EIA radiocarbon dates across the EM is still rather limited (**see Table 6**). For example, whilst radiocarbon analysis has been undertaken at several EM sites (e.g., Sarepta), a number of dates have been generated prior to the introduction of Accelerator Mass Spectrometry (AMS) and standardized laboratory preparation, measurement and reporting practices in the 1980s. Additionally, whilst most ^{14}C dates have been dated using short-lived organic material such as cereals and seeds (e.g., Gordion), there is a risk that ^{14}C dates at the sites of Troy and Kastanas Toumba (dated using

charcoal) may be too old for their context, due to the old wood effect (Kealhofer et al. 2019; Kromer et al. 2003; Weninger and Jung, 2009).

Significantly, archaeologists face difficulty in choosing where to place the chronological boundary between the end of the LBA and the start of the EIA, as the transition was not a singular event and was not simultaneous across the EM (Sharon, 2014). Continuity in socio-political and cultural attributes of the LBA can also be seen into the IA across the EM (Sharon, 2014; Hodos, 2020). Additionally, the destruction of LBA sites, which mark the end of the LBA at several sites, temporally vary by as much as half of a century or more between the late 13th and mid-12th centuries BCE (Sharon, 2014). For example, the end of the LBA at Hazor may have occurred as early as 1250 BCE, whilst the destruction of Ugarit is dated to ca. 1190-1185 BCE (Millek, 2023). Critically, different archaeological approaches and frameworks lead to differences in regional chronologies. For example, whilst the beginning of the Iron Age across the mainland Levant is defined at the onset of the “crisis” (ca. 1140 BCE), the LBA of the western Aegean continues beyond the end of the palatial period until the new order of the IA is firmly in place (ca. 1070/1050 BCE) (Sharon, 2014). Establishing an absolute chronology of the LBA-EIA transition on a regional scale across the EM is also complex, due to the high number of micro differences in changes seen between individual archaeological sites.

Table 6. Number of sites across the Aegean and Levant with ¹⁴C dating across the LBA-EIA transition.

Region		No. of sites with ¹⁴ C determinations across the LBA-EIA transition
Türkiye		5
The western Aegean		<10
The Levant	Northern Levant	<5
	Southern Levant	>10
	Cyprus	<5

3.3. The Late Bronze Age-Early Iron Age Transition across Türkiye

It is helpful to first introduce the Hittite Empire when examining the archaeology of LBA-EIA Türkiye, as the Hittites have been the traditional focus of archaeological research surrounding the LBA-EIA transition due to their high archaeological visibility. Significantly, the Hittites are recognized as one of the greatest powers of the ancient Near East, known for their significant political and military achievements, as well as rich cultural traditions (Sagona and Zimansky, 2009: 253). Through their military campaigns, the Hittites are understood to have been indirectly engaged in LBA trade and exchange throughout the EM (Glatz, 2020). As stated by Sagona and Zimansky (2009: 266), the archaeology of the Hittites is an archaeology of imperialism, as reflected in the archaeological evidence of monumental architecture, fortification and generally homogenous material culture. Whilst the core territory of the Hittite Empire in the LBA lay across the central plateau, Hittite power and influence spread across a vast territory beyond Türkiye (Sagona and Zimansky, 2009: 253). During the LBA, the Hittite king also ruled over a network of vassal states throughout the northern Levant (e.g., Ugarit), which were under the immediate control of local rulers (Bryce, 2011: 95). Due to its status as a trade nexus, the northern Levant was an important region of interest to not only the Hittites but also other Near Eastern political and military powers of Egypt and Mesopotamia (Casana, 2013: 108). Hittite kings are, therefore, also understood to have vied with other empires, including Egypt, Mitanni and Assyria, over political dominance and power during this time (Sagona and Zimansky, 2009: 253; Casana, 2013: 198; Bryce, 2019). Throughout the LBA, the Hittites also faced threats from the Kaška in the Black Sea region of northern Türkiye and states in the west, including those in the Lukka Lands and Arzawa (Glatz, 2015; Mac Sweeney, 2010: 8; Bryce, 2019: 234). In addition to political and military threats, including rebellions and dynastic power struggles, the Hittites also experienced diseases and changing economic conditions (Glatz, 2020: 265). As introduced in Chapter 2, existing proxy records from Türkiye also suggest that the Hittites faced changing environmental conditions.

Notably, archaeobotanical research in Hittite settlements is rare (Rössner, 2019: 115). Additionally, there is little textual information concerning Hittite agriculture and rural economy. However, the Hittite Law Code and cadastral documents have provided some insight into Hittite daily life and agriculture (Hoffner, 1974: 54; Yakar, 2000: 260; Diffey et al. 2017: 10). It is believed that the sustenance and prosperity of the Hittite empire depended on agriculture, with a substantial grain supply needed to feed the general population and its large army (Bryce, 2002: 72; Dörfler et al. 2011). Agriculture, alongside animal husbandry, was a

main pillar of the state economy, with taxation based on agricultural output (Yakar, 2000: 271; Diffey et al. 2020: 1219). Hittite farming likely encompassed relatively small-scale, independent household farming, large 'feudal' estates and the sharecropping of crown land (Diffey et al. 2017). The Hittites are thought to have been reliant on local resources as the transport of bulk subsistence products would not have been possible at this time due to the geographical location of the central plateau (see Chapter 2 for the topography of Türkiye) (Manning et al. 2023). Additionally, unlike other Near Eastern civilizations such as Egypt, the Hittites did not possess irrigation systems, so the agrarian economy relied upon natural precipitation (Dörfler et al. 2011: 105). As suggested by Yakar (2000: 271), in the semi-arid central plateau, cereal yields likely fluctuated during severe and long winters, which is reflected in Hittite religion. Significantly, the Storm-God was considered the divine force for ensuring rainfall over the land and received great veneration, whilst apparent reference to drought is also described in the Telepinu Myth. Yakar (2000: 272) also suggests that Hittite farmers' fear of drought was reflected in the religious celebration of the Festival of Rain (Houwink ten Cate, 1992: 97).

The End of the Late Bronze Age and the Transition to the Early Iron Age

At the turn of the 13th century BCE (ca. 1200 BCE), Türkiye witnessed the destruction and abandonment of several Hittite sites, including the capital Hattuša, and ultimately, the demise of the Hittite state (Seeher, 2011; Schachner, 2020: 396). As summarized by Glatz (2020: 267), a number of explanations for the demise of the Hittites have been proposed over the years, including geopolitical processes and loss of control from conflicts in border zones, internal political fragmentation, the re-emergence of regional power bases, the crisis of legitimation for Hittite lineage, climate-induced food shortages and an inability to adapt to a complex inter-connected and decentralised international market (e.g., Hawkins, 2002; Bryce, 2005; Schachner, 2011; Sherratt, 2003; Broodbank, 2013; Knapp and Manning, 2016). The end of the Hittites as an administrative entity notably brought about the end of once-important partnerships and influence over vassal states like Ugarit (Schachner, 2020: 396). The end of the Hittite Empire also saw major socio-cultural changes such as a shift from urban settlements and monumental architecture to smaller settlements with domestic architecture (Kealhofer and Grave, 2011; Schachner, 2020: 396). Whilst our understanding of the EIA is rather limited, this period is generally understood as a time of cultural and political fragmentation across the region, bearing witness to new political landscapes and lifestyles (Genz, 2003; Summers, 2008; Kealhofer and Grave, 2011). For example, new power centres emerged (e.g., Phrygia) alongside the rise of a subsistence economy in smaller centres (Kealhofer and Grave, 2011; Sams, 2011).

Whilst the end of the LBA across Türkiye has traditionally been considered an all-encompassing and civilizational “collapse”, it is now recognized that LBA and EIA societies may have experienced divergent socio-cultural and political trajectories during and following the disintegration of the Hittite Empire, as will be presented in this chapter (Glatz, 2020; Castellano, 2018). It is therefore important to understand not only changes seen across Türkiye at the end of the LBA and the start of the EIA but also any continuity or diversity in socio-economic, political and/or cultural conditions.

To identify any changes, continuities and diverse societal trajectories across Türkiye LBA-EIA societal conditions across northern, central, western and southern Türkiye will be presented here. As much of our understanding of LBA-EIA societal conditions across Türkiye has come from the excavation of several key sites in central Türkiye due to their visibility, the archaeology of the central plateau will be reviewed. Due to its important location between the heartland of the Hittite Empire and northern Levantine vassal territory, LBA-EIA archaeological evidence from southern Türkiye will also be discussed in this chapter. The archaeology of northern and western Türkiye will also be examined here, as these areas, which were relatively peripheral to the empire, provide insight into societal conditions outside immediate Hittite control and influence. Due to the climate focus of this thesis, consideration of LBA-EIA agricultural conditions will also be discussed for each region. See **Figure 20** for the location of all sites discussed in text.

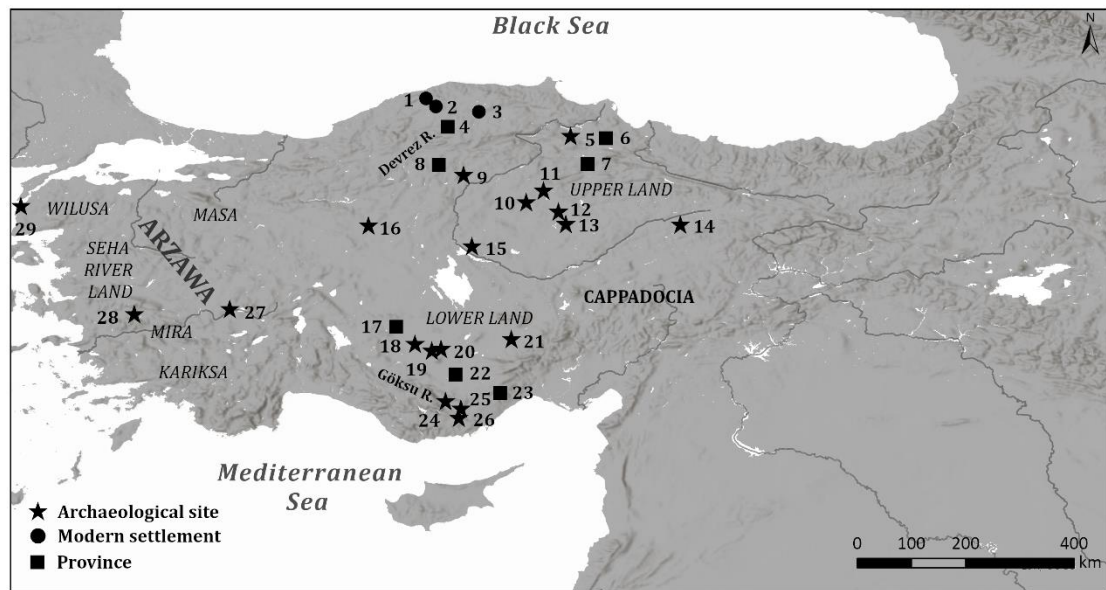


Figure 20. Map of all archaeological sites, modern settlements and provinces mentioned in text: 1) Okçular 2) Pınarbaşı 3) Devrekani 4) Kastamonu 5) Oymaağaç Höyük 6) Samsun 7) Amasya 8) Çankırı 9) Maltepe 10) Hattuša 11) Alaca Höyük 12) Uşaklı Höyük 13) Çadır Höyük 14) Kuşaklı 15) Kaman-Kalehöyük 16) Gordion 17) Konya 18) Domuzboğazlayan 19) Türkmen-Karahöyük 20) Büyük Aşlama 21) Kınık Höyük 22) Karaman 23) Mersin 24) Attepe 25) Kilise Tepe 26) Çingentepe 27) Beycesultan 28) Kaymakçı 29) Troy. Source: Author's original.

3.3.1. The Late Bronze Age

3.3.1.1. Northern Türkiye

During the LBA northern Türkiye was a frontier zone where the Hittites frequently encountered their enemies who lived in the hinterlands, the Kaška, who are likely to have been semi-nomadic (von Schuler, 1965; Freu, 2005; Glatz and Matthews, 2005; Zimansky, 2007; Matthews and Glatz, 2009; Yakar, 2008). In contrast to the highly visible archaeology of the Hittite Empire, the Kaška are archaeologically difficult to detect, with evidence of Kaška occupation understood from chance finds from Kınık in Devrekani, a cave in Pınarbaşı in Kastamonu province, and occupation in the Okcular Valley (Glatz and Matthews, 2005; Glatz, 2015). Whilst it is impossible to reconstruct the size and nature of their settlements, it is believed that they were small-scale and shifted, indicating a seemingly low degree of social centralization and a tendency towards frequent site relocation (Glatz, 2015; Glatz and Matthews, 2005: 59; Glatz et al. 2009). Hittite sites in the region are notably scarce as Hittite leaders were likely disinterested in the central Black Sea region due to its dramatic

topography, which would have restricted the ease of movement (Glatz, 2017). The little that we do know suggests that there was a limited settlement hierarchy across more northerly areas, as evidenced by site size and significance, with the exception of Maltepe in Çankırı and Oymaağaç Höyük in Samsun, known to be the cultic site of Nerik (Glatz et al. 2009; Glatz, 2017). Further south, in the Çankırı and Amasya provinces, a higher number of LBA sites can also be identified, which are largely considered fortified frontier sites (Glatz et al. 2009; Matthews and Glatz, 2009).

The material culture of LBA settlement across the north differs. Across much of northern Türkiye, there are limited ceramic finds, with late imperial ceramics represented in only small numbers in Paphlagonia (Glatz et al. 2009: 111). However, at Oymaağaç Höyük the ceramic repertoire is largely dominated by standardized Hittite plain pottery (Mielke, 2016a: 45; Mielke, 2022). The conditions of these LBA vessels correspond to the general tendencies of Hittite pottery towards the end of its development (Mielke, 2016a: 46; Mielke, 2016b). Additionally, the architecture of the site provides an isolated example of imperial construction in northern Türkiye, as sites believed to have been occupied by the neighbouring Kaška are characterized by a lack of dressed stone architecture (Glatz et al. 2009).

Agricultural Conditions

As archaeological evidence from northern Türkiye is scant, our understanding of agricultural conditions is also limited. For example, our understanding of crops grown by the Kaška is limited, though it is thought that the Kaška likely grew a range of crops in their lands, including flax (Glatz and Matthews, 2005). Like most semi-nomadic tribes in antiquity, it is likely that segments of the Kaška population were practising agriculture and seasonal and transhuman pastoralism (Yakar, 2008: 821; Hammer and Arbuckle, 2017: 231). If the Kaška did grow a range of crops and practised extensive herding, which involves spatial diversification and mobility, they may have sought to reduce variance in subsistence returns to manage water and subsistence risk (Marston, 2011; Hammer, 2018). Predominantly our understanding of LBA agricultural conditions in the north comes from the Hittite site of Oymaağaç Höyük. During the LBA, barley appears to dominate the cereal assemblage at the site, followed by wheat and legumes, lentil, lentil vetch and field bean (Rössner, 2019: 114-115). The dominance of barley is expected during this period as barley was the base of nutrition in many BA societies. A sufficient barley yield is guaranteed, even during extremely bad years (Dörfler et al. 2011). Notably, the range of cultivated crops indicates a degree of crop diversity (polyculture), which is a common strategy to minimize crop failure and thus increase resilience to agricultural risks

such as drought (Marston, 2011). The storage of surplus crops is also evident, as a large-scale silo pit at the site used to store a substantial volume of cereal grains (Richter, 2016: 38). The accumulation of large quantities of staple products is a distinctive feature of Hittite Türkiye, with these products playing a crucial role in the political economy (Castellano, 2018: 278). Whilst the use of large grain storage facilities is believed to represent tax payments to the state, such storage would also mitigate against harvest failures (Dörfler et al. 2011: 113; Diffey et al. 2017: 11).

Archaeozoarchaeological evidence published from this region is also limited. The majority of zooarchaeological remains from Oymaağaç Höyük are from domestic cattle, smaller ruminates and pigs (Kunst and Böhm, 2016: 88). Notably, during the LBA, there is a dominance of sheep to goat with a ratio of 5:2 (Kunst and Böhm, 2016: 88). The ratio of sheep and goats to cattle can reflect drought sensitivity and risk management as caprine as sheep and goats can thrive with less water than cattle (Mace, 1993; Miller et al. 2009; Marston, 2017: 122). As stated by Miller et al. (2009), sheep and goats also produce different amounts and types of resources, with sheep generally yielding more meat of a slightly higher caloric value per individual, whilst goats provide milk for a longer period of time.

3.3.1.2. Western Türkiye

Before introducing the archaeological evidence of western Türkiye, it is important to highlight that there is a notable scarcity of well-excavated sites, with Troy and Beycesultan the predominant focus of archaeological research (Pavúk, 2015: 83). However, through archaeological survey, more sites in the region are being identified, such as Kaymakçı (e.g., Roosevelt et al. 2018).

In the LBA, western lands known as Arzawa were home to an array of political, social and cultural groups, with several kingdoms (e.g., Wilusa in the north and the Seha River Lands in the south) under the vassalage of the Hittite Empire (Bryce, 2011: 363; Mac Sweeney, 2018: 53; Aslan, 2019: 939). The western lands were never fully incorporated into the administrative systems or the cultural sphere of the Hittites, with sites and kingdoms generally maintaining their independence (Hawkins, 1998; Sagona and Zimanksy, 2009: 285). For example, Maša and Karkiša remained independent of Hittite control (Bryce, 2011: 374). Significantly, despite the vassal status of western lands, western states often took arms against the empire, threatening their territory (Bryce, 2011: 373-374).

During the LBA, the site of Troy was a powerful and prosperous settlement, as reflected by its size, fortification and large architectural structures (Aslan, 2019: 954; Grave et al. 2013). Significantly, as the site of Troy is comparable to a significant regional power during the LBA, a number of scholars have proposed that Troy was home to the kingdom of Wilusa (Easton et al. 2002). Monumentality and fortification can also be identified at the site of Kaymakçı, which Roosevelt and Luke (2017) propose is a likely candidate for the capital of the Seha River Land (Roosevelt et al. 2018: 681). The site of Beycesultan, located in a prominent position between the Aegean coast and the central plateau, also demonstrates prosperity and centralization during the LBA as evidenced by its LB architecture, social organization and the presence of elite goods (Lloyd, 1972; Mac Sweeney, 2010: 13). The import of luxury items such as metals, jewellery and ivory at this time also indicates the connection of the site to long-distance trade routes across the EM (Lloyd, 1972; Mellaart and Murray, 1995; Mac Sweeney, 2011: 70). Troy was also part of Aegean trade networks, as evidenced by a small quantity of Mycenaean ceramic imports and imported Aegean style jewellery, although the majority of finds at Troy were locally made (e.g., wheel-made Grey and Tan wares (Aslan, 2019).

Whilst there would have been instances when the Hittite Empire intervened in the region, there is little evidence of Hittite involvement or administrative control across the western lands in the LBA (Mac Sweeney, 2010: 8; Glatz, 2009). Notably classic signs of Hittite governance and influence (e.g., administrative systems, standardized pottery production) are absent across the region (Mellaart and Murray, 1995: 108; Seeher, 2005: 40; Glatz, 2009; Mac Sweeney, 2010: 8). Instead we see a high degree of micro-regionalism and diversity in culture and social practices during the LBA, reflecting the independence of western states and settlements (Mellaart and Murray, 1995: 105; Mountjoy, 1998; Bayne, 2000; Basedow, 2002; Cline, 2008; Mac Sweeney, 2010: 8). For example, LBA pottery at Beycesultan demonstrates strong local characteristics with indigenous styles (Mellaart and Murray, 1995; Mac Sweeney, 2010: 18).

Agricultural Conditions

Due to a lack of systematic archaeobotanical analysis, little is known about agricultural practices in this region, with few sites possessing botanical and faunal data (e.g., Troy and Kaymakçı) (Riehl, 1999; Marston et al. 2022). Before presenting the archaeobotanical and faunal evidence of Troy and Kaymakçı during LBA occupation, it is important to state that agricultural and subsistence strategies are thought to have differed across western Türkiye, as different settlements in different landscapes belonged to different polities and made

independent economic decisions (Marston et al. 2022). For example, Shin et al. (2021) suggest that the agricultural system of Kaymakçı operated with autonomy based on the diversity of agricultural strategies employed.

During the LBA, cultivation appears to have been intensive at Troy, with the same fields cultivated for long periods, as reflected by the life form of potential weeds (Riehl, 1999: 47). Notably, storage facilities can also be identified at the site which may indicate hedging in the case of food shortages or the control of surplus (Pavúk et al. 2014). At this time there was a specialization in the cultivation of emmer and einkorn wheat at Troy (Riehl, 1999: 44, 86). Bitter vetch, chickpea and small-seeded legumes were also abundant at Troy during the LBA, which suggests some degree of crop diversification to mitigate the risk of crop failure (Riehl, 1999: 45; Marston, 2011). Further south, the archaeobotanical assemblage of Kaymakçı demonstrates a diverse range of crops cultivated during the LBA, including barley (primary cereal crop), free-threshing wheat, emmer wheat, bitter vetch (primary pulse crop), chickpea, lentil, grass pea and grape (Roosevelt et al. 2018: 675; Shin et al. 2021).

During the LBA diverse animal husbandry practices were employed at Kaymakçı (Shin et al. 2021: 13). Domestic ruminants (sheep, goat and cattle) were abundant during LBA occupation, with the presence of older sheep and goat suggestive of a local wool industry (Roosevelt et al. 2018; Shin et al. 2021: 13). There is also a clear focus on pig husbandry, unlike other LBA sites across Türkiye, which suits the marshland environment of the site (Roosevelt et al. 2018; Marston et al. 2022; Slim et al. 2020). Additionally, there is also extensive use of wild animals (fish and deer) at the site (Shin et al. 2021: 13).

Together, the archaeobotanical data and faunal evidence from Kaymakçı suggest a diverse and extensive agricultural system during the LBA (Shin et al. 2021).

3.3.1.3. The Central Plateau

The North-Central Plateau

During the LBA the core region of the Hittites, known as the kingdom of Hatti, was located in the north-central plateau in the Upper Lands (Matessi, 2016). Until the beginning of the 13th century BCE, Hatti was home to the capital of the empire and one of the most important cities of the ancient Near East, Hattuša (Mielke, 2011a). The Upper Lands were also home to several provincial cities and small polities near trade routes and fertile agricultural land. Hittite sovereign practices appear to have been deeply embedded within the social, ritual and

economic landscapes of the central heartland (Glatz, 2020), with greater homogeneity seen in socio-political conditions compared to western Türkiye. Overwhelmingly, these sites display settlement features that indicate complex urban organization, a characteristic of the imperial state. Across sites such as Hattuša, Alaca Höyük, Çadır Höyük, and Uşaklı Höyük there is a substantial corpus of LBA monumental buildings. The architecture of these sites, for example, includes temple complexes, large grain storage facilities, public monuments, gate systems and fortifications (e.g., Mielke, 2011a; 2011b; Ross et al. 2019a; Mazzoni et al. 2019). At the capital of Hattuša, a palace complex can also be identified as the royal citadel (Mielke, 2011b: 162). Whilst it is difficult to estimate the size of LBA occupation at sites, the level of urban complexity and grand scale of architecture suggests that populations were likely substantial.

In the LBA, ceramics were largely mass-produced (Seeher, 2011). At this time, vessels were almost entirely wheel-made and undecorated (Seeher: 2011; Genz, 2003). At Gordion for example, LBA pottery is simple and standardized, suggesting that it was mass-produced by specialist potters (Henrickson, 1993; 1994; 1995; Henrickson and Blackman, 1996; Voigt, 2011). Whilst ceramic assemblages of the LBA are dominated by vessels typical of the empire, the presence of a range of different functional types and differentiated distribution of pottery inside settlements is understood to reflect the economic complexity of daily life in Hittite urban centres (Schoop, 2011: 267).

The South-Central Plateau

During the LBA, settlement was very large at the site of Türkmen-Karahöyük, a regional centre in the Konya plain (with a conservative estimate of 125 ha), quadrupling in size from the MBA (Osborne et al. 2020a). It is noteworthy that this is the only LBA site in central Türkiye whose size remotely compares with Hattuša (Glatz, 2009: 132-133; Mielke, 2011b: 183-184; Massa et al. 2020). Based on the substantial size of the site, it appears that it was a major urban centre on the Konya plains (Osborne et al. 2020a). Due to its size, it has been tentatively suggested that the site may have been the location of the city of Tarḫuntašša, which was briefly made the Hittite capital in the later decades of the empire (Massa et al. 2020). The presence of NCA ceramic forms, Eggshell Ware and Drab Ware also appears to support a direct connection of the site with the Hittite heartland (Osborne et al. 2020a).

Agricultural Conditions across the Central Plateau

During the empire period of the LBA large-scale production and storage of agricultural products was important across the Hittite heartland. For example, evidence of large grain

storage facilities has been identified at the sites of Hattuša, Alaca Höyük, Kuşaklı Höyük and Kaman-Kalehöyük (Seeher, 2000: 270-78; Seeher, 2006: 80-81; Çınaroğlu and Çelik, 2010: 276-77; Mielke, 2001; Mielke, 2011b: 176; Fairbairn and Omura, 2005). For a summary of these grain stores, see Diffey et al. (2017: 12) and Castellano (2018: 272).

In addition to the dominance of barley at Hittite sites, including Hattuša and Kuşaklı, the Hittites also cultivated several wheat species (e.g., einkorn, emmer, bread wheat) during the empire period, which is preferred for human consumption (Dörfler et al. 2011; Marston, 2012: 387). For example, barley and naked wheat were dominant crops at the site of Gordion (Marston, 2012: 387). A high ratio of bitter vetch to lentils is also evident in the LBA, which suggests increased sensitivity to the risk of drought and is thus indicative of a risk-minimizing agricultural strategy (Marston, 2012: 388).

Animal husbandry across the central plateau can be understood from the animal assemblages found at several sites, including Hattuša, Gordion, Çadır and Kaman-Kalehöyük. Caprinae were dominant at the site of Gordion during LBA, with a high ratio of sheep and goat to cattle, reflecting either environmental or economic conditions (Marston, 2017: 114). The higher ratio of caprine, which can thrive with less water than cattle, is suited for the semi-arid environment of the central plateau (Mace, 1993; Miller et al. 2009; Marston, 2017: 122, 134). The dominance of caprinae appears to indicate a more extensive agricultural system during the LBA in contrast to a more intensive agricultural system, which would instead see a high proportion of cattle and pigs (Miller et al. 2009: 919; Marston, 2017: 114). During the LBA, a high abundance of large cattle and oxen can be identified at the site of Çadır, which may reflect an increase in the status and wealth of the settlement within the Hittite realm, centralized provisioning of the settlement and/or intensification in local agricultural production (Steadman et al. 2017: 245; Ross et al. 2019b: 314).

3.3.1.4. Southern Türkiye

During the LBA, the Göksu River Valley provided an important long-term communication route between central Türkiye and the port of Ura on the EM coast of Türkiye, where the Hittite Empire had trading concerns (Lemaire 1993; Mac Sweeny and Şerifoğlu, 2017). The region was not densely settled during the LBA, with only one prominent site considered the key to our understanding of the valley, Kilise Tepe (Mac Sweeny and Şerifoğlu, 2017). This medium-small site is important as it possessed a local Hittite administrative function from at least the first half of the LBA through to the beginning of the EIA, as evident from the presence of Hittite

seals, hieroglyphic inscriptions of a type familiar from the late empire and symbolic use of artefacts in architectural contexts at the site (Postgate, 2007a; Postgate, 2008; Jackson and Postgate 2010: 424-425; Jackson et al. 2013: 7-8; Şerifoğlu et al. 2014; Bouthillier et al. 2014). The sites of Çingentepe and Attepe were also inhabited during LBA, providing evidence of typical Hittite pottery, reflective of Hittite cultural influence or the presence of a Hittite or Hittite-influenced administrative class living there (Postgate, 2007a; Mac Sweeney and Şerifoğlu, 2017). Ceramics associated with the Hittite Empire can also be identified at Kilise Tepe during the LBA, including fragments of drab ware and monochrome ware (Symington, 2001; Postgate, 2008).

Within the site of Kilise Tepe, the LBA is represented by a large administrative building (the Northwest building), associated with Hittite material culture and administrative practices (Blakeney, 2007; Postgate and Thomas, 2007; Postgate, 2007a; Jackson and Postgate, 2010: 424-425; Jackson et al. 2013: 7-8; Şerifoğlu et al. 2014). During the later stages of the empire, an architectural break can be seen when the Northwest building was succeeded by the Stele building, a rectangular, multi-roomed structure with a large square central space (Postgate, 2008; Bouthillier et al. 2014: 106). As stated by Postgate (2008), the Stele building likely had some degree of cultic function but also acted as a storehouse. In a more residential quarter of the site remains of solidly built LBA domestic houses were also identified on the western side of the mound.

Agricultural Conditions

Addressing the crop composition of LBA Kilise Tepe, a significant concentration of einkorn wheat appears to have been cultivated alongside other crops, including hulled barley, lentil and grape (Bouthillier et al. 2014: 131). Einkorn appears to have been an important crop at the site due to the large concentration of seeds (some 700) and the fact that it was the dominant glume wheat in the Stele building storage rooms (Bouthillier et al. 2014: 131; Bending and Colledge, 2007: 591). During the terminal LBA, there is a greater frequency of free-threshing wheat, possibly suggesting labour optimization (Karakaya and Riehl, 2019: 152). In addition to barley, lentil and grape, bitter vetch, grass pea, common pea, flax and olive have also been identified during this period (Bending and Colledge, 2007: 593). The presence of crops adapted to low water expense (e.g., bitter vetch and grass pea, alongside barley) indicates an element of risk management in subsistence strategy to prevent crop failures and to stabilize crop yields (Karakaya and Riehl, 2019: 152; Riehl, 2009).

At Kilise Tepe, sheep and goat make up the most frequent species identified at the site during the LBA, followed by cattle and pig (Baker, 2008; Bouthillier et al. 2014: 132). During the LBA the goat-to-sheep ratio was high at the site (3.2 goats to 1 sheep) (Bouthillier et al. 2014: 132). The presence of caprinae at the site would suggest the production of milk and wool (Baker, 2008: 421). There may have been a focus on plough animals for arable farming during the LBA as the age at death of cattle indicates that fewer juvenile to sub-adult animals were killed during this period (Baker, 2008: 423; Bouthillier et al. 2014: 132).

3.3.2. The End of the Bronze Age and Transition to the Early Iron Age

3.3.2.1. Northern Türkiye

Unfortunately, we still know very little about the EIA of northern Türkiye as the study of the region is still in its infancy (Şerifoğlu, 2015). Across Inner Paphlagonia, there is little evidence of settlement structures of the EIA but it is thought that there must have been settlements that are less archaeologically visible during the IA in the north. It is also likely that there may have been some degree of cave habitation as well (Şerifoğlu, 2015). Existing literature examining Inner Paphlagonia does, however, highlight that EIA presence and settlement is extremely scant (Matthews, 2009: 152).

During the EIA Oymaağaç substantially contracted in size and witnessed significant changes in architecture and ceramic production. For example, the architecture of EIA occupation at Oymaağaç significantly differs from that of the LBA, dominated by pits concentrated south of the temple, which had a primary function of storage (Hnila, 2019: 45). Additionally, in contrast to the wheelmade ceramics of the LBA, EIA ceramics found at the site were handmade (Yılmaz, 2012).

Agricultural Conditions

Into the EIA, the archaeobotanical assemblage at Oymaağaç indicates a predominance of barley, which is considered a drought-resistant crop (Rössner et al. 2019: 115; Riehl, 2009). Naked wheat, other types of wheat, millet and legumes (e.g., lentil, lentil vetch, pea, flat pea, and field bean) have also been identified at the site (Rössner et al. 2019: 115).

Caprine remains can be identified in EIA contexts at Oymaağaç (Kunst et al. 2016: 213). Wild mammals (e.g., equids and small mammals) can also identified, with a higher proportion and diversity than the preceding LBA, which may suggest that the economic basis of the site

became more diverse during the IA (Kunst and Böhm, 2016; Kunst and Böhm, 2019; Hongo, 1998).

3.3.2.2. Western Türkiye

The end of the LBA is marked by destruction at Troy and Beycesultan (Knapp and Manning, 2016: 127). However, not all sites in the west experienced conflagration. For example, there is no indication of destruction at the site of Kaymakçı (Roosevelt et al. 2018: 680). Additionally, some groups in this region, such as the state of Mira, are also thought to have maintained their strength and independence across the transition period (Mac Sweeney, 2010: 8). Whilst there was a period of low population at Troy (Troy IIIVb phase), Troy also appears to have been densely occupied during the 12th and 11th centuries BCE, likely continuing to serve as a regional centre (Aslan, 2019).

Whilst archaeological evidence from northwestern Türkiye in the EIA is still rather limited, it suggests that the EIA was generally not a populous time, with limited architecture and few tombs identified at Troy (Aslan, 2019). Into the EIA, Troy witnessed several socio-cultural changes, including the introduction of new building techniques, changes in settlement layout, and the appearance of new distinctive styles of handmade ceramics (e.g., handmade coarse ware) (Grave et al. 2013). Significantly, the introduction of new architectural features and new handmade ceramics has been thought to indicate a population movement from the north (Grave et al. 2013). For example, Rose (2014: 39) suggests that handmade wares at Troy were locally produced by migrants from Thrace. However, it is also important to highlight that there is some continuity in previous ceramic traditions (e.g., wheelmade Grey and Tan ware), and so whilst there is an influx of new traditions, there is also continuity in local knowledge (Hnila, 2012; Grave et al. 2013).

Agricultural Conditions

Intensive cultivation seen during the LBA at Troy also continues into the LBA-EIA transition as indicated by increased abundance of perennials, with an extension of arable fields into a previously uncultivated valley (Riehl, 1999: 44). During the terminal LBA-EIA barley and bitter vetch were the main crops (Riehl, 1999: 85). Lentils are also more abundant in this period alongside broomcorn millet, which is resistant to drought and grows well in poor soils (Riehl, 1999; Pavúk et al. 2014).

3.3.2.3. The Central Plateau

The North-Central Plateau

Following the demise of the Hittite Empire, there is a significant contraction in settlement size in the IA across the north-central plateau (Genz, 2011). Whilst the same Hittite sites are settled in the EIA, there does not appear to be any connection with the preceding Hittite period, instead, there is a partial return to older BA traditions (Genz, 2004). In contrast to the large urban cities and towns of the LBA, EIA occupation was largely reduced to small unfortified villages (Mora and d'Alfonso, 2012: 388; Genz, 2004; Henrickson and Voigt, 1998; Matsumura, 2008). This is, for example, particularly apparent at the sites of Hattuša and Gordion where the size of the sedentary population was significantly reduced following the transition. At Hattuša, EIA occupation was largely reduced to a small hamlet located on the hill of Büyükkaya, whilst at Gordion, EIA settlement was home to a relatively small-scale community that practised a household-scale economy (Genz, 2004, 7-10; Kealhofer et al. 2019; Henrickson and Voigt, 1998). At both sites, this population decline was likely caused by an exodus of the ruling class and BA/Hittite-affiliated population due to the moving of the capital, with new settlers arriving at the settlements at the beginning of the IA (Seeher, 2010; Voigt, 2011). Within these small settlements, buildings were largely limited to domestic dwellings and possible workshops (Seeher, 1997: 327-31; 1998: 235-39; Genz, 2004: 7-10; Voigt, 1994: 267-68; Steadman et al. 2015; Ross et al. 2019a; Omura, 1996: 93; 2000: 32; Matsumura, 2008). Notably, the limited extent of occupation and absence of urban complexity at the site is thought to indicate a dramatic transformation (Seeher, 2018; d'Alfonso et al. 2020: 16).

In the EIA, the post-Hittite ceramic repertoire found at sites is strikingly different, with the disappearance of the Hittite ceramic tradition (Genz, 2003; Genz and Mielke, 2011: 242). In contrast to the centralized mass-production of ceramics during the LBA, EIA vessels were generally handmade with more decoration, indicative of household production (Henrickson, 1993: 111-17; 1994: 106-108; Voigt, 2011; Ross et al. 2019a; Genz, 2003: 179; 2004: 24-26; Genz 2011: 346). Interestingly, at Kaman-Kalehöyük, wheel-made pottery continues to be produced into the EIA suggesting a degree of continuity in production (Matsumura, 2000: 126-127). Additionally, whilst the number of wheel-made vessels at Çadır dropped, they never entirely disappeared (Ross et al. 2019: 310). Whilst some wheel-thrown wares (31%) were still present in the earliest IA levels at Büyükkaya, the smoother surfaces of the pottery can be easily distinguished from rough textured Hittite wheel-thrown ware of the empire period (Seeher, 2010: 223).

The South-Central Plateau

In contrast to the clear transformation in socio-political conditions seen across the north-central plateau after the LBA, the transition is much less clear across south-central Türkiye. Importantly there is evidence for settlement and socioeconomic continuities at settlements across the LBA-EIA transition (Matessi et al. 2019; d'Alfonso et al. 2020). For example, IA occupation at Türkmen-Karahöyük remained at the extremely large extent that was seen during the preceding LBA, suggesting the persistence of the urban character of the settlement (Massa et al. 2020: 66). It must however be noted that occupation knowledge of the site draws on surface survey opposed to extensive excavation and thus further validation is still required through planned excavation. The site of Kınık Höyük in southern Cappadocia also demonstrates evidence of substantial EIA occupation and enduring urban infrastructure (d'Alfonso 2010: 36-38). For example, during the later EIA large-scale public infrastructures were built, whilst a fortification system was in use at the site until the 9th century BCE (d'Alfonso et al. 2020: 23; Matessi et al. 2019: 123-33; Massa et al. 2020: 66). Fortification in the IA appears to indicate a significant continuity in territorial organisation and political administration during the transition to the post-Hittite period at the site (Matessi et al. 2019: 132-33). Despite the large degree of continuity at the settlements of Türkmen-Karahöyük and Kınık Höyük following the transition, it is, however, also important to emphasize that there are still examples of notable changes experienced at other sites following the Hittite demise. During the EIA, several major LBA sites such as Domuzboğazlayan and Büyük Aşlama either declined in size or were abandoned (Massa et al. 2020: 67).

Agricultural Conditions across the Central Plateau

In contrast to the LBA, large-scale storage facilities are unattested during the EIA in central Türkiye, demonstrating an apparent lack of interest in centralized long-term accumulation of large quantities of staple products. Economic focus in the later IA in the region appears to have instead been placed on metallurgy and textile production (Castellano, 2018: 279).

During the EIA, cereal agriculture at Gordion favoured a higher ratio of barley to naked wheat, which indicates risk mitigation in crop management (Marston, 2017: 122). The high ratio of bitter vetch to lentil seen during the LBA also endures in the EIA, which demonstrates low-risk cultivation across the transition as vetch can provide good yields even under drought conditions, unlike lentils, which produce very low yields (Enneking 1995; Siddique et al. 1993; Marston, 2012: 388; Marston, 2017: 122). Interestingly, there is a rise in the absolute amount of einkorn during the EIA at Gordion, which is one of the least likely crops to be grown in a

period of increasing aridity due to its moisture requirements (Riehl, 2009). This increase has been proposed as a marker of Phrygian Iron Age culture and immigration due to the relative frequency of einkorn in south-east European contexts, which is the homeland of the Phrygians (Miller, 2010: 43; Marston, 2017: 274).

Caprine predominance is also seen into the EIA at Gordion (Zeder and Arter, 1994; Marston, 2017: 114-116). However, the proportion of sheep to goat decreases, which may reflect a degradation of the pasture area as goats require less water than sheep (Zeder and Arter, 1994: 113-114; MacKinnon, 2014: 221). There is also an increase in wild deer in the animal bone assemblage at the site during the EIA, indicating hunting during this period. For example, deer comprise nearly 6% of the total assemblage, which represents a significant contribution of meat to the diet (Marston, 2017: 116). A wide range of wild animals can also be identified in the EIA at Kaman-Kalehöyük (Hongo, 1998: 253), suggestive of an increased significance of hunting. In the EIA there is a decrease in the relative proportions of cattle at Çadır which may suggest a less significant investment of resources and due to their use in intensive agricultural labour, a less intensive agricultural system (Arbuckle, 2012; Ross et al. 2019a: 35). Continuity is however seen into the EIA in goat management, which is suggested by Ross et al. (2019b: 314) to perhaps reflect a conservative risk reduction strategy during the LBA and EIA periods. A reduction in the size of both sheep and cattle is also seen in EIA occupation levels at Hattuša and Kaman-Kalehöyük (von den Driesch and Pöllath, 2003: 29; Hongo, 2003: 265). The EIA at Kaman-Kalehöyük also witnesses an increase in the ratio of goat to sheep, which may, therefore, indicate deteriorating environmental conditions and poor pasture as goats require less water than sheep and tolerate lower quality pasture (Hongo, 1998: 253). Whilst an increase in pigs during the EIA would be expected across the region, as they are often associated with decentralised economies, pigs are the least common domesticate at most sites across both periods, which may indicate a preference against rearing pigs (Zeder, 2003).

3.3.2.4. Southern Türkiye

Into the IA, settlement numbers in the Göksu River Valley decline, with scant evidence of occupation (Şerifoğlu et al. 2014; Jackson and Postgate, 2010; Jackson et al. 2012). At Kilise Tepe, the general lack of IA remains may also be attributed to the poor quality of stratified IA levels (Postgate, 2008). Whilst evidence for IA occupation is quite limited, it does appear that occupation did continue into the first millennium BCE, although the population density of sites significantly declined. In contrast to the LBA, easily identifiable architectural remains are not present at the site during the EIA, except for another house structure with rooms and a

storage pit (Postgate and Thomas, 2007: 175-176; Postgate and Mac Sweeney, 2017). Storage pits, a fire installation and postholes thought to be EIA in date have also been identified at the site (Bouthillier et al. 2014: 124). As stated by Mac Sweeney and Şerifoğlu (2017), the lack of architectural remains during this period is seen as a good indication of a lifestyle change, as well as a decline in population following the LBA. The ceramic repertoire at the site also differs between LBA and IA occupation. For example, the use of homogenous ceramic wares of the empire ceased into the EIA, replaced by coarser localised hand-made wares with red-painted designs (Hansen and Postgate, 1999; Postgate, 2008).

Agricultural Conditions

In sampled IA levels, there is a degree of continuity in cereals also identified from LBA levels, though barley becomes a more prominent crop (Bouthillier et al. 2014: 131). Into the EIA, there is also a significant presence of einkorn, which indicates the enduring use of this crop at the site across the LBA-EIA (Bouthillier et al. 2014: 131). Interestingly, the cultivation of water-demanding, and thus drought-susceptible, field crops (e.g., free-threshing wheat, lentil, flax and einkorn) and arboricultural crops (e.g., grape, olive and fig) during the transition period and IA suggests that there was not a significant issue of water availability in the region (Karakaya and Riehl, 2019: 152). Significantly, the range of crops exploited at Kilise Tepe appears relatively consistent from the LBA to the EIA, with cereals (einkorn and hulled barley), pulses (lentils and grass pea) and fruits/tree products (olive, grape and fig). This temporal consistency may suggest agricultural continuity between occupation phases (Bending and Colledge, 2007: 594). In summary, it appears that the LBA-EIA populations of the site participated in a stable, broad-based plant economy with considerable diversity in exploited crop species (Bending and Colledge, 2007: 594).

Sheep and goat continue to dominate the zooarchaeological assemblage of Kilise Tepe during the terminal LBA and EIA, though the ratio of sheep and goat drops from 1.4 to 1 (Baker, 2008; Bouthillier et al. 2014: 132). During the terminal LBA and into the EIA, goats were killed off at a younger age, which may reflect environmental stress with inadequate resources for lactating females (Baker, 2008: 422). During the terminal LBA and EIA, the mortality profile of cattle indicates the continued use of cattle from the LBA for arable purposes (Baker, 2008: 423).

3.3.3. Summary of Late Bronze Age and Early Iron Age Socio-Cultural and Political Differences across Türkiye

As demonstrated above, there are a number of socio-cultural and political differences across Türkiye during the LBA and EIA. Notably, unlike the northern and western regions, the central plateau saw relative homogeneity in socio-political and cultural conditions during the LBA due to the direct influence and control of the Hittite Empire. During the LBA, sites across the plateau demonstrate complex urban organisation, with evidence of monumental architecture, including temple complexes and fortification. The Hittite heartland also saw the mass production of standardized wheelmade ceramics. Agricultural production was also intensive, as reflected by the presence of large grain silos at sites such as Hattuša and Kaman-Kalehöyük, demonstrating the centralization and storage of grain surplus. Hittite administrative and cultural influence can also be seen in the south, across the Göksu River Valley (e.g., at Kilise Tepe). For example, large administrative and cultic buildings and Hittite ceramics can be seen at Kilise Tepe.

In comparison to the central plateau and the Göksu River Valley, there is little evidence of Hittite influence during the LBA in the northern and western regions of Türkiye. Instead, these regions show greater diversity in social and cultural practices. During the LBA, there were few Hittite sites in northern Türkiye due to the region's restrictive topography. Sites demonstrating Hittite influence (e.g., monumental architecture and standardized Hittite pottery) include Oymaağaç Höyük and frontier sites further south. Notably, the region was also home to the semi-nomadic Kaška, who are thought to have lived in smaller and less archaeologically visible settlements. Whilst Oymaağaç Höyük, like other Hittite sites, shows evidence of intensive agricultural production as reflected by the presence of large grain storage facilities, the Kaška are thought to have likely engaged in both agriculture and pastoralism, with a range of crops grown, which may indicate agro-biodiversity and risk sensitivity. Despite its vassal status under the Hittites, western Türkiye also demonstrates little Hittite influence or control in the LBA. Significantly, a high degree of micro-regionalism can be seen in cultural practices across the western lands, reflecting their independence. Additionally, diverse crop production and animal husbandry can be seen at Kaymakçı, which is thought to indicate autonomy in agricultural decision making and production at the site. However, important settlements in the region (e.g., Troy, Beycesultan and Kaymakçı) do share some architectural similarities to Hittite sites (e.g., fortification).

At the end of the LBA and into the EIA, the central plateau saw significant socio-political transformation. Notably, the end of the LBA brought about the demise of the Hittite Empire and its control and influence over the region. Across the LBA-EIA transition, major settlement changes can be seen at sites including Hattuša and Gordion, which saw smaller occupation in the EIA. Significant architectural changes, from monumental buildings and fortification to more domestic dwellings can also be seen at sites, alongside the end of mass-produced ceramics, which suggests a change in material culture and lifeways. However, the production of wheelmade ceramics of the LBA is identified into the EIA at Kaman-Kalehöyük, reflecting some degree of production continuity. In the north and south, the Hittite sites of Oymağaç Höyük and Kilise Tepe also saw a significant contraction in size and occupation, as did Troy in western Türkiye. Additionally, these sites saw the introduction of coarser handmade ceramics during EIA occupation. However, at Troy, there is also some continuity in previous wheelmade ceramic traditions. Sites across Türkiye also appear to demonstrate several changes in crop cultivation and animal husbandry during EIA occupation. Significantly, sites show an increase in drought-resistant crops such as barley and bitter vetch. Additionally, grain storage facilities of the LBA also appear to have fallen out of use during the EIA. Caprine remains can also be identified at sites during the EIA, whilst several faunal assemblages also contain a number of wild mammals into the EIA.

However, socio-cultural differences can also be seen across the different areas of Türkiye in the EIA. For example, settlement differences can be seen between the north-central and south-central plateau across the LBA-EIA transition. Whilst the north-central plateau saw smaller village-like occupation of sites in the EIA Türkmen-Karahöyük and Kınık Höyük in the south-central plateau appear to have seen continuity in their size, occupation and urban infrastructure. Additionally, in western Türkiye, it is thought that some groups (e.g., the state of Mira) maintained their strength and independence across the transition.

Given the political and socio-cultural diversity across Türkiye during the LBA and EIA, as outlined in this chapter, it is clear that a one-size-fits-all view of the LBA-EIA should not be applied to Türkiye.

3.4. The Late Bronze Age-Early Iron Age Transition across the Western Aegean

A brief introduction to the societal conditions of the western Aegean during the LBA and EIA periods, as understood from well-excavated and well-published sites, is presented in this chapter. It is important to highlight that understanding of the LBA-EIA across the Aegean has been predominantly based on finds from highly visible archaeological sites, such as the

Mycenaean palaces (Dickinson, 2019: 44). As the leading settlements were largely inhabited by elite members of society opposed to the general population, understanding of everyday life in the LBA-EIA Aegean is skewed and only partial (Dickinson, 2019: 44; Meyer and Knapp, 2021; Shelmerdine and Bennet, 2008).

For a map of all western Aegean sites discussed below, see **Figure 21**.

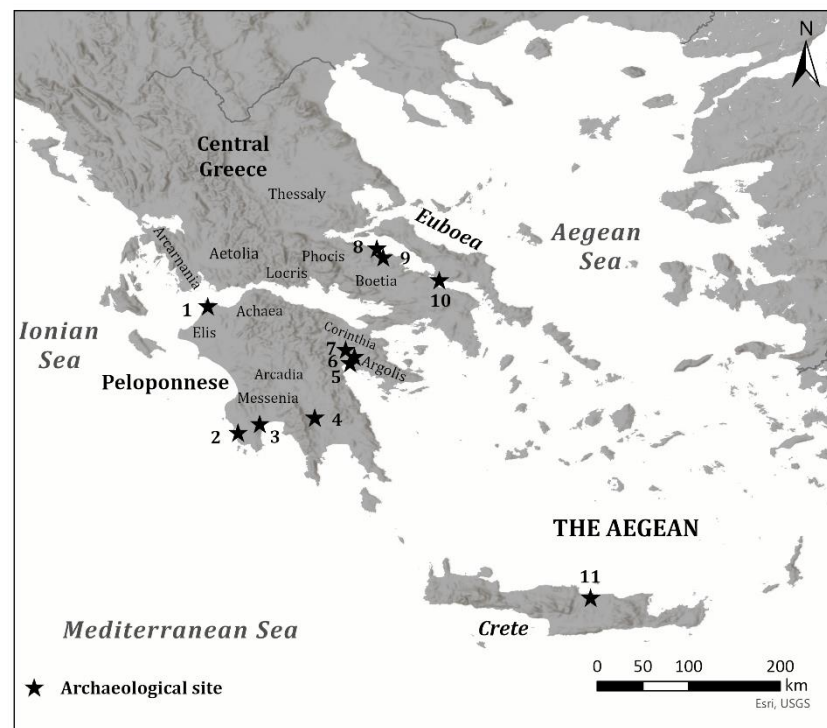


Figure 21. Map of Aegean archaeological sites mentioned in text. 1) Teichos Dymaion 2) Pylos 3) Nichoria 4) Menelaion 5) Tiryns 6) Midea 7) Mycenae 8) Kynos 9) Mitrou 10) Lefkandi 11) Knossos. Source: Author's original.

3.4.1. The Late Bronze Age

During the LBA, the Aegean world was home to the Mycenaean palatial system, which consisted of an intensely connected network of palace-centred polities (Shelmerdine and Bennet, 2008; Nakassis, 2022). At this time, palaces dominated the economic, cultural and political spheres across much of the LBA Aegean due to their power and influence, exerting control over important economic sectors, including areas of agriculture, as will be discussed further (Shelton, 2012; Maran and Wright, 2019: 114). Beyond their influence across the

Aegean, the palaces were also tied into the international trade and exchange networks of the wider EM region during the Late Helladic (LH III) period of the LBA (Maran and Wright, 2019: 116; Dickinson, 2012: 484; Deger-Jalkotzy, 1995: 370-374). Whilst the great centres of the Mycenaean civilization were situated across the mainland of the Peloponnese, within the Argolid and Messenian states, and central Greece, including Boeotia and Thessaly, Mycenaean influence was widespread throughout the region (Dickinson, 2006: 24). During the LBA Minoan Crete was also home to large palaces which managed economic activity over large areas (Bennet, 2007: 188). However, several areas across the region, including Achaea, Corinthia, Elis, Arcadia, and Aetolia, have not revealed any evidence of palatial centres (Middleton, 2020: 10). Instead, these regions may have continued to operate at the level of village-centred societies outside the control of any centre (Shelmerdine and Bennet, 2008: 289).

Leading Mycenaean settlements of this palatial period were substantial, with populations that likely reached the several thousands (Dickinson, 2006: 25). The most important settlements were also centred upon the palaces (Dickinson, 2006: 25). It is, however, important to highlight that whilst we can learn more about a period and the lives of everyday inhabitants from ordinary settlements opposed palaces etc., relatively little is known about the lower echelon sites which have traditionally been passed over by excavators in favour of larger settlements and palaces (Shelmerdine and Bennet, 2008: 308; Dickinson, 2019: 44). During the LBA the dominance of the palatial system is also reflected by the homogeneity and spread of Mycenaean material culture across the Aegean world, including parts of western Türkiye. For example, pictorial pottery, which appears to have been mass-produced, has been found across the Greek mainland as well as the Aegean islands (Mountjoy, 1993; Shelton, 2012: 145). Chamber-tomb cemeteries have also been found in areas peripheral to the palaces, as demonstrated at Phocis and Locris (Dickinson, 2006: 24).

It is important to note that whilst the LBA palatial period in the Aegean is generally regarded as a time of stability and prosperity, signs of decline can also be identified during the late 13th century BCE (Dickinson, 2006: 41; Deger-Jalkotzy, 2008). For example, increased investment in fortifications is seen at several sites, likely in response to the conditions of this period (Deger-Jalkotzy, 2008: 388). The decline of the palatial system also appears to be reflected by the reduced influence within the EM trade network (Dickinson, 2006: 41; Broodbank, 2013: 459-460).

Agricultural Conditions

Whilst our knowledge of Mycenaean agricultural production is predominantly based on speculation, documentary evidence suggests that the palaces were involved in several areas of agriculture during the LBA, including flax cultivation and cereal production (Pagnoux and Zurbach, 2020: 275). Due to palatial involvement, food production systems were likely relatively homogeneous during this time (Dibble and Finné, 2021). However, it is important to emphasize that the palaces did not maintain total control over food supply (Foxhall, 1995: 243). Agricultural regimes are thought to have been successful during the palatial period as large population and settlement numbers seen at this time would have required significant agricultural support (Bennet, 2007: 207). However, the agricultural basis of the palatial system may have been taken beyond its means through the overexploitation of arable land and soils, reflecting the decline of the palaces (Deger-Jalkotzy, 2008: 389). For example, wheat and barley are thought to have been of low quality and contaminated by weeds at several sites (Kroll, 1984; Deger-Jalkotzy, 2008: 389).

During the LBA, cereal assemblages of Aegean sites generally demonstrate diversified subsistence agriculture (Pagnoux and Zurbach, 2020: 276). For example, a variety of cereals, including several wheat species (einkorn, emmer, spelt and free-threshing wheat) and legumes, including lentil and bitter vetch, were cultivated in this period (Megaloudi, 2006; Shelmerdine and Bennet, 2008: 309).

Linear B texts highlight the palatial provision of cattle for traction during the palatial period of the LBA (Halstead, 1999). For example, at Knossos, there is evidence for the palatial provision of plough cattle to increase grain production (Bennet, 2007: 207). The palaces also appear to have invested in sheep for their wool during the LBA, demonstrating palatial involvement in textile manufacture (Halstead, 1993; 1999). Pigs were also present at LBA sites such as Pylos (Halstead, 1993; Slim et al. 2020). In contrast to Mycenaean sites, subsistence in the northern Aegean differed, relying on wild animals and mixed animal husbandry, including pigs (Slim et al. 2020).

3.4.2. The End of the Bronze Age and Transition to the Early Iron Age

As will be presented below, societal conditions across the western Aegean at the end of the LBA and transition into the EIA are predominantly understood from settlement changes, including the decline in settlement size and the destruction and abandonment of important sites, including the palaces, in addition to changes in the material culture (e.g., burial traditions

and the loss of palatial features of the LBA such as monumental architecture). It is, however, important to state that the apparent decline in settlement size and population numbers from the end of the LBA into the EIA is based on the comparison of easily recognisable LBA sites versus poorly recognisable EIA settlements (Dickinson, 2019: 43-44).

Around ca. 1200 BCE, the Mycenaean palatial system of the Aegean LBA (LH IIIB and LM IIIB, see 2.4.3) came to a dramatic end, following the destruction and abandonment of several sites, including the palaces (e.g., Tiryns, Pylos, Mycenae) and several non-palatial sites, (e.g., Menelaion, Teichos Dymaion) across the region (Dickinson, 2006; Deger-Jalkotsky, 2008; Dickinson, 2012; Eder and Lemos, 2019). Following the end of the palatial system, former palatial regions also notably saw the disappearance of a consolidated hierarchy, which was replaced by a less stable political order of small and powerful competing groups (Maran and Wright, 2019: 117; Eder and Lemos, 2019: 136). The end of the Mycenaean palatial system also significantly saw the loss of complex political, social and economic organization and palatial traditions which had characterized the palatial period, including monumental architecture and the use of the writing system Linear B (Deger-Jalkotsky, 2008; Cunningham, 2017; Georgiadis, 2020: 65; Dickinson, 2006).

Whilst the demise of the palatial period resulted in a fundamental transformation of the Aegean way of life, with significant changes in social organization, demography and economy, the Aegean LBA did not come to an end (Deger-Jalkotzy, 2008: 403). The subsequent postpalatial period (LH IIIC) has often been conflated with the EIA, though as stated by Eder and Lemos (2019: 133), this masks the variety of processes which took place during this lengthy sub-period of over 100 years. The demise of the Mycenaean palaces would have immediately affected everyday conditions across the region as societal conditions would have been shaped by palatial experiences (Eder and Lemos, 2019: 134). However, the region also witnessed diverse regional societal conditions and societal trajectories as summarized below (Dickinson, 2019: 38; Deger-Jalkotzy, 1991; 2008; Dickinson 2006: 67-76; Maran and Wright, 2019: 117; Middleton, 2020: 12). Whilst palatial sites including Midea and Tiryns were reoccupied, occupation was modest, with smaller village-like communities (Deger-Jalkotzy, 2008: 403). In contrast, several sites in areas which had been devoid of palaces generally do not appear to have suffered around 1200 BCE. For example, across the Euboean Gulf, several coastal sites, including Lefkandi, Kynos, and Mitrou, were densely inhabited during LH IIIC and maintained their importance into the EIA, which is likely due to their position in relation to

maritime exchange routes (Thomatos 2006: 252-260; Lemos, 2012; Maran and Wright, 2019: 119).

By the end of the 11th century BCE, significant changes in settlement patterns and material culture can be seen, marking the end of the Aegean LBA and the start of the EIA. For example, most Aegean sites appear to have been abandoned (Dickinson, 2006; Deger-Jalkotzy, 2008). Dickinson (2012: 487) also states that there is not a single site across Laconia and Achaia that presents evidence of EIA occupation. Settlements also declined in the eastern regions of the Peloponnese, such as the Argolid (Deger-Jalkotzy, 2008). Whilst some continuity in Mycenaean material culture could be seen across the postpalatial period into the 11th century BCE, little can be recognized as Mycenaean (Shelton, 2012: 146). For example, from the LH IIIC onwards, there was more of a marked preference for single burial, replacing the chamber tombs of the palatial period (Morgan, 2009: 44).

In contrast to the decline seen on the Greek mainland, multiple sites across Crete demonstrate evidence of prosperity and overseas contact into the EIA (Dickinson, 2012: 487). Evidence of settlement continuity can also be identified across the LBA-EIA in more peripheral, non-palatial areas of the Aegean. For example, settlements and cemeteries of central and northern Greece remained in use beyond the transition from the Mycenaean era to the EIA (Deger-Jalkotzy, 2008). Some sites also appear to have grown and flourished in the EIA, such as Lefkandi, whose EIA occupation appears to be substantially larger than its LBA predecessor (Foxhall, 1995: 246).

Agricultural Conditions

Whilst Mycenaean agriculture has been well studied, agricultural conditions of the EIA have received little attention due to the relative scarcity of archaeobotanical evidence and lack of written evidence (Pagnoux and Zurbach, 2020: 275). However, the demise of the Aegean palatial system is understood to have had important effects on agrarian systems (Pagnoux and Zurbach, 2020: 281). For example, this period saw the end of production strategies that demanded high labour or capital inputs (Foxhall, 1995: 248). The end of palatial agricultural involvement and intensive land exploitation is also thought to have led to the recovery of the natural environment, as evidenced by an improved quality of grains (Kroll, 1984; Deger-Jalkotzy, 2008: 406). However, it is also important to state that dramatic changes do not appear to have taken place at the levels of local settlements and small-scale farmers, who had been liberated from palatial economies and thus were able to retain their products and surplus (Foxhall, 1995: 250; Eder and Lemos, 2019: 138).

Generally, there is broad continuity in the range of crops grown across the region between the LBA and EIA. For example, the archaeobotanical evidence at sites such as Nichoria is not drastically different from those grown in the LBA (Foxhall, 1995: 248). For example, hulled barley is present across the LBA and EIA. However, the frequency of less water-demanding crops does increase at sites following the palatial period. Notably, barley became the most frequent cereal at the end of the BA in Greece (Pagnoux and Zurbach, 2020: 274). Emmer and einkorn, which can both withstand dry summers also become the most common wheat species at this time. Einkorn can grow on poorer soils and under colder conditions, whilst Emmer may have been cultivated as a summer crop to avoid crop failure during a hard winter, as it can be sowed in both winter and spring (Pagnoux and Zurbach, 2020: 274). Additionally, new cereal species were also introduced across the Aegean at the end of the LBA, including spelt, common millet and foxtail millet, which may indicate risk-averse cultivation (Pagnoux and Zurbach, 2020: 274). As summarized by Pagnoux and Zurbach (2020: 274), the short growing cycles of common millet and foxtail millet allows some flexibility in sowing time and allow a crop yield. Common millet also has a wide range of adaptations to different climates and soils (Pagnoux and Zurbach, 2020: 274).

Changes can also be seen in animal husbandry at the end of the LBA. For example, the appearance of cattle herding can be seen following the end of the palatial period (Wallace, 2020: 252). Dibble and Finné (2021) also highlight that faunal records indicate a proportional increase in goats in areas with less rainfall into the IA, which was likely an adaptive response to drier climatic conditions.

3.5. The Late Bronze Age-Early Iron Age Transition across the Levant

During the LBA, the Levantine mainland, extending from the Amuq plains of southern Türkiye in the north to the Sinai Peninsula in the south, acted as an important corridor between Türkiye, Egypt and Mesopotamia (Manolova, 2019: 1185). At this time, both the Egyptian and Hittite Empires sought to control and influence the region, which offered desirable goods, such as olive oil, and provided important trade routes (Manolova, 2019: 1186; Van De Mieroop, 2016: 174). In contrast to the mainland, politico-economic organization in LBA Cyprus was not under the control of the Egyptian or Hittite states.

Due to the diversity of socio-political and cultural conditions across the Levant, as will be introduced below, the LBA-EIA archaeology of the Levantine mainland (northern and southern

Levant) will be examined separately from Cyprus. All Levantine sites mentioned below can be seen in **Figure 22**.

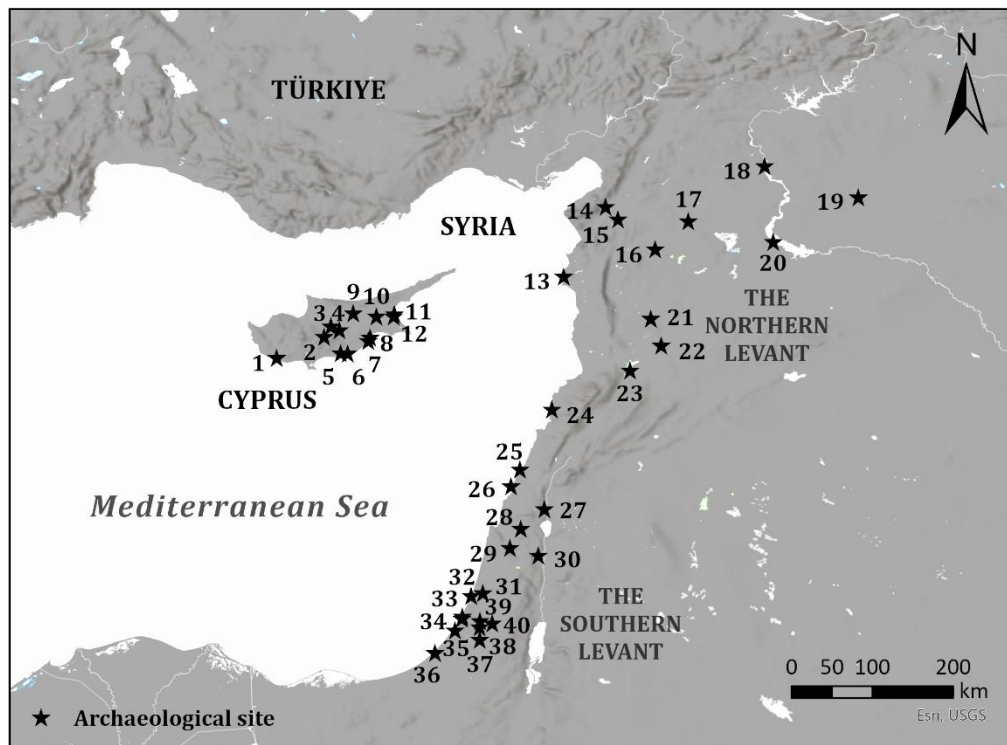


Figure 22. Map of Levantine archaeological sites mentioned in text. 1) Palaepaphos 2) Apliki 3) Arediou 4) Analiontas 5) Kalavassos 6) Maroni 7) Hala Sultan Tekke 8) Kition 9) Palioklichia 10) Sinda 11) Salamis 12) Enkomi 13) Ugarit 14) Tell Tayinat 15) Tell Atchana 16) Tell Afis 17) Aleppo 18) Carchemish 19) Hamman et-Turkman 20) Emar 21) Hamath 22) Qatna 23) Qadesh 24) Byblos 25) Sarepta 26) Tyre 27) Hazor 28) Tell el Wawiyat 29) Megiddo 30) Beth shean 31) Aphek 32) Jaffa 33) Tel Mor 34) Ashdod 35) Ashkelon 36) Deir El-Balah 37) Lachish 38) Tel es Safi/Gath 39) Tel Miqne/Ekron 40) Beth Shemesh. Source: Author's original.

3.5.1. The Late Bronze Age

3.5.1.1. The Northern Levant

During the LBA, city-states and kingdoms of Syria in the northern Levant, such as Ugarit, Qatna and Qadesh, appear to have been politically subordinate to Hittite kings (Luciani, 2014; Bryce, 2005: 48). At this time, the site of Carchemish on the Euphrates acted as a key location in the

empire's control of the region, as it served as the seat of the Hittite viceroy in Syria (Bryce, 2005; Liverani, 2014; Hawkins and Weeden, 2016). Further south, the city-states of the Lebanese LBA were under the control and rule of New Kingdom Egypt (Heinz and Kulemann-Ossen, 2014). During the LBA, the economic organization of northern Levantine kingdoms was based on palaces, with economic activities focussed on the trade and craftsmanship of bronze and textiles (Pfalzner; Liverani, 2014: 329; Akkermans and Schwartz, 2003: 352). Due to the trade focus of the region, several important sites were located along the northern Levantine coast, such as the port kingdom of Ugarit, which was a major centre of LBA trade and culture under the control of the Hittite administration, as well as the harbour cities such as Byblos and Tyre (Pfalzner, 2012). Whilst the Hittites dictated much of the northern Levant's politics, there is little direct evidence of Hittite presence in the region (Casana, 2017: 159). Most forms of material culture during LBA occupation, such as ceramics, were distinctly localised in style and character (Casana, 2017: 159, 169). Imported painted wares from neighbouring areas, including the Aegean, Cyprus and Mesopotamia, are also prominent across Levantine assemblages (Casana, 2017: 168).

In the LBA, the northern Levantine coastal and inland plains were densely occupied (Casana, 2017: 169). Much of our understanding of LBA settlement comes from urban centres, which display features such as fortification, as in the case of Lebanese sites (Heinz and Kulemann-Ossen, 2014). Key sites across Syria also reflect the centrality of the palace system, as attested by monumental architecture at sites such as Qatna (Luciani, 2014). Whilst urban sites are important, the archaeology of the region suggests that most of the population lived in smaller villages in the countryside, supporting the larger cities by providing subsistence and other services (Luciani, 2014; Heinz and Kulemann-Ossen, 2014).

3.5.1.2. The Southern Levant

During the LBA, the small and diverse city-states of the southern Levant were largely under the domination of the Egyptian Empire, which granted Egypt the political and economic control of important and strategic trade routes of the period (Killebrew, 2005: 32; Manolova, 2019: 1186). Despite the region's vassal status, the southern Levant still possessed some autonomy within the international trade network (Panitz-Cohen, 2014: 549; Manolova, 2019: 1186). At this time, a host of important centres, including Jaffa, Tel Mor and Ashdod, which were clustered along the southern Levantine coastline, appear to have flourished due to their active engagement in the EM trade network (Manolova, 2019: 1187).

Settlements of the LBA were smaller than those of the Middle Bronze Age, with urbanism also experienced on a smaller scale (Panitz-Cohen, 2014: 545). For example, evidence for monumental architecture and fortification appears to have declined into the LBA (Gonen, 1984; 1992a; London, 1989; Panitz-Cohen, 2014). Major centers, including Megiddo, also appear to have been unfortified during the LBA (Stern, 2016: 167; Manolova, 2019). During the LBA, the rural sector of the population became increasingly influential alongside the small yet important urban centers (Bunimovitz, 1995: 324; Falconer, 1994: 329; Panitz-Cohen, 2014: 545). Egyptian presence in the southern Levant is seen at numerous sites, such as Beth Shean and Deir El-Balah, as reflected in the material culture, which shows Egyptian influence (Panitz-Cohen, 2014: 548). For example, Egyptian administrative buildings and temples are evident at sites such as Tel Mor, Aphek, Beth Shean and Lachish (Killebrew, 2005: 11; Mumford, 2014: 77-78). Locally produced Egyptian-style ceramic assemblages and Egyptian-style burial customs are also evidenced at sites such as Deir el-Balah (Killebrew, 2005: 65). Despite the intensity of Egyptian presence during the LBA, the landscape of the southern Levant was also politically fragmented and socio-economically disparate, as Egypt's imperial reach was far from uniform (Panitz-Cohen, 2014: 552; Manolova, 2019: 1186). Direct Egyptian control was limited to a few garrisons, such as Deir el-Balah and Jaffa, with vassal city-states across the region retaining significant autonomy and self-governance (Manolova, 2019: 1186). Whilst a relatively homogeneous LBA material culture, particularly ceramics, reflects the influence of Egyptian imperialist policy, there is also evidence of regional differences in cultural traditions across the region (Gonen, 1992b; Panitz-Cohen, 2014).

3.5.1.3. Cyprus

In the LBA, the political landscape of Cyprus comprised a series of largely autonomous regional polities whose administrative patterns varied, and territorial grounds diverged (Georgiou, 2015: 130-131). During this period, Cyprus played an important role in EM trade through copper production (Steel, 2014). To support copper production, several large urban centres, including Enkomi, Kition, and Hala Sultan Tekke, developed along the southern and eastern coasts of the island during the LBA (Georgiou, 2017; Steel, 2014; Sherratt, 2014). Whilst no palaces are currently known to have existed across the LBA, several buildings of monumental size and design are evident at urban centres, including temples at sites such as Kition (Sherratt, 2014: 503). Alongside important urban centres of the period, some village sites, such as Analiontas and Arediou, located in the Cypriot hinterland, functioned as centres of agricultural production, supporting the population of these urban centres and sustaining the complex

economic activity of the LBA (Webb and Frankel, 1994; Steel, 2009; Steel, 2014: 581; Georgiou, 2017).

3.5.1.4. Agricultural Conditions across the Levant

During the LBA, agriculture of the northern and southern Levant was integrated into the palatial economies of vassal city-states and kingdoms (Kamlah and Riehl, 2020). Whilst agricultural outputs varied across the Levant, the cultivation of olive at northern Levantine sites and grape in the south offered desirable products of olive oil and wine to the Hittite and Egyptian Empires (Sherratt, 2014; Kamlah and Riehl, 2020). To maintain the local and regional networks of palatial centres and the overruling Hittite and Egyptian Empires the production of agricultural surplus would have been critical (Karakaya and Riehl, 2019; Kamlah and Riehl, 2020). Vermeersch et al. (2021) suggest that agricultural products of the southern Levant likely constituted an important part of tributes during this period of Egyptian hegemony. For example, the cultivation of grape at sites such as Aphek and Qubur el-Waleide may point to agricultural surplus production within an Egyptian tribute system and wine deliveries from Canaan to Egypt (Vermeersch et al. 2021). Like its neighbours, agricultural production is also thought to have been intensive across LBA Cyprus (Lucas, 2014). Due to the external contact of Cyprus and the rest of the EM, the resulting intensification of copper production in the 13th century BCE is understood to have led to the intensification of agricultural production (Webb and Frankel, 1994). Intensive agricultural production is exemplified by large storage capacities at some sites. For example, at House A at the mining settlement of Apliki, there is evidence of storage capacity beyond its immediate storage requirements (Webb and Frankel, 1994). At the site of Palioklichia which is thought to have functioned as an agricultural support village, there is also evidence for the collection and processing of surplus to distribute to mining communities (Webb and Frankel, 1994). Whilst the purpose of grain storage at sites such as Palioklichia is thought to have been for the regional distribution of grain to support the political economy of Cyprus (Webb and Frankel, 1994), the storage of surplus grain may also mitigate against poor harvests during bad years.

Palatial control of agricultural production across the northern and southern Levant in the LBA is understood to have focussed on the cultivation of a limited number of crops (Karakaya and Riehl, 2019). The most prominent cereal found at sites across the Levantine region was barley (Karakaya and Riehl, 2019: 151-152). Bitter vetch and grass pea/red vetchling, which are well-adapted to poor soil conditions and low water expense, are also found in archaeobotanical assemblages (Karakaya and Riehl, 2019: 152). However, across the southern Levant, free-

threshing wheat, which is a water-demanding crop, was also ubiquitous in LBA crop assemblages, appearing to show higher proportions than barley at LBA sites as Beth Shean, Tel Aphek (Karakaya and Riehl, 2019). A higher proportion of free-threshing wheat is also found at sites located in the north Orontes Valley, such as Tell Atchna and Tell Tayinat, which receive higher rainfall amounts (Karakaya and Riehl, 2019: 143). Whilst archaeobotanical data from LBA Cyprus is rather limited, the data that we do have appears to indicate varietal diversification of the crop assemblage, which is significant as it suggests a degree of agro-biodiversity and, as such, higher resilience (Lucas, 2012; Altieri et al. 2015). As summarized by Kofel et al. (2021), the most common plant macroremains identified at Late Cypriot sites (e.g., Hala-Sultan Tekke) are various forms of barley, different species of wheat, fig, lentils, common grape vine, olive and almond.

In the LBA, the animal economy of the Levant was predominantly based on sheep, goats and cattle, with sheep and goat husbandry focussed on meat, milk and wool production, whilst cattle could provide traction power for crop cultivation (Akkermans and Schwartz, 2003: 353; Sapir-Hen et al. 2014: 712; Knapp 2013: 398-399). In addition to the presence of domesticates, faunal remains of wild mammals (e.g., deer, gazelle, horses, donkeys) can also be identified at several Levantine sites such as Lachish and Aphek, with several animals holding a symbolic societal role (Knapp, 2013: 398-399; Sapir-Hen, 2022).

3.5.2. The End of the Bronze Age and Transition to the Early Iron Age

As will be summarized below, archaeological understanding of Levantine societal conditions during the LBA-EIA is based on evidence of settlement changes, including destructions and abandonments across the Levant and changes in material culture, notably in burial traditions and the loss of palatial features such as monumental architecture.

3.5.2.1. The Northern Levant

Whilst the EIA is still poorly documented across the northern Levant, it has traditionally been understood that the end of the LBA brought about socio-political disintegration across the region. Notably, the end of the LBA saw the destruction and abandonment of several major urban centres (e.g., Ugarit and Emar) and regional centres (e.g., Alalakah, Hamman et-Turkman and Tel Brak) (Akkermans and Schwartz, 2003: 358). The end of the LBA also significantly saw the end of Hittite and Egyptian control of the region, as well as the demise of palace-centred economies (Killebrew, 2014; Akkermans and Schwartz, 2003: 361). Significantly, the demise of the Hittite state brought about regional instability across the

northern Levant (Harrison, 2009: 187; Knapp and Manning, 2016: 127). During the EIA, the political landscape of the Levant was fragmented between an assortment of small states and kingdoms such as Tabal and Gurgum (Harrison, 2009; Harrison, 2021: 326; Knapp and Manning, 2016: 127; Osborne, 2020b).

A number of small rural settlements have been identified in the EIA through excavation and survey (e.g., across the Amuq Plain and Beqa Valley) (Sader, 2014). As summarized by Sader (2014), the rural character of sites can be identified by the absence of public buildings. These settlements are instead characterized by domestic dwellings. During the EIA, new cultural practices are introduced, as identified by the emergence of painted pottery and cremation as a burial practice into the EIA, which may indicate the arrival of foreign groups or the adoption of foreign traditions by local populations (Sader, 2014: 619).

Notably, the events of the terminal LBA did not have a uniform impact across the northern Levant, as sites experienced different fates during the transition into the IA (Sader, 2014). Alongside evidence of socio-political changes, the archaeological record also indicates that some LBA societal and cultural features, such as settlement patterns and elements of material culture, continued into the IA (Mazzoni, 2000: 31). For example, survey data from the North Orontes Valley survey indicates significant levels of settlement continuity during the LBA-EIA transition (Harrison, 2009: 187). Hittite imperial control also appears to have survived to some degree at key sites of LBA Hittite power, such as Carchemish (Harrison, 2009: 187; Hawkins, 2009: 164). Several Syrian sites also present evidence for continuity in BA tradition and Hittite influence in the form of monumental religious architecture, as reflected by the IA temples at Aleppo and Tell Afis (Sader, 2014: 615). Some large Syrian centres, such as Hamath, and important sites located along the Lebanese coast, such as Tyre and Sarepta, also saw continuity in occupation into the IA (Akkermans and Schwartz, 2003: 361; 386). Additionally, as stated by Mazzoni (2000: 31), with the exception of Ugarit, Alalakah and Ekar, most settlements appear to have recovered from the events of the terminal LBA. Into the EIA, the location and size of most LBA towns and cities remained largely unchanged, which suggests a resiliency whereby settlement decisions were not linked to the elite but were instead linked to more local traditions of land tenure and agricultural subsistence (Casana, 2013: 120).

3.5.2.2. The Southern Levant

At the end of the LBA, the southern Levant also witnessed the destruction and abandonment of important LBA sites, including Hazor, Lachish and Megiddo (Knapp and Manning, 2016: 130;

Millek, 2018). Into the IA, the region witnessed the decline and retreat of Egypt from its LBA territory and the subsequent collapse of the Egypto-Canaanite city-state system (Killebrew, 2014: 599; Finkelstein, 2003: 75). With the loss of this imperial power came the end of the extensive economic networks in which the southern Levant participated during the LBA (Harrison, 2012: 644-645). The retreat of Egypt profoundly transformed the societal and cultural landscape of the southern Levant after the region was freed from imperial control (Killebrew, 2005: 83). This reversion to a diverse and fragmented landscape appears to have encouraged the decline of most LBA city-states and the construction of new urban centers (Killebrew, 2005: 83). Unsurprisingly a rather dramatic shift in settlement pattern is therefore seen across much of the region in the EIA. For example, some partially destroyed LBA coastal sites such as Ashdod, Tel Miqne/Ekron, Tell es-Safi/Gath and Ashkelon were replaced with new settlements and witnessed a change in the material culture, including a new dominating Aegean style of ceramics (Cline, 2014: 122; Killebrew, 2014: 599). Traditionally, these changes have been interpreted to indicate the influx of a new population known as the Philistines (Knapp and Manning, 2016). The archaeology of the EIA reveals a decline in the number of settlements across areas such as the southern coastal plain and the Shephelah and a shift towards smaller, rural settlements (Gilboa, 2014). Further inland, however, across the more marginal central hills of the region, the EIA saw significant growth in small agricultural villages (Killebrew, 2005: 97; Greenberg, 2019: 343). In some areas, a decline in the material culture of Levantine areas is also evident, as reflected by the absence of LBA prestige items such as ivory and glass vessels (Gilboa, 2014: 634).

Despite the traditional focus on widespread decline throughout the southern Levant, the archaeological record suggests that the fate of southern Levantine sites varied (Gilboa, 2014; Killebrew, 2014). For example, alongside the evidence for destruction and instability, the archaeology of the EIA southern Levant also presents evidence of continuity from the LBA (Killebrew, 2005: 97; Killebrew, 2014). For example, settlement continuity can be seen at rural settlements of Lower Galilee, such as Tell el Wawiyat, which indicates clear demographic and cultural continuity across the transition (Dessel, 1999; Finkelstein, 2005: 15). It is also important to highlight that the retreat of Egypt was not sudden or dramatic, rather it was a prolonged and gradual decline over the course of approximately 100 years (Millek, 2021: 255). Therefore, several sites across the region such as Deir el-Balah and Aphek continued to serve as administrative centers well into the 12th century BCE (Killebrew, 2005; Killebrew, 2014: 599). LBA ceramic traditions also continued across the region, as evidenced at sites like Beth Shemesh (Bunimovitz and Lederman, 2011; Killebrew, 2014).

3.5.2.3. Cyprus

Due to a relative lack of material evidence and the scholarly focus on the preceding LBA, understanding of the EIA has been rather obscure (Meyer and Knapp, 2021: 433). Like its EM neighbours, Cyprus also experienced destruction and abandonment events across the 13th and 12th centuries BCE. A host of sites, such as Hala Sultan Tekke, Palaeopaphos, and Sinda, are understood to have suffered destruction, whilst many sites were abandoned (e.g., Kalavassos and Maroni) (Karageorghis, 1992). These events, and those that occurred across the wider EM, substantially impacted the island (Iacovou, 2013: 25-27; Georgiou, 2017). For example, demand for Cypriot copper declined, which impeded economic activity (Knapp, 1997: 68; Georgiou, 2015). As a result of this economic decline, the island also saw a reduction in the number of urban centres across the island (Iacovou, 2007: 17; Georgiou, 2015: 131). The transition to the 12th Century BCE was characterized by substantial transformation in the island's material culture, reflecting the disruption to the social order of Cyprus at the end of LC II (Georgiou, 2017; Steel, 2014). For example, notable changes can be seen within ceramic production and burial practice, such as the introduction of new handmade pottery and cremation (Steel, 2014: 584).

However, the events of the 13-12th centuries BCE do not appear to have as been as devastating for Cyprus compared to other areas of the EM (Georgiou, 2017). As Cyprus was not under the control of a strong central state, a uniform impact of these events was not felt across the island (Georgiou, 2015; 2017). Whilst some sites experienced total abandonment, others experienced survival and relocation, as at Enkomi, and continuity and prosperity, as at Kition and Palaeopaphos (Karageorghis, 1992; Iacovou, 2013: 26). Significantly, into the 12th century BCE state functions were kept alive as the Cypriot polities that did survive into the 12th Century BCE exercised the same economic and political activities as before, such as trading copper (Cadogan, 1998: 13; Georgiou, 2015: 132). Despite losing access to certain overseas markets following the crisis events, trade with Cilicia and the Levant continued into the 12th century BCE, whilst commercial relations with the Aegean and the central Mediterranean increased (Gilboa, 1989; 2005; Sherratt, 1999; Knapp, 1990; Voskos and Knapp, 2008: 673). Several polities of Palaepaphos and Kition also appear to have flourished in the 12th century BCE, as reflected by the monumental expansion of urban structures (Georgiou, 2017: 210).

Into the EIA, Cyprus experienced a major shift in settlement pattern, reflected by the final abandonment of LBA sites at the end of the 12th Century BCE, such as Hala Sultan Tekke, and the emergence of new centres which developed into IA city kingdoms (Iacovou, 1994; Steel,

2014: 587). However, alongside the establishment of new towns and cemeteries such as Salamis, some LBA centres, such as Kition, survived the LBA (Voskos and Knapp, 2008; Iacovou, 1994; Iacovou, 2014: 662). In the EIA, several differences between LBA and EIA material culture can also be identified. For example, the EIA saw the end of shaft graves, which had characterized the 12th century BCE, as well as intra muros chamber tombs (Iacovou, 2014: 668). The Cypriot EIA also saw the introduction of a new ceramic tradition of Proto-White Painted Ware, which reflects a complete transformation in the island's ceramic industry (Iacovou, 1988; Steel, 2014: 579, 587).

3.5.2.4. Agricultural Conditions across the Levant

As suggested by Karakaya and Riehl (2019: 155), the breakdown of old palatial regimes and palatial economies of the Levant at the end of the LBA may have led to a period of emancipation into the IA, with local farmers freed from the economic ties and former obligations to those who governed them. The absence of uniformity in animal husbandry strategy across the southern Levant also suggests a lack of state-level integration within agricultural production (Sapir-Hen et al. 2014: 715). It, therefore, appears that in contrast to the LBA, agropastoral strategies of the EIA prioritized needs for food and materials at the settlement level (Porter, 2016: 388-389).

In the IA, continuity can be seen in the range of crops cultivated across the northern and southern Levant (Karakaya and Riehl, 2019: 152). For example, silos at Iron I sites in the highlands of the Levant suggest that wheat and barley remain important subsistence crops (Rosen, 1994: 342-343; Ilan, 2018: 299). However, the Levant also witnessed an increase in the cultivation of drought-susceptible and water-demanding crops, including free-threshing wheat, lentil, flax and einkorn, which contrasts with the theories of increasingly arid conditions into the IA (Karakaya and Riel, 2019: 152). Additionally, whilst the analysis of cereal grains from Tell Tweini suggests moderate crop stress across the transition, measurements do not suggest that cereal production was significantly impacted by climatic change (Karakaya and Riehl, 2019: 152).

During the EIA, the Levant appears to have exploited livestock in different ways (Sapir-Hen et al. 2014: 714). For example, whilst high frequencies of cattle are seen at the sites of Ekron and Beth Shemesh, sites like Ashdod demonstrate higher frequencies of sheep, whilst other Levantine sites appear to present a similar sheep/goat ratio to the LBA, which suggests that in these areas LBA animal-husbandry strategies continued into the EIA undisturbed (Sapir-Hen et

al. 2014: 715). Wild animals are less prevalent during Iron I, though the hunting of deer continues (Sapir-Hen, 2022).

3.6. Summary of the Late Bronze-Early Iron Age Transition across the Eastern Mediterranean

The archaeological evidence examined in this chapter presents several significant political and socio-cultural changes seen across Türkiye and the wider EM region during the LBA-EIA transition. Significantly, the end of the Hittite Empire and the LBA led to a profound transformation of lifeways and economic dependencies across the north-central plateau and several sites beyond the central plateau (e.g., Oymaağaç, Kilise Tepe). The demise of the Hittite Empire also brought about significant changes across its once-northern Levantine territory, leading to political fragmentation and regional instability. The retreat of the Egyptian Empire in the southern Levant also brought about notable socio-cultural changes, including the introduction of new distinctive settlement and material culture at several coastal sites (e.g., Ashdod). To the west of the Levantine coast, the demise of the Cypriot city-state system of the LBA also resulted in a number of changes, including a significant transformation in material culture (ceramic production and burial). North-west of Cyprus, the end of the Mycenaean palatial system in the Aegean also brought about considerable changes in political, social and economic organization and new cultural traditions. Notably, in areas peripheral to the Mycenaean palatial system, several settlements also appear to have grown and flourished in the EIA (e.g., Lefkandi).

However, settlement and socio-economic continuity can also be identified across the transition period. For example, significant settlement continuity can be seen across the LBA-EIA transition in the North Orontes Valley, the Lebanese coast and the rural settlements of Lower Galilee in the southern Levant. Several sites across the EM, including Türkmen-Karahöyük and Kınık Höyük in south-central Türkiye and Lefkandi in the Aegean, also maintained their importance in the EIA. There is also some continuity in BA cultural traditions across some areas of the northern and southern Levant.

Due to the climatic focus of this thesis, it is also important to consider changes and continuities in agricultural conditions across Türkiye and the wider EM, as summarized below.

Scale of Agricultural Production

During the LBA, a focus on intensive agricultural production can be identified at several EM sites under centralised political control. For example, large grain stores can be identified at

several Turkish sites (e.g., Hattuša and Kaman-Kalehöyük). Cattle were also likely used for traction at several EM sites in the LBA (e.g., Knossos), indicating intensive agricultural labour. However, the end of the LBA across the EM appears to have brought with it the end of intensive production strategies as reflected by a reduction in the proportion of cattle remains during EIA occupation and an apparent disinterest in centralized long-term accumulation of large quantities of staple product previously seen during the LBA.

However, diverse and extensive agricultural practices were also present in the LBA, as evident at sites (e.g., Kaymakçı in western Türkiye) that were independent from the economic control of an imperial power (Marston et al. 2022). Diverse and extensive agricultural practices are also likely to have been practised by less archaeologically visible groups such as the Kaška in northern Türkiye.

Crop Cultivation

As summarized by Halstead (1993: 68), agricultural yields are variable, and in semi-arid regions such as the southern Aegean and the central plateau of Türkiye, farmers will have faced shortfalls of staple crops. Farmers can cushion themselves against shortage in the face of poor agricultural yields (Halstead, 1993: 68). During the LBA, drought-resistant crops (e.g., barley, bitter vetch) were cultivated in high frequencies across the EM. The cultivation of crops adapted to low water expense is indicative of risk management, which may indicate a degree of societal resilience (Marston, 2011; Karakaya and Riehl, 2019). Significantly, an increase in the percentage frequency of drought-resistant crops (notably barley) at the end of the LBA is seen in several EM archaeobotanical assemblages, which may suggest an increased concern for agricultural risk management. Whilst there are some changes in the range of crops cultivated across the transition period, crop cultivation was diverse during both the LBA and EIA periods across several EM sites. The practice of polyculture at sites would suggest a degree of risk management in the LBA and EIA. As summarized by Marston (2011), crop diversification can minimize the chance of subsistence failure in the face of external stresses (e.g., climate change) through higher yields and greater yield stability.

Animal Husbandry

Several changes in animal husbandry can be seen across the LBA transition. For example, an increase in the ratio of goat to sheep at sites such as Gordion and Kaman-Kalehöyük may indicate less favourable environmental conditions in the EIA, as goats require less water than sheep and can therefore adapt better to drier, scrubrier landscapes (MacKinnon, 2014: 221).

However, it is important to recognize that whilst livestock exploitation can be related to environmental processes, animal husbandry is also related to several other factors (e.g., the economy, symbology) (Sapir-Hen et al. 2014). For example, whilst an increase in goats at several EIA sites may suggest a drier landscape, there may also be a cultural preference for goats, as goats can produce more milk than sheep (MacKinnon, 2014: 221).

Evidently, change and continuity can be seen across Türkiye and the wider EM during the LBA-EIA transition. For a summary of LBA-EIA changes and continuities across the EM, see **Table 7**.

Table 7. Summary table of changes and continuities seen in the archaeological record between LBA and EIA occupation at key sites across Türkiye. Please note only changes considered significant are included here.

* Signifies where there is limited or no information that can be used to determine continuities or changes in a particular settlement feature at a site.

Region			Are there any substantial changes between LBA and EIA in socio-political and cultural features across the different areas of the EM during the LBA-EIA transition?			
			Political organization	Demography and settlement patterns	Material culture	Agricultural production and subsistence
Türkiye	Northern Türkiye		✓	✓	✓	*
	Western Türkiye		✕	✓	✓	✕
	Central Türkiye	North	✓	✓	✓	✕
		South	✕	✕	*	
	Southern Türkiye		✓	✓	✓	✕
The western Aegean			✓	✓	✓	✕
The Levant	The Northern Levant		✓	✓	✓	✕
	The Southern Levant		✓	✓	✕	
	Cyprus		✕	✓	✓	

3.7. Key Issues Regarding the Archaeology

Whilst the breadth and intensity of archaeological research surrounding the EM LBA-EIA transition has enlightened our understanding of this transformative period over the last century, several limitations of the archaeological evidence exist. Such limitations must be addressed as they have the potential to encourage and support incorrect or simplified interpretations of past societal conditions.

Firstly, dating and defining the LBA-EIA transition period is challenging. Existing chronologies are subject to several limitations and so the robustness and chronological resolution of this period is quite poor by absolute dating standards. Whilst future advancements in radiometric methods will seek to further increase the robustness and precision of archaeological dating, we must accept that LBA-EIA chronologies will likely remain rather limited as some chronological issues may never be resolved (e.g., due to the absence of archaeological material from historical excavations). Such chronological limitations, therefore, present a significant challenge to any attempts to establish a chronological linkage between the events of the LBA-EIA transition and climatic change.

Secondly, assumptions of catastrophic change that underpin the existing climate hypothesis may, in part, be based on flawed comparison and interpretation of the archaeological evidence. As highlighted by Dickinson (2019: 43-44), comparisons are made between easily recognized LBA evidence and poorly recognizable EIA evidence, which has been largely taken to reflect a major decline in site numbers and population between the LBA and the EIA. Dickinson (2019: 44) also suggests that it is easier to identify abandoned sites compared to those that experienced occupation continuity into the historical period, as early strata at a site may have been destroyed or disturbed. Our limited knowledge of the EIA is due to a lack of both archaeological and literary documentation. Unfortunately, at archaeological sites, there is difficulty in finding well-stratified occupation levels and good contexts for EIA occupation (Yakar, 2011). Therefore, it is difficult for us to detect and understand links and developments between these two periods and thus fully understand the LBA-EIA transition (Mora and d'Alfonso, 2012). An urban bias is also evident in LBA-EIA archaeological research due to a lack of excavation of non-urban settlements (Luciani, 2014: 519; Dickinson, 2019: 44). Only in recent years has archaeological research started to pay specific attention to less archaeologically visible rural settlements (Luciani, 2014: 519; Kamlah and Riel, 2020: 194). As introduced in Chapter 1, traditionally, there has been a tendency to concentrate on the excavation of leading settlements largely inhabited by elite members of society, who would

have only formed a small percentage of the total populace of this time, and so archaeological understanding of this period is skewed towards the lives of elites (Dickinson, 2019: 44; Meyer and Knapp, 2021). As the majority of LBA populations would have lived in rural villages and more peripheral areas, our understanding of the LBA across the EM is, therefore, only partial (Sherratt, 2014; Shelmerdine and Bennet, 2008: 308).

Thirdly, significant limitations also surround our understanding of LBA-EIA agriculture, as agricultural archaeology is still in its relative infancy across the EM (Pagnoux and Zurbach, 2020: 270). As summarized by Kamlah and Riehl (2020: 193), archaeological investigations rarely focus on areas of ancient cultivation. Additionally, at some sites, there is a rarity of plant remains due to less-than-optimal preservation conditions. In well-ventilated soils, seeds will decay unless they are charred and so the parts preserved are those that were processed directly or indirectly with fire (Dörfler et al. 2011). This limits our understanding of crop yield and subsistence strategies because these charred remains are only partially representative of past agricultural activity. Furthermore, existing archaeobotanical evidence at sites is generally of rather low resolution (Smith and Munro, 2009). We, therefore, still possess a relatively limited understanding of agricultural conditions with which to truly understand the potential impact of proposed climatic changes at the end of the LBA.

Finally, we must consider that bias and preservation can affect our interpretation of settlement across more peripheral regions, such as northern Türkiye during the Bronze and Iron Ages. For example, whilst a scarcity of höyüks in the north may reflect divergent social organisation, subsistence strategies, and cultural traditions, we must also consider that the nature of the evidence can be shaped by excavation and survey bias or taphonomic processes, including differential site visibility (Glatz, 2017; Postgate 2007b: 13).

3.8. Chapter Summary

As introduced in Chapter 1, the climate hypothesis has presented the end of the LBA as a time of disaster and “collapse” across the EM due to the demise of once-powerful civilizations and empires and the destruction and abandonment of once-important sites (e.g., Ugarit). However, the archaeological evidence presented in this chapter demonstrates that LBA-EIA societal conditions across Türkiye and the wider EM region were complex and varied. Whilst the archaeological evidence generally identifies significant societal, political, economic, and cultural changes seen into the EIA, the EM did not solely witness widespread destruction and devastation. Through inter-regional and microregional analysis of the archaeological evidence,

different societal trajectories and fates can also be identified throughout Türkiye, the western Aegean and the Levant. There is also evidence of agricultural risk management at several sites during the LBA and EIA, which is indicative of societal adaptation and resilience in the face of challenges surrounding agricultural yield. Furthermore, whilst we still know very little about the everyday lives of peoples in the LBA and EIA and rural settlements, it is evident that some settlements and societies made decisions that were not linked to imperial or palatial systems of the BA, demonstrating a resiliency to the events of the LBA-EIA transition. It is, therefore, apparent that whilst many dramatic changes can be seen during the LBA-EIA transition, this period of time may not have been catastrophic for all people living across Türkiye and the wider EM region.

As presented in 3.7 our understanding of the transition period across Türkiye and the wider EM region remains limited by several key issues, including large chronological uncertainties, archaeological bias and the infancy of agricultural archaeology which continues to limit our understanding of agricultural systems of the LBA-EIA.

Chapter 4 - Methods

4.1. Introduction

To enhance the spatial and temporal availability of palaeoclimate data in Türkiye and the wider EM covering the LBA-EIA transition, this thesis presents a new highly resolved stalagmite proxy record (Ko-1) from Kocain Cave in southwestern Türkiye. Kocain, pronounced Koja-eeen, means 'mighty cave' in Turkish, so Kocain Cave translates as 'Mighty Cave Cave'. To contextualize the results of this new record, this chapter also provides a review of hydroclimatic and temperature variability surrounding the LBA-EIA through the examination of existing proxy records from the EM and surrounding areas.

As discussed in Chapter 1, several studies have suggested that a drying/cooling event around ca. 3.2 ka BP coincided with the end of the LBA in the EM and contributed significantly to the events of the transition (e.g., Kaniewski et al. 2015; Langgut et al. 2013; Drake, 2012; Manning et al. 2023). However, as highlighted in Chapters 1, and 2 and section 4.3 of this chapter, our understanding of palaeoclimate variability during the LBA-EIA transition period in the EM is limited by the uncertainties associated with coarsely resolved proxy records with uncertain chronologies. If we are to understand climatic conditions of the LBA and EIA periods across the EM it is important to undertake a critical examination of robust proxy records which provide a more accurate representation of palaeoclimate variability, as will be provided in this thesis.

To understand LBA-EIA climate conditions across the EM, this thesis not only provides a critical review of existing proxy records but also presents a new highly resolved stalagmite record (Ko-1) from Kocain Cave in southwestern Türkiye. By presenting a new robust proxy record, the spatial coverage of EM proxy records covering the LBA-EIA transition period can be improved. By enhancing the spatial coverage of EM proxy records, we can not only better understand climate changes across the EM at a regional scale but also better understand subregional and more localized climate conditions. A stronger understanding of subregional and more localised climate conditions allows us to address the variability and complexity of hydroclimate and temperature variability across the region as discussed in Chapter 2.

- 1) This chapter will present the methodology used to construct and analyse the new Ko-1 stalagmite proxy record (see 4.2). As part of this methodology, this chapter will cover:

- The rationale for constructing a new stalagmite proxy record for palaeoclimatic analysis.
 - A brief introduction to speleothem science, to understand speleothems as a climate archive.
 - The analytical methods used to construct the new Ko-1 stalagmite record.
- 2) This chapter will also introduce the methodology used to examine existing proxy records across the EM surrounding the LBA-EIA transition (see 4.3). As part of this methodology, this chapter will cover:
- The rationale for the examination of existing proxy records covering the LBA-EIA transition period across the EM and bordering areas.
 - The selection criteria used to examine existing proxy records.

4.2. Constructing a New Palaeoclimate Proxy Record from Türkiye

To better understand palaeoclimatic conditions during the LBA-EIA transition period across Türkiye and the wider EM region, this thesis offers a new highly resolved oxygen and carbon isotope record from Stalagmite Ko-1 from Kocain Cave in southwestern Türkiye (see section 4.2.4.1). It is important to highlight that whilst this thesis presents a new stable isotope record for stalagmite Ko-1, stable isotope and trace element analysis on the same stalagmite has been undertaken previously in PhD studies by Göktürk (2011) and Jacobson (2021). Analysis of stalagmite Ko-1 was undertaken by Göktürk (2011) as part of an examination into late Holocene climate variability in Türkiye over the last ~ 5700 yrs, whilst Ko-1 analysis was undertaken by Jacobson (2021) as part of an examination into past human-environment-climate relationships of the Late Antiquity (3rd-7th centuries CE) across the EM and Middle East. Whilst the Ko-1 record of Jacobson (2021) has been published, the Göktürk (2011) analysis of Ko-1 has not. It is also important to highlight that the high-resolution stable isotope analysis of Ko-1 presented in this thesis (on average 4 yrs) allows us to more precisely understand palaeoclimate variability surrounding the LBA-EIA transition than previous stable isotope analysis (11 yrs) undertaken by Jacobson (2021). This is particularly significant given new evidence for multi-year droughts in Türkiye at the end of the LBA presented by Manning et al. (2023).

Speleothems as a Climate Archive

This thesis presents a new speleothem record as speleothems, which are secondary mineral deposits formed in caves, are widely recognized as important climate archives (Gunn, 2004; Fairchild et al. 2007; Wong and Breecker, 2015). As summarized by Fairchild et al. (2006), speleothems capture the response of a cave to its external environment, with cave temperature generally reflecting the mean annual external temperature and dripwater discharge reflecting the amount of infiltration into the cave, largely showing little alteration. Notably, the spatial coverage of speleothems depends on the location of the cave and climatic zones. Whilst some speleothem records can provide information on monsoon systems and global sea level changes (e.g., Fleitman, et al. 2007; Cai et al. 2015; Bard et al. 2002; Dumitru et al. 2021), others can record changes in regional climate and environment (Fairchild and Baker, 2012; Lechleitner et al. 2018). Speleothems have long been considered a highly important and advantageous climate archive due to their (1) widespread global distribution, (2) amenability to radiometric dating and precise and accurate absolute chronologies, (3) excellent preservation of calcium carbonate precipitated from meteoric water in caves, (4) capacity to record seasonal to decadal-scale climatic information over thousands of years, and (5) ability to provide multiple geochemical proxies, including abundant hydroclimatic proxies such as oxygen and carbon isotopes, trace elements, annual growth bands etc. (McDermott, 2004; Fairchild et al. 2006; Fairchild and Baker, 2012; Lachniet, 2009; Wong and Breecker, 2015; Baldini et al. 2021; Cheng et al. 2019). It is, however, important to also recognize that stalagmite records and their interpretation are not without challenges. For example, a major limitation of speleothem analysis is the difficulty in providing unambiguous palaeoclimatic interpretations of proxy data (McDermott, 2004). However, despite the limitations of speleothem analysis, speleothems remain one of the most important geological archives for palaeoclimatic research, contributing to significant advancements in the identification and dating of important changes in climatic variability (Cheng et al. 2019; Fairchild et al. 2006).

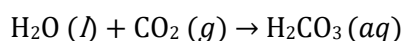
The incremental growth of speleothems provides a record of changing climate conditions directly above the cave in which they form, with variable applicability to adjacent and surrounding regions (e.g., Fleitmann et al. 2011; Woodhead et al. 2019). Speleothems can record several key aspects of climate variability, including rainfall variability, changes in atmospheric circulation, mean annual temperature and vegetation response through the measurement of geochemical and physical proxies as outlined in 4.2.1 (McDermott et al.

2004). As speleothems contain multiple hydrologically sensitive proxies (e.g., oxygen and carbon stable isotopes), speleothems are largely understood as an archive of past hydroclimate changes (Johnson, 2021). Over the last few decades, there has also been advancement in the development of speleothem-based quantitative temperature reconstructions through a range of methods such as fluid inclusion analysis (e.g., Meckler et al. 2015; Meckler et al. 2021; Affolter et al. 2019).

4.2.1. Speleothem Formation

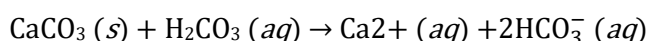
Speleothems, commonly composed of calcium carbonate (CaCO_3), form as the result of precipitation from groundwater that has percolated through the karst system, through soil and bedrock. As the rainwater percolates through the rock, it gradually becomes saturated with calcium carbonate. On reaching the cave, the calcium carbonate precipitates out, due to the degassing of carbon dioxide (CO_2), to form speleothems. Speleothem formation is summarized further below. Diagrams of the cave environment and speleothem growth can be seen in **Figure 23**.

Speleothems occur within carbonate rocks, typically limestones (CaCO_3) or dolomite. These carbonate rocks are aquifers located in karstic regions where there is little or no surface drainage of water (Fairchild et al. 2006; Fairchild and Baker, 2012). The process of speleothem formation occurs through different regions of the karst aquifer: the soil, the epikarst, which is a zone that sits below the soil, the bedrock, and the cave environment. Within the soil and upper epikarst, carbonate dissolution occurs. As rainwater percolates through the soil and upper bedrock, meteoric water comes into contact with a high partial pressure of CO_2 ($p\text{CO}_2$) in the soil, resulting from root respiration and the decomposition of organic matter (Genty and Massault, 1997). As the infiltrating rainwater mixes with soil CO_2 , CO_2 dissolves into solution, forming carbonic acid (H_2CO_3). This reaction can be seen below.



The acidic water percolates further through the karst system, reaching the limestone bedrock.

As the acidic water solution percolates through the carbonate, the carbonic acid starts to slowly dissolve it. This is summarized in the reaction below.



Once the carbonate-rich solution reaches the cave atmosphere, it encounters a gas phase with a lower $p\text{CO}_2$ than previously encountered, leading to the degassing of CO_2 from the solution and precipitation of CaCO_3 . Calcite precipitation follows the below reaction:



Speleothems can be deposited in different forms, with three types used in palaeoclimatic research (1) flowstones, (2) stalactites and (3) stalagmites (Fairchild et al. 2006). However, stalagmites, which grow from the cave floor toward the ceiling fed from the drip water of an overhead stalactite, are favoured for palaeoclimate research due to their relatively simple growth structure (Fairchild, 2006).

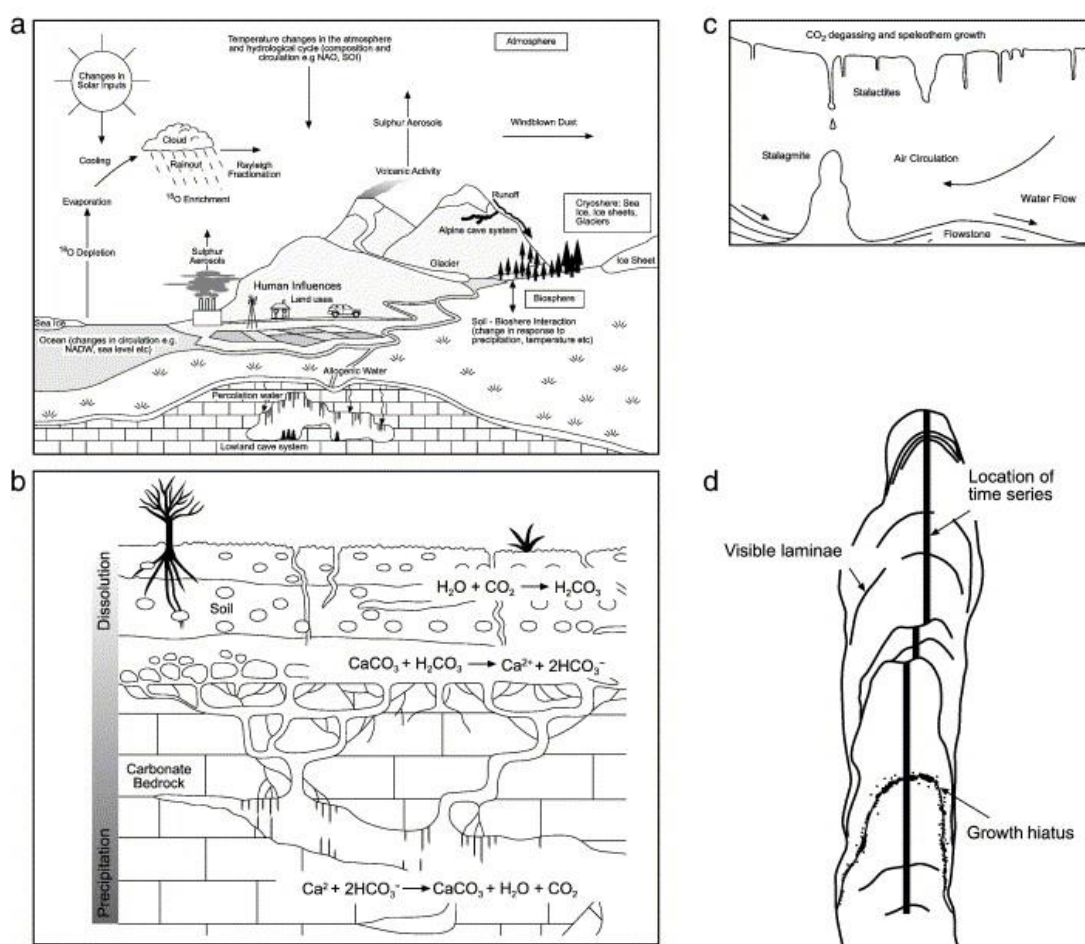


Figure 23. The cave environment and speleothem formation (a) Diagram showing how caves are influenced and interact with the atmosphere, biosphere, geosphere and hydrosphere. (b) Geochemical processes of the karstic system as adapted from Tooth (2000). (c) Cave processes. (d) Cross section of a stalagmite illustrating growth layers (laminae) and position of the growth

axis. Source: Fairchild et al. (2006), Figure 1. Copyright © 2006. Used with permission of Elsevier. Permission conveyed through Copyright Clearance Center Inc.

Speleothem Climate Proxies

Climatic and environmental changes above the cave are preserved in the speleothem as chemical and physical proxies (see **Figure 24**). A host of different speleothem proxies (e.g., stable isotopes, trace elements, fluid inclusions, pollen, biomarkers) are incorporated into stalagmite calcite during its growth (Fleitmann et al. 2008). The most widely employed geochemical speleothem proxy is $\delta^{18}\text{O}$, which primarily serves as a tracer of the hydrological cycle, whilst $\delta^{13}\text{C}$ is understood to be sensitive to local water balance (Feinberg and Johnson, 2021). As this thesis undertakes oxygen and carbon stable isotope analysis on stalagmite Ko-1, this chapter will introduce a summary of oxygen and carbon isotopes in speleothems. Trace element concentrations (e.g., Mg, Sr, P) and fluid inclusions are also commonly employed in speleothem studies to understand palaeohydrology and palaeotemperature respectively (Treble et al. 2003; Fairchild and Treble, 2009; Meckler et al. 2015; Affolter et al. 2019). Trace element and fluid inclusion analysis was, however, not undertaken in this thesis. Additionally, whilst not examined in this thesis, physical speleothem properties such as variations in growth rate and crystal fabric can also be examined to determine additional information about surface climate (Feinberg and Johnson, 2021). Analysis of calcite fabrics has not been undertaken in this research as this process can be quite destructive. The sample was instead preserved for other analyses.

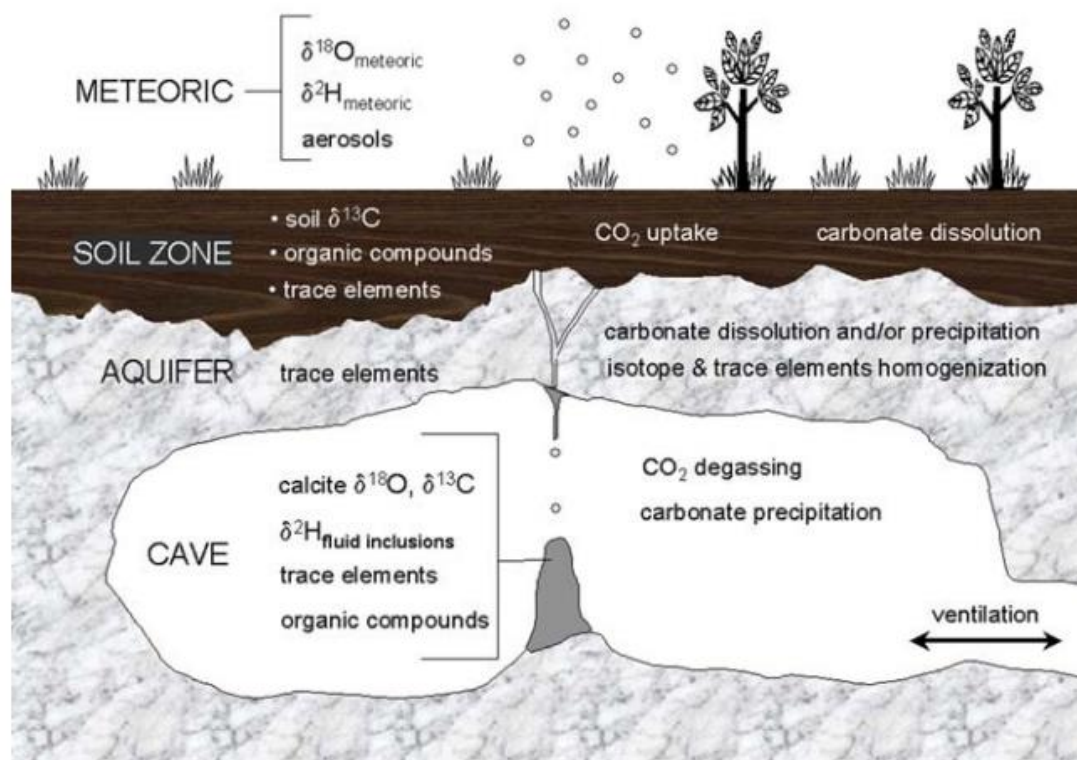


Figure 24. Speleothem climate proxies. Source: Frisia and Borsato (2010), Figure 15. Copyright © 2010. Used with permission of Elsevier. Permission conveyed through Copyright Clearance Center Inc.

4.2.2. Dating and Age-depth Modelling

To understand when a speleothem formed and its duration of growth, a chronology must be established. Whilst several dating methods can be employed to determine the age of speleothem growth layers, Uranium-Thorium (U-Th) dating is the most widely used technique as it is the only reliable dating technique for speleothems (Fairchild and Baker, 2012; Richards and Dorale, 2003). Excellent chronologies can be established from U-Th dating as this dating method enables age determination with high precision and accuracy (Fairchild and Baker, 2012). For example, under close to ideal circumstances, speleothems deposited at 10 ka can reach 2σ uncertainties as low as ± 10 years (Wendt et al. 2021). Additionally, due to analytical advancements in recent decades, including the multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS) method, precise and accurate U-Th dates can be obtained

relatively fast from small amounts of sample in contrast to the tens of grams of carbonate required decades ago (Hoffman et al. 2007; Fairchild and Baker, 2012; Scholz et al. 2014).

As summarized by Spötl and Boch (2019), U-Th (disequilibrium) dating determines the relative abundances of unstable U and Th isotopes based on the radioactive decay of the parent isotope ^{238}U . As a speleothem grows, it incorporates appreciable concentrations of highly soluble U from natural waters into its mineral structure but fails to incorporate Th, which is insoluble, unless it is transported in by detrital contamination or by organic matter (Richards and Dorale, 2003; Wendt et al. 2021). As soon as Uranium atoms have been incorporated into speleothem calcite, ^{230}Th begins to build up from the decay of ^{234}U . The amount of daughter products of uranium decay is therefore taken as a direct measure of the time elapsed since the incorporation of uranium in the speleothem. ^{230}Th ideally originates solely from the radioactive decay of parent ^{234}U through a closed system, whereby no gain or loss of these isotopes, other than through their intrinsic decay, should have occurred since speleothem formation (Dorale et al. 2004; Spötl and Boch, 2019). As summarized by Scholz et al. (2014), generally, the fundamental requirements for U-Th dating are fulfilled for most speleothems due to the protected cave environment. However, some speleothems can also contain detrital Th resulting from the incorporation of mineral or organic particles which can bias U-Th ages if not corrected for (Spötl and Boch, 2019; Wendt et al. 2021).

Age-depth Modelling

Each radiometric date refers to one particular growth layer of the speleothem and so the age between two adjacent U-Th ages must be estimated, which is achieved by calculating a relationship between radiometric ages at certain distances and the distance of the proxy analyses along the growth axis of the speleothem, usually referred to as the age-depth model (Fairchild and Baker, 2012; Scholz et al. 2012). However, as first summarized by Scholz et al. (2012) over a decade ago, a standard approach for the construction of speleothem age models and corresponding uncertainty has not yet been established. Several age-depth modelling methods have been developed over the last few decades to construct speleothem chronologies: linear interpolation, linear regression, Bchron (Haslett and Parnell, 2008), Bacon (Blaauw and Christen, 2011; Blaauw et al. 2019), OxCal (Ramsey, 2008a; Ramsey, 2009; Ramsey and Lee, 2013), COPRA (Breitenbach et al. 2012) and StalAge (Scholz and Hoffmann, 2011).

The new Ko-1 record of this thesis employs the StalAge model, as StalAge was designed specifically for the construction of speleothem age models and is frequently used within speleothem studies. As summarized by Scholz and Hoffman (2011) StalAge uses U-series ages and their corresponding age uncertainty for modelling and includes stratigraphic information to constrain and improve the age model. StalAge is understood to offer a high degree of reproducibility and comparability of speleothem records from different studies (Scholz and Hoffman, 2011). Additionally, StalAge can be applied to datasets including those featuring problematic data such as outliers, age inversions, growth hiatuses and large changes in growth rate (Scholz and Hoffman, 2011).

4.2.3. Stable Isotopes

Isotopes are atoms with the same number of protons but different numbers of neutrons. Whilst isotopes share almost the same chemical properties they differ in mass and physical properties. Unlike unstable isotopes which emit radiation, stable isotopes do not.

Stable isotope analysis reports the stable isotope composition of a particular element in a molecule or compound. A fundamental principle of stable isotopes is that there is a preferential fractionation of isotopes between phase changes (e.g., liquid to gas), with one phase preferentially incorporating the heavier or lighter isotope relative to the other phase (Sharp, 2007).

Calcite (CaCO_3) can contain several distinct isotopic signals, recorded as variations in the relative abundance of isotopes, notably oxygen (^{16}O and ^{18}O) and carbon (^{12}C and ^{13}C). Isotopic compositions are expressed as relative differences in isotopic ratios compared to a reference using the delta (δ) notation, reported in per mil (‰) (Sharp, 2007). An isotope ratio mass spectrometer (IRMS) is used to determine the ratio (R) of the heavy (rare) isotope to the light (abundant) isotope in a sample. A positive δ value means that the ratio of the heavy to the light isotope is higher in the sample than it is in the standard, whilst a negative δ value means the opposite (Sharp, 2007).

The delta (δ) value is given by

$$\delta = \left(\frac{R_x - R_{std}}{R_{std}} \right) \times 1000$$

Where R is the ratio of the abundance of the heavy to light isotope, x denotes the sample, and std is an abbreviation for the standard. For the elements, carbon and oxygen R is given by

$^{13}\text{C}/^{12}\text{C}$ and $^{18}\text{O}/^{16}\text{O}$ respectively (Sharp, 2007). Two international reference standards are used to report variations in oxygen isotope ratios: Vienna Pee Dee Belemnite (VPDB) and Vienna Standard Mean Ocean Water (VSMOW) (Sharp, 2007). Variations in carbon isotope ratios are reported to the VPDB standard (Sharp, 2007).

$\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ stable isotope ratios are recognized as hydrologically sensitive geochemical proxies, reflecting important processes at different spatial scales (Johnson, 2021; Lechleitner et al. 2017). Whilst $\delta^{18}\text{O}$ variability generally reflects larger scale atmospheric circulation processes (McDermott, 2004; Lachniet, 2009), $\delta^{13}\text{C}$ is understood as a proxy for local soil dynamic processes and is therefore thought to have been more sensitive to changes at local to regional level (e.g., Ridley et al. 2015; Cheng et al. 2015). Climate interpretations of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ signals can, however, be complicated by a range of processes that can contribute to fractionation before calcite precipitation, including evaporative effects, open/closed bedrock dissolution, cave pCO_2 levels, changing drip rates, PCP and other processes within the karst system (Bar-Matthews et al. 1996).

4.2.3.1. Oxygen Isotopes ($\delta^{18}\text{O}$)

$\delta^{18}\text{O}$ is the most ubiquitous speleothem-based proxy, offering information on past hydroclimatic variability across timescales ranging from annual to millennial (Fleitmann et al. 2008). Assuming equilibrium conditions (see 4.2.3.3), the oxygen isotopic composition of calcite will reflect the isotopic composition of precipitation ($\delta^{18}\text{O}_\text{p}$), and so calcite $\delta^{18}\text{O}$ is understood to contain information about the climate at the time of stalagmite growth (Lachniet, 2009). Variations in $\delta^{18}\text{O}_\text{p}$ are influenced by several different processes within the global water cycle, including moisture source, the amount and seasonality of precipitation at a cave site, and average temperatures, and so the interpretation of stalagmite $\delta^{18}\text{O}$ can be complex (McDermott, 2004; Lachniet, 2009). As summarized by Bajo et al. (2017), whilst the processes that contribute to rainfall $\delta^{18}\text{O}$ are complex, global and regional patterns of rainfall $\delta^{18}\text{O}$ are generally well understood (Lachniet, 2009; Rozanski et al. 1982; McDermott, 2004).

Processes related to $\delta^{18}\text{O}$ variability can be seen in **Figure 25** and will be discussed below. For further information on speleothem $\delta^{18}\text{O}$, see reviews by McDermott (2004) and Lachniet (2009).

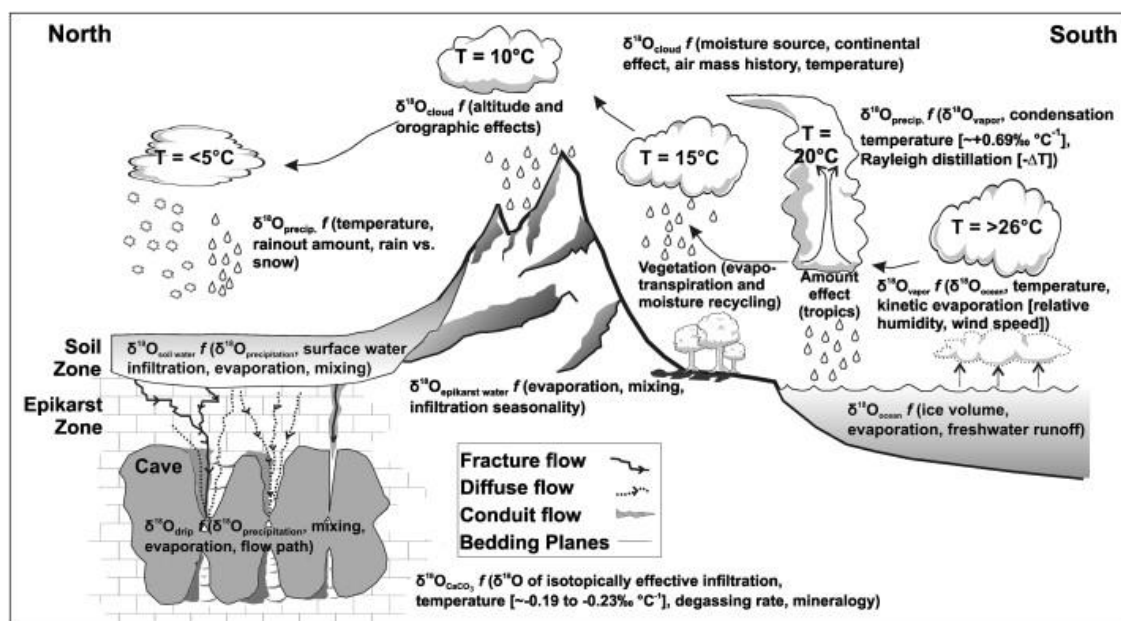


Figure 25. Primary processes related to $\delta^{18}\text{O}$ variability relevant to speleothem palaeoclimatology. Source: Lachniet (2009), Figure 1. Copyright © 2009. Used with permission of Elsevier. Permission conveyed through Copyright Clearance Center Inc.

Moisture Source

Whilst the source effect is considered a major control on $\delta^{18}\text{O}_p$ (Rozanski et al. 1993; Clark and Fritz, 1997), it is not introduced here as the moisture source of $\delta^{18}\text{O}$ is often the major determinant of $\delta^{18}\text{O}_p$ values across long timescales, which does not apply to this thesis. For a summation of the source effect, which is the observation that air masses derived from different moisture sources have distinctive $\delta^{18}\text{O}$ values, see Lachniet (2009).

Precipitation Amount

Speleothem $\delta^{18}\text{O}_p$ can also reflect changes in precipitation amount known as the amount effect, which is the observed decrease in $\delta^{18}\text{O}_p$ with increased rainfall amount (Dansgaard, 1964; Rozanski et al. 1993; Lachniet, 2009). Therefore, higher rainfall amounts will lead to more negative $\delta^{18}\text{O}_p$ values, whilst a reduction in rainfall amount will correspond to less negative $\delta^{18}\text{O}_p$ values. The amount effect is thought to be a major control determining speleothem $\delta^{18}\text{O}_p$ in semi-arid regions, including the EM as demonstrated by Levantine records (e.g., Bar Matthews et al. 2003; Verheyden et al. 2008; Orland et al. 2009; Cheng et al. 2015).

Temperature

Temperature changes can also impact $\delta^{18}\text{O}_p$, known as the temperature effect. The temperature effect is the observed positive correlation between the mean annual air temperature (MAAT) at a site and the mean $\delta^{18}\text{O}$ value of precipitation ($d\delta^{18}\text{O}_p/dT$) (Dansgaard, 1964; Fricke and O'Neill, 1999). As condensation of atmospheric vapour requires cooling of the air mass, the removal of moisture from an air mass is temperature-dependent (Dansgaard, 1964; Lachniet, 2009). The cooling of the parcel of air can arise due to several factors, including orographic lifting, advection, convection, or frontal lifting (Rozanski et al. 1993). Therefore, vapour masses will experience increased depletion of $\delta^{18}\text{O}$ under colder conditions compared to warmer conditions (Pape et al. 2010).

Seasonality

Changes in seasonality also have a strong control on $\delta^{18}\text{O}_p$ as changes in the relative proportions of summer vs. winter precipitation can result in variation of $\delta^{18}\text{O}$ values in speleothems (Wang et al. 2001; Denton et al. 2005; Lachniet, 2009). Seasonality is thought to be an important control on $\delta^{18}\text{O}_p$ across the EM and Middle East (EMME), with lower $\delta^{18}\text{O}$ values in winter compared to higher $\delta^{18}\text{O}$ values in summer (Feng et al. 2009; Lachniet, 2009).

Continentality

$\delta^{18}\text{O}_p$ values can also be influenced by the continental effect, which refers to the progressive depletion of $\delta^{18}\text{O}_p$ as vapor masses move further inland from the moisture source (Dansgaard, 1964; Rozanski et al. 1993; Clark and Fritz, 1997). As a vapour mass moves across a continent, its isotopic composition evolves due to topographic effects and temperature extremes characterizing continental climates (Clark and Fritz, 1997).

Altitude

The altitude effect also influences $\delta^{18}\text{O}_p$, whereby water vapor masses become increasingly depleted in $\delta^{18}\text{O}$ over regions of increasing elevation due to increased rainout and a higher degree of fractionation (Clark and Fritz, 1997). This process, which causes orographic precipitation, occurs when air masses are forced to flow over high topography. As air rises over mountains, it cools, and water vapor condenses. It is, therefore, common for rain to be concentrated on the windward side of mountains and for rainfall to increase with elevation in the direction of storm tracks.

Kinetic Fractionation

Speleothem $\delta^{18}\text{O}$ can also be controlled by kinetic fractionation processes, such as the degassing of CO_2 and evaporation of H_2O during calcite precipitation, which can obscure climate signals (Fleitmann et al. 2004; Lachniet, 2009; Baker et al. 2019). If kinetic fractionation occurs, calcite will be enriched in $\delta^{18}\text{O}$ (Hendy, 1971).

Precipitation and Cave Monitoring

As $\delta^{18}\text{O}$ is influenced by a range of environmental controls and processes across the ocean, atmosphere, soil zone, epikarst and cave system, it is widely accepted that monitoring of modern precipitation and drip waters within cave systems should be undertaken to constrain the climate signal preserved in speleothem $\delta^{18}\text{O}$ (Lachniet, 2009; Wong and Breecker, 2015; Baker et al. 2019). By compiling cave monitoring data, it is possible to examine the modern-day relationship between $\delta^{18}\text{O}_\text{p}$ and the oxygen isotope composition of drip water ($\delta^{18}\text{O}_\text{dripwater}$), allowing us to better understand and quantify past rainfall conditions from speleothem $\delta^{18}\text{O}$ (Baker et al. 2019). Whilst the importance of cave monitoring is evident it is important to highlight that cave monitoring data is not always available as multiyear to decadal monitoring efforts are expensive and time-consuming (Wong and Breecker, 2015). Therefore, the practicality of monitoring is not always feasible (Wong and Breecker, 2015). The importance of precipitation and cave monitoring is outlined and demonstrated further in a number of studies (e.g., Baker et al. 2014; Meyer et al. 2014; Carlson et al. 2020).

4.2.3.2. Carbon Isotopes ($\delta^{13}\text{C}$)

As highlighted by several studies, speleothem $\delta^{13}\text{C}$ can also provide information on climate and environmental conditions (Quade et al. 1989; McDermott, 2004; Ridley et al. 2015; Fohlmeister et al. 2020). Speleothem $\delta^{13}\text{C}$ is influenced by several different factors, including vegetation composition (e.g., C3 vs. C4 plants) and soil processes above the cave, bedrock dissolution, PCP, and kinetic fractionation, as will be summarized below (e.g., Dorale et al. 1992; Genty et al. 2006; Hendy, 1971; Fohlmeister et al. 2020; Mickler et al. 2006). As it is difficult to attribute individual processes as the driving force behind variability in speleothem $\delta^{13}\text{C}$, understanding this proxy signal can be complex (Fohlmeister et al. 2020). Carbon isotope ratios are, therefore, generally discussed less than oxygen profiles. Despite the complexity of carbon isotope interpretation, careful examination of $\delta^{13}\text{C}$ can provide additional important climate information on changes at a local to regional level (Genty et al. 2003; Cosford et al. 2009; Ridley et al. 2015; Cheng et al. 2016; Lechleitner et al. 2017). In some cases, $\delta^{13}\text{C}$ signals

may also be easier to interpret than corresponding $\delta^{18}\text{O}$ signals, especially when $\delta^{18}\text{O}$ is affected by multiple and competing effects that will mask the primary climate signal (Fohlmeister et al. 2020). For example, $\delta^{13}\text{C}$ isotopes are generally less sensitive than $\delta^{18}\text{O}$ to any short-term variability and, therefore, record less noise (Bar Matthews and Ayalon, 2011; Burstyn et al. 2019).

Vegetation and Biogenic Activity

Speleothem $\delta^{13}\text{C}$ is largely dependent upon factors that act on soil CO_2 , including changes in the type and density of vegetation above the cave and biogenic activity that is independent of vegetation type (Genty et al. 2003; Genty et al. 2006; Dorale et al. 1992; Bar-Matthews et al. 1996; Hellstrom et al. 1998; Drysdale et al. 2004). As summarized by Stoll et al. (2023), the $\delta^{13}\text{C}$ of CO_2 in the soil and karst reflects the relative contributions of isotopically light-respired CO_2 and isotopically heavier atmospheric CO_2 . Conditions that favour higher vegetation productivity, and faster rates of respiration in soils lead to higher soil pCO_2 and lower $\delta^{13}\text{C}$ values, whilst in less productive and slower respiring systems, $\delta^{13}\text{C}$ will be higher (Stoll et al. 2023).

For example, the $\delta^{13}\text{C}$ composition of soil CO_2 can vary according to the photosynthetic pathway of vegetation above the cave, e.g., C3, C4 or CAM plants (Cerling, 1984; Denniston et al. 2001; Dorale et al. 1992; Genty et al. 2003). The isotopic ratio of ^{13}C to ^{12}C differs between C3 and C4 pathways, with lower ^{13}C values in C3 plants compared to higher ^{13}C values in C4 plants (Hobbie and Wener, 2004). Stalagmites precipitated in caves surrounded by C3 plants typically have $\delta^{13}\text{C}$ values ranging from -14‰ to -6‰, whilst $\delta^{13}\text{C}$ values for stalagmites forming below C4 plants typically range from -6‰ to 2‰ (McDermott, 2004; Baker et al. 1997; Dreybrodt, 1988). The distribution of these vegetation types is determined by climate parameters including moisture balance and temperature (Ehleringer et al. 1997; Denniston et al. 2001). C3 plants (trees and shrubs) are better adapted to cooler and moister growing seasons, whilst C4 plants (drought-adapted grasses) have evolved to take advantage of hotter and drier conditions (Cerling, 1984; Dorale et al. 1992). Vegetation density and soil respiration rates can also control soil CO_2 , thus influencing $\delta^{13}\text{C}$ values (Amundson et al. 1989; Cerling, 1984; Quade et al. 1989). Generally, lower $\delta^{13}\text{C}$ values correspond to higher vegetation density and microbiological activity in the soil (Fohlmeister et al. 2020).

Bedrock Dissolution

In addition to the influence of vegetation and biological activity within the soil above a cave site, $\delta^{13}\text{C}$ can also be influenced by changes in carbonate bedrock dissolution, which controls the proportion of carbon supplied by the limestone (or dolomite) bedrock (Hendy, 1971; Genty et al. 2001). For example, weaker dissolution of carbonate bedrock can result in lower $\delta^{13}\text{C}$ (Zhao et al. 2015). For a further summary of carbonate dissolution, see Fohlmeister et al. (2020).

Prior Calcite Precipitation

Prior calcite precipitation (PCP) can also influence speleothem $\delta^{13}\text{C}$ values. PCP, which can occur due to changes in hydrology and cave atmospheric pCO_2 , is the process in which calcite precipitation occurs along the water flow path before reaching the apex of the stalagmite (Fairchild et al. 2000; Fohlmeister et al. 2020). PCP can occur in any void or region in the epikarst where groundwater or drip water can degas CO_2 (Meyer et al. 2014). During the process of PCP ^{12}C is preferentially released into degassed CO_2 , enriching the residual solution in ^{13}C , which goes on to form the stalagmite, enriched in $\delta^{13}\text{C}$ (Baker et al. 1997; Fairchild and McMillan, 2007). The degree of PCP typically depends on the pCO_2 gradient between the water and the gaseous phase and the length of the period where water is in contact with the cave air before dripping (Fohlmeister et al. 2020). During drier periods PCP is enhanced as aerated zones increase in the aquifer and the residence time of the water becomes longer which results in higher speleothem $\delta^{13}\text{C}$ values (Fairchild et al. 2000). As supersaturated groundwaters in equilibrium with elevated soil pCO_2 come into contact with air pockets along epikarst flow routes, the solution will degas and calcite will precipitate at the air-water interface (Johnson et al. 2006; Fairchild and Baker, 2012). Higher speleothem $\delta^{13}\text{C}$ values can, therefore, also be understood as an aridity signal.

Kinetic Fractionation

Speleothem $\delta^{13}\text{C}$ can also be affected by kinetic fractionation, related to the rate of calcite precipitation, as kinetic effects can enrich $\delta^{13}\text{C}$ (Hendy, 1971; Mickler et al. 2006; Ridley et al. 2015).

Carbon Isotopes as a Climate Proxy

Despite the complex controls on speleothem carbon isotopes as summarized above, drier conditions are generally reflected by more positive $\delta^{13}\text{C}$ values whilst more negative $\delta^{13}\text{C}$ is

understood to reflect wetter conditions above the cave site (e.g., Wang et al. 2019). Drier climate intervals can promote PCP due to lower groundwater flow, increased contribution of bedrock carbon and reduced soil bio productivity due to the degradation of vegetation and soil, leading to more positive $\delta^{13}\text{C}$, whilst wetter conditions conversely contribute to more negative $\delta^{13}\text{C}$ (Genty et al. 2003; Ridley et al. 2015). Across semi-arid areas, including the Mediterranean, negative $\delta^{13}\text{C}$ in speleothems has been linked to increased biological activity, including soil microbial activity, above the cave, which is in turn linked to precipitation (e.g., Bar-Matthews et al. 2003).

4.2.3.3. Equilibrium and Kinetic Fractionation

Whilst $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of cave drip water can reflect different climate-related processes, speleothem $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ can also be altered by non-equilibrium processes and temperature-dependent fractionation during calcite precipitation (Scholz et al. 2009; Fairchild and Baker, 2012; Baker et al. 2019). Notably, kinetic fractionation processes such as the kinetic loss of CO_2 and evaporation of water can affect the isotopic composition of speleothems, blurring the climatic signal (Fleitmann et al. 2004).

A common assumption when interpreting the stable isotopic composition of speleothems is that calcite precipitated in isotopic equilibrium with its corresponding drip water (Mickler et al. 2006). If the loss of CO_2 from the solution is slow, the temperature is stable and there is no evaporation, calcite can be precipitated in isotopic equilibrium with the drip water (Hendy, 1971). This means that the portioning of light and heavy isotopes is only a function of cave air temperature (Lauritzen and Lundberg, 1999). Therefore, when calcite is deposited under isotopic equilibrium speleothem $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ will only depend on the isotopic composition of drip water and corresponding temperature-dependent fractionation (Scholz et al. 2009). However, if the degassing of CO_2 is rapid, kinetic fractionation will occur, and the speleothem will grow under conditions of isotopic disequilibrium. Under isotopic disequilibrium, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ will show a simultaneous enrichment (Scholz et al. 2009).

It is important to highlight that in addition to kinetic isotope effects, positive covariation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ can be influenced by climate (Mickler et al. 2006). For example, it is common for stalagmites in arid and semi-arid environments to grow under isotopic disequilibrium as drier conditions result in slower infiltration rates and increased degassing, increasing both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values (Fleitmann et al. 2004; Mickler et al. 2006). Whilst speleothem records may be influenced by kinetic effects, even when strong $\delta^{18}\text{O}$ - $\delta^{13}\text{C}$

covariations occur, speleothem records can still provide information on palaeoclimate (Mickler et al. 2006).

Testing Isotopic Equilibrium

As kinetic fractionation can obscure climate signals preserved in speleothem calcite, it is important to test for isotopic equilibrium when examining speleothem $\delta^{18}\text{O}$ (Lachniet, 2009). Several tests can be performed to determine whether a stalagmite grew in isotopic equilibrium. Commonly, many studies have employed a 'Hendy Test,' whereby a positive covariation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ along a growth layer is thought to be indicative of kinetic fractionation (Hendy, 1971). Whilst the 'Hendy Test' has been widely applied in speleothem studies, this test is associated with several limitations (for a summary, see Lachniet, 2009). Stalagmites can also be tested for isotopic equilibrium through replication by comparing isotopic values to those from a different stalagmite/s from the same cave or a nearby cave that precipitated under conditions of isotopic equilibrium (Dorale and Liu, 2009). The correlation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ along a growth axis can also be tested, whereby a strong positive correlation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ along the growth axis may indicate kinetic fractionation (Mickler et al. 2006).

4.2.4. Analysis of Stalagmite Ko-1

The methodology used to construct the new Ko-1 stalagmite record is presented below. The cave setting of Kocain Cave and its surrounding climate will be introduced here. The methodology used to establish the chronology of Ko-1, and the methodology used to undertake stable isotope analysis is also presented below.

4.2.4.1. Kocain Cave Setting and Climate

As highlighted by Koç et al. (2020), the Taurus Mountain range of southern Türkiye is a major karstic region, home to several caves, including Kocain Cave (entrance: 37°13'57" N, 30°42'42" E, 730 m a.s.l) which is located in Antalya province in southwestern Türkiye (see **Figure 26**). Kocain Cave, which was formed within Jurassic-Cretaceous neritic limestones, has the largest cave entrance in Türkiye. The cave is approximately 633m long, with a gallery size of 36000 m² and a ceiling height of 80m. Additionally, due to its large volume and large cave entrance, with an opening width of 70m, cave ventilation is strong into the cave (Koç et al. 2020). Whilst cave temperatures vary slightly near the entrance, deeper in the cave temperature is constant, around 18°C. The terrain above the cave is sparsely covered by C3-type vegetation, typical of

the Mediterranean region, consisting mainly of evergreen shrubs and maquis (Roberts et al. 2011).

Stalagmite Ko-1, which is 32cm in length, was collected approximately 450m from the entrance of Kocain Cave in August 2005. Stalagmite Ko-1 can be seen in situ within Kocain Cave before its collection, as shown in **Figure 27**. Stalagmite Ko-1 was selected due to its good quality and appearance. The sample was also rather large, with relatively high growth rates. Additionally, Ko-1 was the only actively growing stalagmite in the interior part of Kocain Cave. Whilst other caves were visited in the area, all other stalagmites possessed dirty layers and U-Th dates were associated with large uncertainties. Furthermore, it is difficult to source good samples in the interior of Türkiye due to lower rainfall.

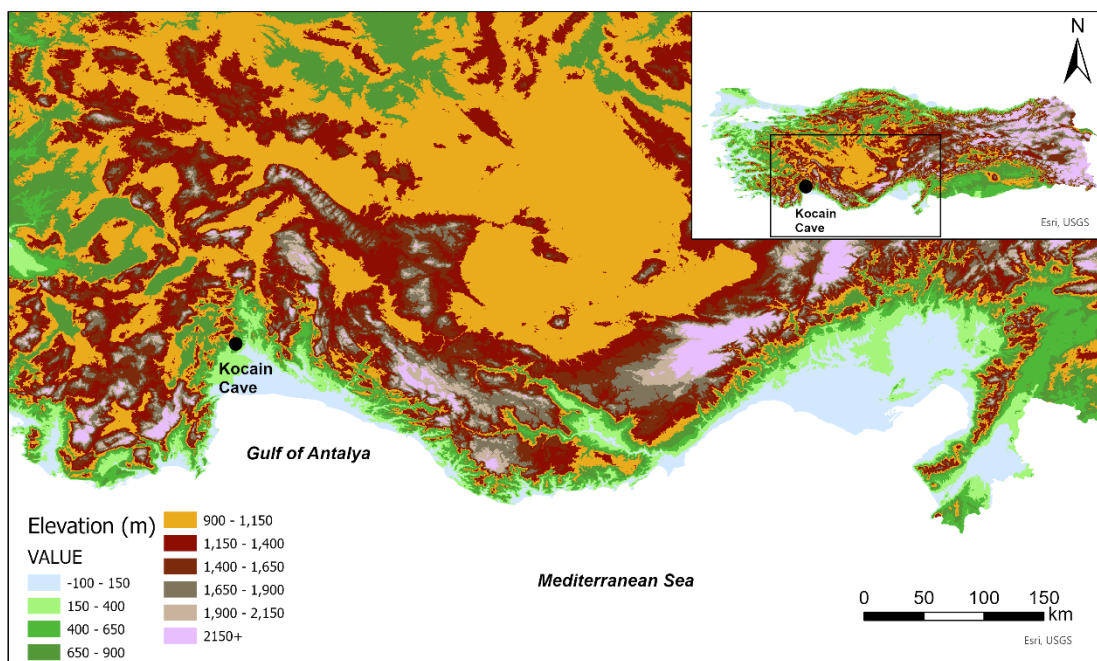


Figure 26. The location of Kocain Cave in southwestern Türkiye. SRTM1 Digital Elevation.

Source: author's original. Model data available from USGS (<https://earthexplorer.usgs.gov/>, accessed 30 January 2023).

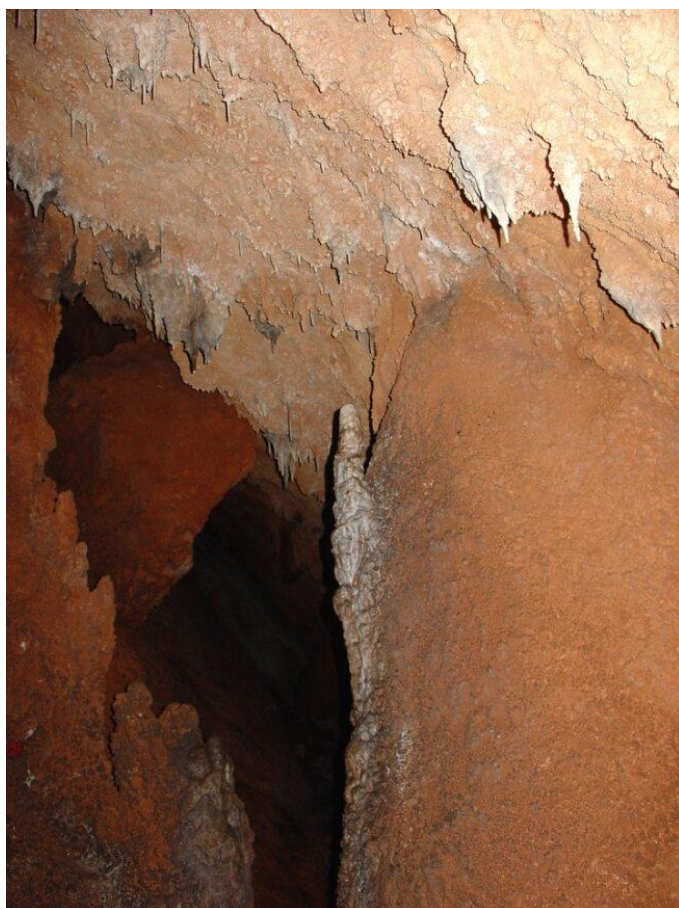


Figure 27. Photograph of Stalagmite Ko-1 located within Kocain Cave (37°13'57" N, 30°42'42" E) in southwestern Türkiye. Photo: Dominik Fleitmann, with permission.

Kocain Cave is located close to the coastline of the Mediterranean Sea, approximately 45km from coastal Antalya (Köppen classification Csa), which experiences a Mediterranean climate of hot, dry summers and mild, rainy winters. Modern meteorological data from the nearest station (Antalya, 36°52' N, 30°42' E, 49 m a.s.l) indicates that winter is the main hydrological season at the cave site, with an average of >200mm of precipitation experienced in Antalya during Dec-Feb (**Figure 28**). During the winter months, Antalya receives abundant orographic rainfall, with precipitation brought from westerly air masses from the Atlantic and storm tracks of the Mediterranean Sea as the ITCZ shifts southwards (Türkeş and Erlat, 2009). GNIP data from Türkiye also highlights the seasonality of precipitation across southwest Türkiye, as the range in average monthly rainfall ^{18}O ($^{18}\text{O}_p$) between lower values of around -6‰ (VSMOW) in winter and -3.41‰ (VSMOW) in summer is pronounced at ~3.28 ‰ (VSMOW) (IAEA/WMO, 2023). Modern meteorological data also identifies seasonal temperature variability in the region, with average minimum monthly temperature values of around 10°C in January, whilst

the average maximum monthly temperature of 28.5°C is reached during July (IAEA/WMO, 2023).

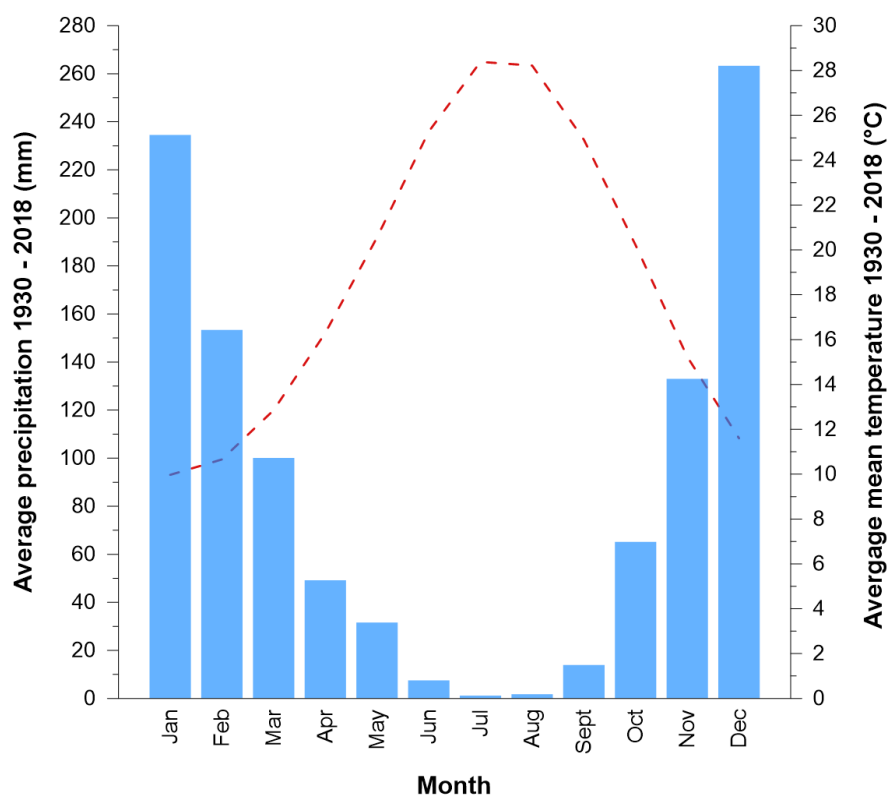


Figure 28. Average precipitation and average mean temperature at Antalya meteorological station from 1961-2018. Source: author's original. Data obtained from the KMNI Climate Explorer (<https://climexp.knmi.nl/>) (Van Oldenborgh, 2020).

4.2.4.2. Establishing the Chronology of Ko-1

To establish the chronology of Ko-1, ^{230}Th dating was performed using Thermo-Finnigan Neptune multi-collector inductively coupled plasma mass spectrometers (MC-ICP-MS) at Xi'an Jiaotong University, China, and the University of Minnesota, USA. Details of the methods used to determine ^{230}Th ages can be found in Cheng et al. (2013). Activity ratios and ages were calculated using the decay constants of Cheng et al. (2013). Corrected ^{230}Th ages assume the initial $^{230}\text{Th}/^{232}\text{Th}$ atomic ratio of $4.4 \pm 2.2 \times 10^{-6}$.

As stated in 4.2.2, this thesis has constructed an age-depth model using the algorithm StalAge (Scholz and Hoffmann, 2011). StalAge produces an age-depth model through the following key steps (Scholz and Hoffman, 2011). For further detail on StalAge modelling, see Scholz and Hoffman (2011).

- 1) Age data are screened to identify major outliers, which are points that are not stratigraphically in agreement with all other data points.
- 2) Age data are screened for minor outliers and age inversions. The uncertainty of potential outliers is increased using an iterative procedure.
- 3) The age model and corresponding 95%-confidence limits are calculated by a Monte-Carlo simulation fitting ensembles of straight lines to sub-sets of the age data.

4.2.4.3. Stable Isotope Analysis

Stable isotope analysis was performed on stalagmite Ko-1 between depths of 127.8 mm and 243.75 mm from the top, producing a total of 466 oxygen and carbon isotope measurements. Carbonate samples for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ analysis were obtained through the collection of calcite every 0.25 mm through the stalagmite. This was done using a CNC-driven Sherline micromill and ethanol-cleaned spatula and scalpel. Ko-1 drill tracks can be seen in **Figures 29 and 30**. Carbonate samples were weighed and analysed at the Department of Environmental Sciences, University of Basel. For stable isotope analysis, approximately 100-200 micrograms of carbonate were used for isotope analysis using a Thermo Scientific Delta V Plus IRMS connected to a GasBench II. Samples were loaded into glass vials and sealed with septa. The automated system flushes the vials with Helium and delivers anhydrous phosphoric acid to the carbonate at 90°C. The evolved CO_2 is collected and passed to the mass spectrometer.

Isotope values ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) are reported as per mill (‰) deviations of the isotopic ratios ($^{18}\text{O}/^{16}\text{O}$, $^{13}\text{C}/^{12}\text{C}$) calculated to the VPDB scale using a within-run laboratory standard calibrated against NBS-19. The 1σ standard deviation of the standard calcite (IAEA-613) was <0.08 ‰ for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$.

The results of Ko-1 stable isotope analysis are presented and discussed in Chapter 5.

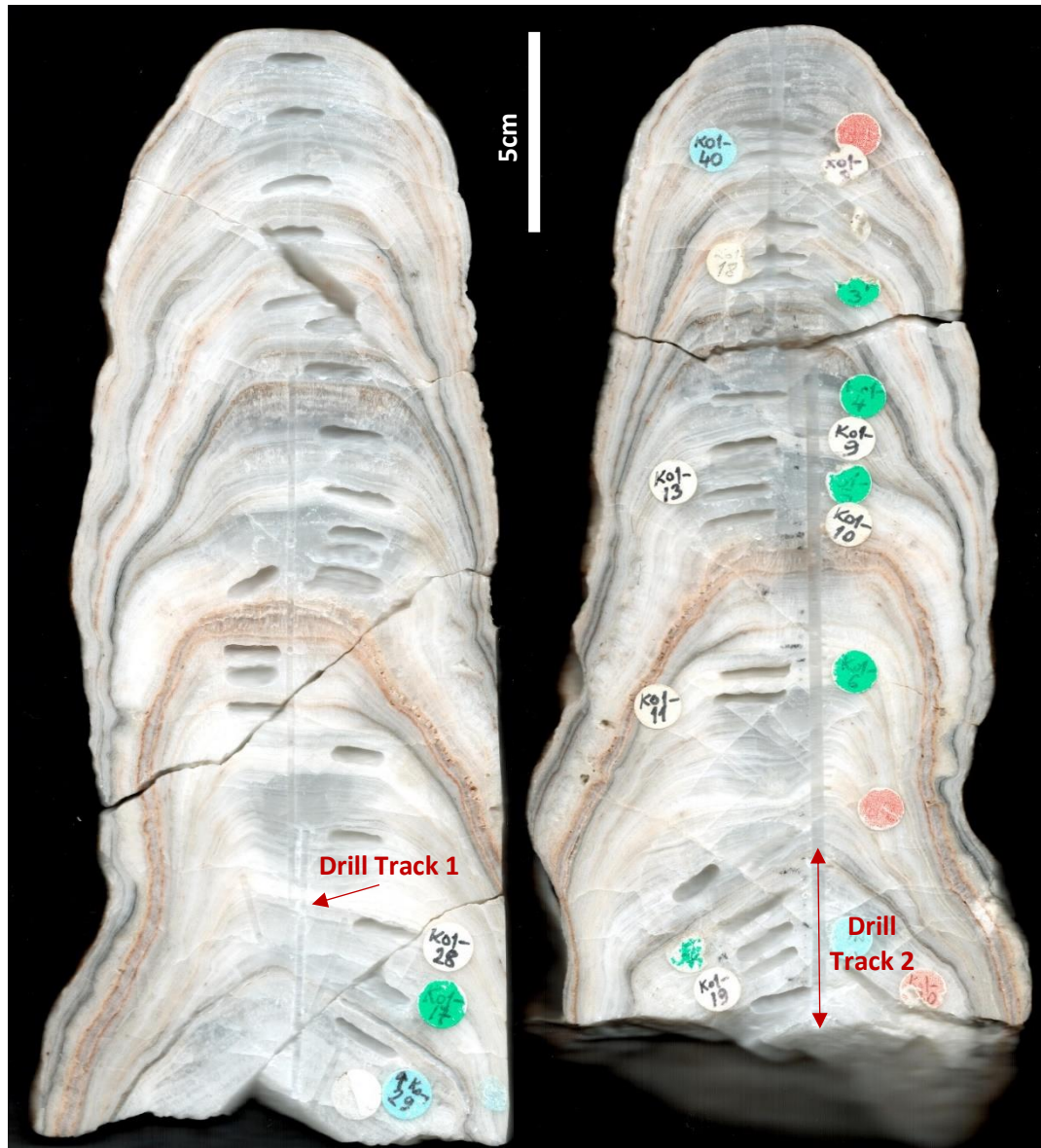


Figure 29. Scan images of the upper samples of Ko-1. Stable isotope drill tracks can also be seen.

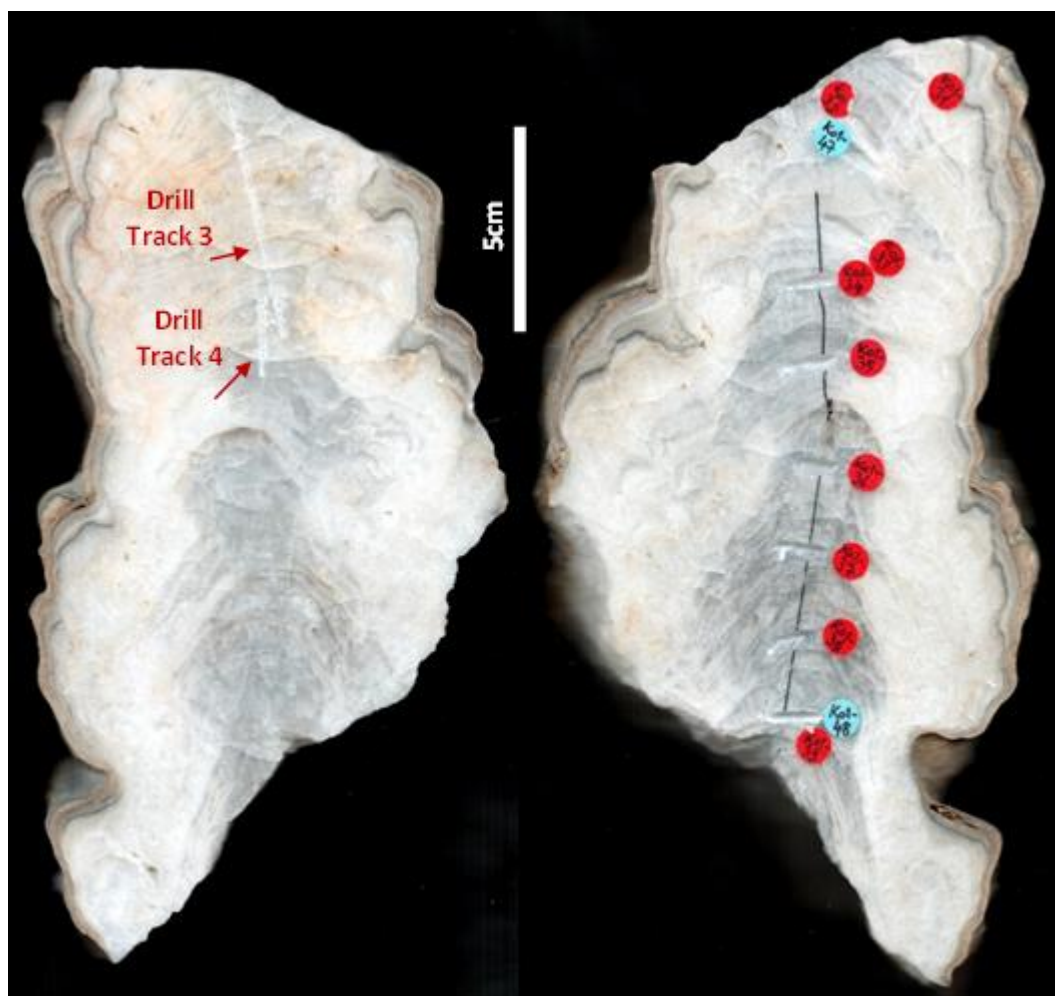


Figure 30. Scan images of the lower samples of Ko-1. Stable isotope drill tracks can also be seen.

4.3. Examination of Existing Proxy Records

Throughout the last few decades, a host of EM palaeoclimate proxy records covering the late Holocene, including the LBA-EIA transition period, have been developed. As presented in Chapter 2, several EM records have detected an apparent synchronous shift towards drier conditions across the LBA-EIA transition period from ca. 3.2 ka BP (e.g., Kaniewski et al. 2013; 2015; 2019a; 2019b; Langutt et al. 2013; 2015; Drake, 2012). However, several of these records (e.g., Eski Acigöl, Soreq) are associated with high temporal and chronological uncertainties. For example, the temporal resolution around 3.2 ka BP is ~ 100 yrs in the Soreq cave record. As these proxy records are associated with a high degree of chronological and temporal uncertainty, they cannot be considered robust or reliable enough to capture the

precise timing of a climatic event or any short-lived climate changes. Additionally, if proxy data is associated with high uncertainty, proxy data can be “moved around” to fit certain hypotheses (Blaauw, 2012). If time series possess a degree of flexibility for adaptability, proxy events may appear aligned and synchronous between archives, even if the raw data indicates asynchronicity (Blaauw, 2012). For example, proxy events may appear synchronous across records due to dating errors (Baillie, 1991). As several of the EM records are associated with a high degree of uncertainty, our understanding of the timing and scale of any climatic change across the region around 3.2 ka BP remains limited. If we are to reliably understand the spatiotemporal variability of past rainfall and temperature conditions during the LBA-EIA transition across the EM, we must examine robust proxy records.

This thesis will therefore provide a new critical assessment of existing EM proxy records through the examination of robust proxy records to identify any important changes in past rainfall and/or temperature variability, including any changes indicative of major and widespread climate changes, during the LBA-EIA transition.

Selection Criteria

The criteria for the inclusion of palaeoclimate proxy records in this review are discussed below.

- i) Proxy records must be located across the EM region, which is defined in this thesis as the region covering the Aegean, Türkiye and the Levant, as can be seen in **Figure 31**. Several proxy records from surrounding areas of the central Mediterranean and Middle East will also be examined. It is traditionally assumed that any major climate events or changes that were large in intensity and/or scale will be registered as proxy events across multiple regions (Blaauw, 2012). Following that reasoning, if the EM experienced a large climate event at ca. 3.2 ka BP there is also a possibility that records from bordering areas of the central Mediterranean and Middle East (ME) would also include evidence for such an event.
- ii) To identify major changes in climate variability and anomalies, proxy records must cover the 1000-year window of the 3.5-2.5 ka BP RCC event, which includes the LBA-EIA transition period of the EM. Any proxy records that do not cover this period will be excluded.
- iii) Proxy records must possess a robust chronology, as absolute age control and dating precision are of fundamental importance for palaeoclimatic reconstruction.

Each record must have at least one absolute date covering the 3.5-2.5 ka BP RCC event and, by inclusion, the LBA-EIA transition period. Any ^{14}C and U-Th dates with a standard deviation greater than 150 years have been excluded to minimize age uncertainties. Proxy records must possess a robust chronology as absolute age control is a fundamental variable which underlies palaeoclimatic reconstruction. Each record must have at least one absolute date which covers the 3.5-2.5 ka BP RCC, thus surrounding the LBA-EIA transition period. Any ^{14}C and U-Th dates with a standard deviation greater than 150 years have been excluded.

- iv) Each proxy record must possess a highly resolved time series. Each proxy record should be resolved with one sample at least every ~35 years or less. Selecting only high-resolution records allows us to better understand the rate of any climatic changes, such as the timing of any abrupt changes, without a smearing effect. Additionally, it becomes possible to identify any multi-year droughts and more accurately recognize the magnitude of any climatic events.
- v) Proxy signals should be directly correlated with a climate variable. As the EM is thought to have experienced both drier and cooler conditions across the LBA and EIA, this thesis will examine records that have been used to quantify past changes in hydroclimate and temperature conditions. Any proxy records which are related more to local processes such as erosion will not be included, to avoid unambiguous proxy interpretation.
- vi) All proxy records to be examined have been published in peer-reviewed journals and will be obtained from an intensive literature search with data accessed from either primary publications, or online repositories of primary data (e.g., the Pangea and NOAA databases) or obtained directly from the authors.

Eastern Mediterranean Hydroclimate and Temperature Proxy Records

It is important to highlight that whilst temperature records are included in this examination, EM temperature records of the late Holocene period are associated with several limitations. In contrast to the general abundance of hydroclimate proxy records across the EM, temperature reconstructions from the region are relatively scarce, thus limiting spatial coverage (Finné et al. 2011). Additionally, the chronological and temporal resolution of most temperature reconstructions is poor (centennial <) and so the palaeotemperature proxy records presented in this thesis are not sufficiently resolved to meaningfully compare with the high-resolution

hydroclimatic proxy records. Despite the weaknesses and limitations of existing palaeotemperature reconstruction across the EM region during the LBA-EIA transition period, temperature proxy records with poor temporal resolution and sub-optimal age control are not excluded from this examination. As Kaniewski et al. (2019b; 2020) suggest that the EM experienced significant temperature cooling at ca. 3.2 ka BP, temperature records must be examined in this thesis alongside highly resolved hydroclimate records, though age control and time series criteria cannot be applied to the few existing EM temperature records. Whilst poorly resolved temperature records introduce a high degree of uncertainty to our understanding of temperature conditions, they also provide information on any longer-term climate trends or patterns surrounding the LBA-EIA transition. Any identified trends or patterns in these temperature proxies can then also be examined against more robust hydroclimate records and tested against the existing climate hypothesis. This thesis will therefore examine more robust hydroclimate proxy records and less robust temperature proxy records.

Additionally, as any significant temperature cooling in the EM would originate from northerly sources it is important to also examine temperature proxy records from higher latitudes. Temperature records from the North Atlantic and Europe will therefore also be considered against EM records.

All hydroclimate and temperature proxy records that cover the LBA-EIA transition period across the EM considered for the examination of palaeoclimatic variability and change can be seen in **Figure 31** and Appendix A2.

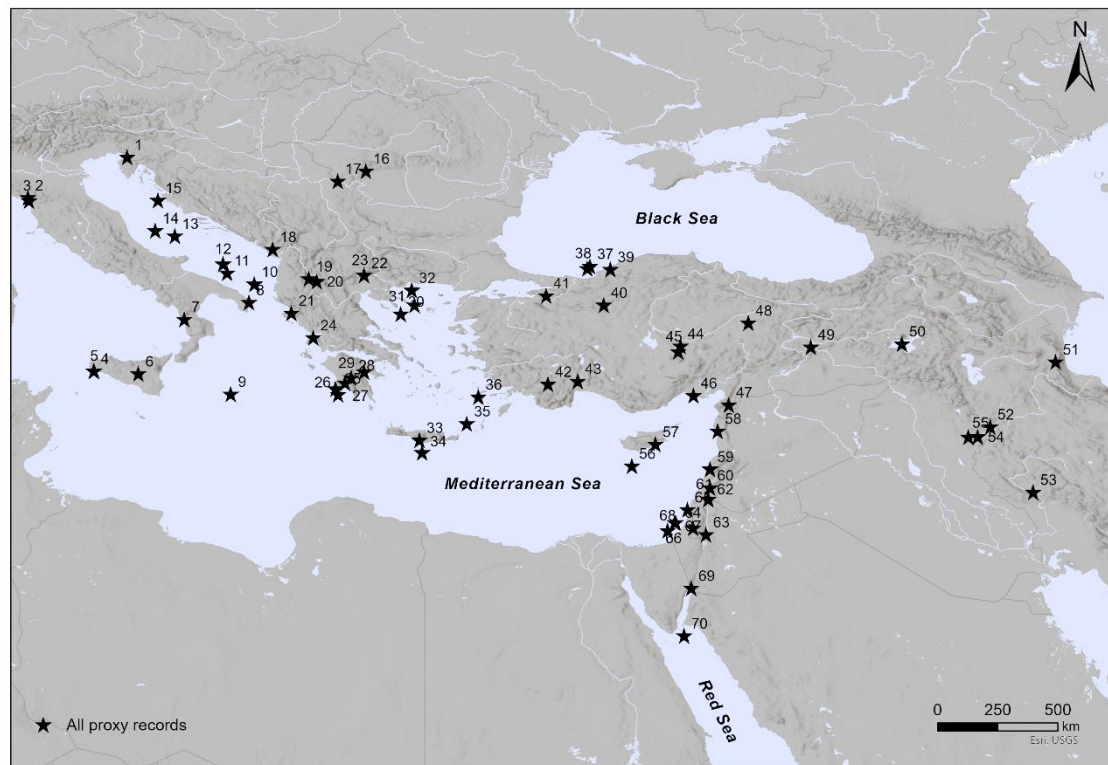


Figure 31. Map of the EM and surrounding areas displaying all palaeoclimatic proxies reviewed in the present study (black stars). Each proxy record and corresponding ID can be found in Appendix A2.

4.4. Establishing the Impact of Changes in Hydroclimate and Temperature Variability on LBA-EIA Societies of the Eastern Mediterranean

By applying the methodology presented in this chapter, it is possible to examine the impact of any hydroclimatic and/or temperature changes on the different societies of the EM during the LBA-EIA transition period. In the EM, a region sensitive to water scarcity, we would expect any major reduction in precipitation amount to impact crop productivity negatively due to reduced soil moisture. Colder temperature conditions can also affect crop yields, as low-temperature stress can impair crop growth. Ultimately low crop productivity can result in poor harvest and disrupted food supply, which is significant given societies' reliance on the stable availability of food resources (Gaastra et al. 2021). Significantly, a common assumption in studies interested in the impact of climate change on societies is that disrupted growing seasons lead to famine, potentially leading to societal “collapse” (Degroot et al. 2021). For example, as introduced in

Chapter 1, Weiss (2017) has suggested that a major precipitation decline in Mesopotamia at ca. 4.2 ka BP led to agricultural failure and, ultimately, the collapse of the Akkadian Empire.

To understand the possible implications of any LBA-EIA climate changes on the lives of EM societies and determine whether climate played a contributory role in the end of the LBA of the EM, we must consider the results of palaeoclimatic analysis (see Chapter 5) against the archaeological evidence presented in Chapter 3. To establish whether climate change contributed to the end of the LBA across the EM Chapter 6 will therefore assess the results of archaeological and palaeoclimate examination presented in this thesis.

Chapter 5 - Results and Interpretation

To further understand the climate conditions of Türkiye across the LBA-EIA transition, this chapter presents new high-resolution stable isotope data from Kocain Cave in southwest Türkiye and also examines existing palaeoclimatic proxy records to present a synthesis of hydroclimatic and temperature conditions across the wider EM during the LBA and the transition into the IA. Results of the new Ko-1 record will also be considered against the existing proxy records, including other highly resolved records from Türkiye, to investigate LBA-EIA climatic conditions across Türkiye and the wider EM region.

5.1. Results of Ko-1 Analysis

New oxygen and carbon stable isotope records for stalagmite Ko-1 from Kocain Cave are presented here, covering the late Holocene and the LBA-EIA transition.

5.1.1. Age-depth Model

A total of 30 U-Th ages have been determined for speleothem Ko-1 (see **Table 8**). 20 U-Th ages were used to construct the chronology of the new Ko-1 record using StalAge (Scholz and Hoffman, 2011). The remaining 10 U-Th ages were excluded from the age model due to the presence of significant detrital contamination ($^{230}\text{Th}/^{232}\text{Th}$ ratios <30), age inversions and high 2σ -age errors (>150 yrs). The year of collection of Ko-1 (2005) was also used as the top age to constrain the model. The age-depth model for Ko-1 is shown in **Figure 32**.

Table 8. Measured U/Th isotope activity ratios and calculated ages for stalagmite Ko-1 with 2σ error. Ages that show significant detrital contamination, age inversions and high age errors are shaded grey in this table and were rejected from the age-depth model. Activity ratios and ages were calculated using the decay constants of Cheng et al. (2013).

* $\delta^{234}\text{U} = ([^{234}\text{U}/^{238}\text{U}]_{\text{activity}} - 1) \times 1000$.

** $\delta^{234}\text{U}_{\text{initial}}$ was calculated based on ^{230}Th age (T), i.e., $\delta^{234}\text{U}_{\text{initial}} = \delta^{234}\text{U}_{\text{measured}} \times e^{234 \times T}$. Corrected ^{230}Th ages assume the initial $^{230}\text{Th}/^{232}\text{Th}$ atomic ratio of $4.4 \pm 2.2 \times 10^{-6}$. Those are the values for a material at secular equilibrium, with the bulk earth $^{232}\text{Th}/^{238}\text{U}$ value of 3.8. The errors are arbitrarily assumed to be 50%.

***B.P. stands for “Before Present,” where the Present is defined as the year 1950 C.E.

Sample	Depth	^{238}U		^{232}Th		$^{230}\text{Th} / ^{232}\text{Th}$		$\delta^{234}\text{U}^*$		$^{230}\text{Th} / ^{238}\text{U}$		^{230}Th Age (yr)		^{230}Th Age (yr)		$\delta^{234}\text{U}_{\text{initial}}^{**}$		^{230}Th Age (yr BP)***	
Number	(mm from top)	(ppb)		(ppt)		(atomic $\times 10^{-6}$)		(measured)		(activity)		(uncorrected)		(corrected)		(corrected)		(corrected)	
Ko-1-20	5	109.3	± 0.1	321	± 6	14	± 2	514.7	± 2.1	0.0025	± 0.0004	177	± 32	120	± 51	515	± 2	61	± 51
Ko-1-21	13.2	99.0	± 0.1	153	± 3	32	± 5	518.4	± 2.3	0.0031	± 0.0005	219	± 34	190	± 40	519	± 2	131	± 40
Ko1-40	21.2	81.0	± 0.1	137	± 3	49	± 6	508.3	± 1.6	0.0051	± 0.0006	366	± 46	333	± 51	509	± 2	273	± 51
Ko-1-14	24.1	87.2	± 0.1	348	± 7	31	± 2	510.2	± 1.7	0.0075	± 0.0005	545	± 37	468	± 66	511	± 2	409	± 66
Ko-1-22	32.5	86.5	± 0.1	247	± 5	49	± 3	508.6	± 3.1	0.0085	± 0.0006	613	± 40	558	± 56	509	± 3	499	± 56
Ko-1-15	43	94.2	± 0.1	334	± 7	57	± 2	516.9	± 2.0	0.0123	± 0.0004	889	± 29	821	± 56	518	± 2	762	± 56
Ko-1-23	47	102.3	± 0.1	433	± 9	48	± 2	514.2	± 2.5	0.0122	± 0.0005	882	± 34	801	± 67	515	± 3	742	± 67
Ko-1-41	53.9	70.4	± 0.1	283	± 6	64	± 3	487.4	± 2.3	0.0156	± 0.0008	1150	± 56	1071	± 79	489	± 2	1011	± 79

Ko-1-42	63.7	98.5	±0.1	222	±5	102	±5	500.3	±1.8	0.0140	±0.0006	1019	±47	975	±56	502	±2	915	±56
Ko-1-24	64.7	104.3	±0.1	597	±12	48	±2	506.5	±2.2	0.0165	±0.0005	1203	±35	1092	±86	508	±2	1033	±86
Ko1-43	73.9	84.5	±0.1	235	±5	95	±4	498.4	±2.0	0.0160	±0.0006	1173	±43	1119	±57	500	±2	1059	±57
Ko-1-16	79	99.0	±0.1	169	±3	166	±5	508.0	±1.5	0.0172	±0.0004	1254	±30	1221	±38	510	±2	1162	±38
Ko-1-49	83.6	94.4	±0.1	396	±8	90	±3	501.9	±1.8	0.023	±0.0005	1684	±37	1603	±68	504	±2	1532	68
Ko-1-25	86.4	98.3	±0.1	921	±18	42	±1	506.3	±2.6	0.0238	±0.0005	1738	±38	1558	±133	508	±3	1499	±133
Ko-1-44	88.9	90.5	±0.1	727	±15	49	±2	506.6	±2.8	0.0237	±0.0006	1729	±41	1574	±117	509	±3	1514	±117
Ko-1-50	90	84.8	±0.1	7960	±159	13	±0	498.8	±2.0	0.0768	±0.0016	5723	±120	3894	±1301	504	±3	3823	1301
Ko-1-45	99.7	95.3	±0.2	3077	±62	20	±1	507.1	±2.7	0.0388	±0.0005	2841	±41	2217	±443	510	±3	2157	±443
Ko-1-51	105	99.8	±0.2	621	±13	88	±2	512.4	±2.8	0.0332	±0.0005	2418	±37	2298	±92	516	±3	2227	92
Ko-1-46	109	132.8	±0.3	247	±5	223	±6	516.1	±3.0	0.0252	±0.0004	1825	±28	1789	±38	519	±3	1729	±38
Ko-1-26	114.6	131.3	±0.2	374	±8	166	±4	514.5	±2.7	0.0287	±0.0004	2088	±29	2033	±48	517	±3	1974	±48

Ko-1-27	127.8	118.5	±0.1	453	±9	145	±3	518.0	±2.6	0.0336	±0.0004	2437	±32	2363	±61	521	±3	2304	±61
Ko-1-28	139.5	94.1	±0.1	513	±10	114	±3	525.7	±3.3	0.0376	±0.0006	2715	±41	2611	±84	530	±3	2552	±84
Ko-1-17	147.5	102.0	±0.1	1403	±28	53	±1	530.1	±1.6	0.0446	±0.0006	3219	±41	2958	±189	535	±2	2899	±189
Ko-1-29	154.3	93.1	±0.1	2860	±57	29	±1	543.4	±2.3	0.0545	±0.0006	3911	±46	3332	±412	549	±2	3273	±412
Ko-1-31	177.4	92.0	±0.1	482	±10	157.2	±3.6	558.3	±2.1	0.0499	±0.0006	3543	±40	3446	±80	564	±2	3387	±80
Ko-1-32	190.6	84.7	±0.1	1126	±23	71	±2	561.5	±2.1	0.0573	±0.0006	4067	±43	3819	±180	568	±2	3760	±180
Ko-1-47	195.6	80.9	±0.1	924	±19	91	±2	562.1	±2.7	0.0629	±0.0007	4474	±50	4262	±158	569	±3	4202	±158
Ko-1-33	214.6	90.9	±0.1	238	±5	358	±8	571.3	±2.1	0.0569	±0.0005	4011	±40	3963	±52	578	±2	3904	±52
Ko-1-34	226.6	117.5	±0.1	153	±3	744	±16	595.6	±2.1	0.0586	±0.0004	4071	±32	4047	±36	602	±2	3988	±36
Ko-1-35	243.6	101.1	±0.1	97	±2	1059	±24	591.2	±2.4	0.0616	±0.0005	4294	±36	4276	±38	598	±2	4217	±38

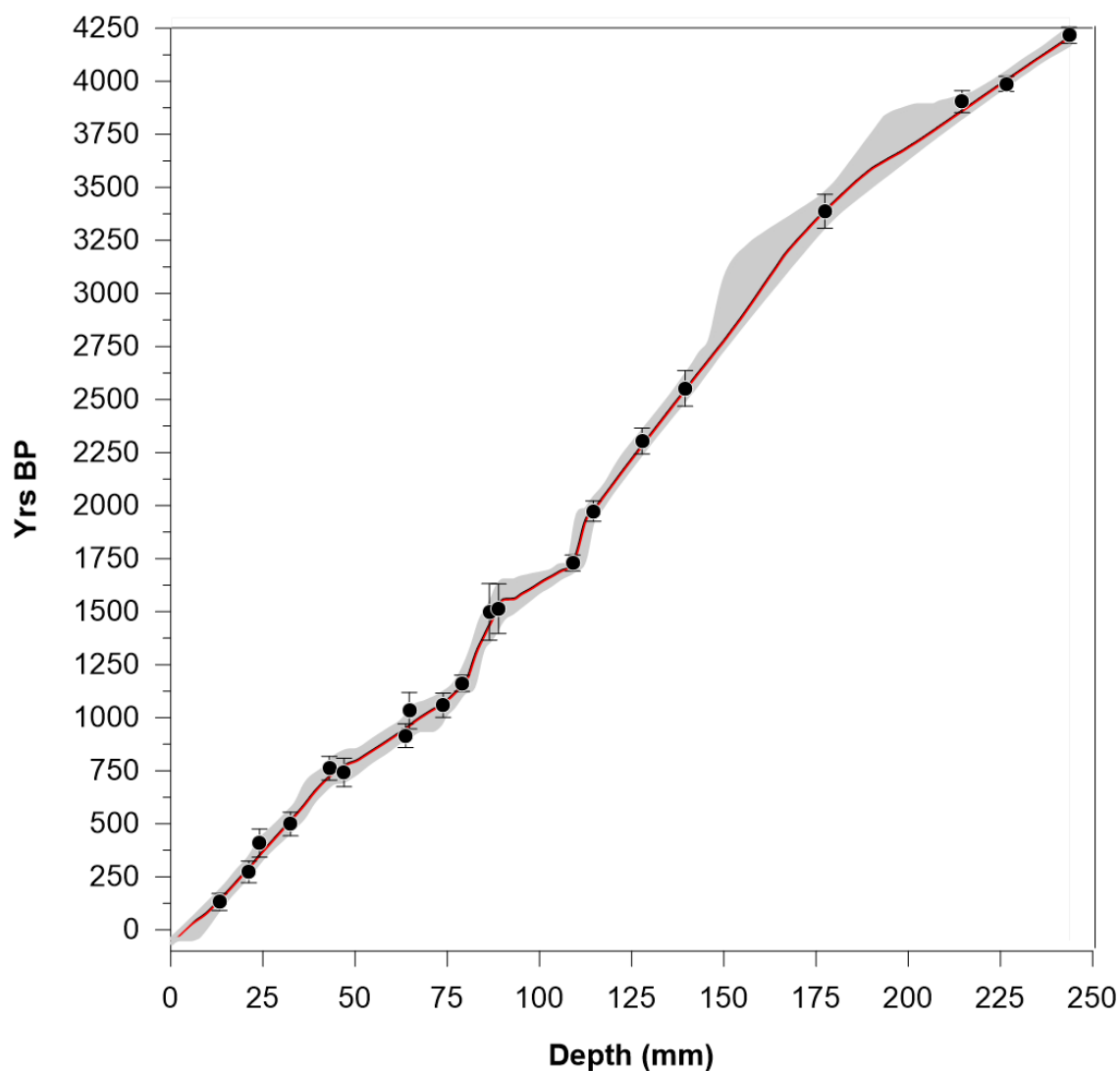


Figure 32. StalAge age-depth model (red line) constructed for stalagmite Ko-1 (Scholz and Hoffmann, 2011). Black circles are the 20 U-Th dates (see **Table 8**) used to produce the age model with their associated error bars (2σ). Grey shading indicates the 95% confidence interval for the age model. Source: Author's original.

5.1.2. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ Results

$\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles obtained from each of the three Ko-1 drill tracks (see Appendix A1 for the isotope profiles of each drill track) have been combined to present a composite stable isotope record for Ko-1 from ca. 4.21 ka BP to 2.29 ka BP (2262-339 BCE) which can be seen in **Figure 33**. The sampling resolution for the Kocain record is, on average, 4 years.

Ko-1 $\delta^{18}\text{O}$ values range from -3.17 to -4.27‰, with a mean value of -3.80‰ whilst $\delta^{13}\text{C}$ values range from -2.36 to -9.52‰, around a mean value of -5.51‰. Between approx. 4.2 ka BP and 3.9 ka BP $\delta^{18}\text{O}$ values vary around -4‰, interrupted by a significant period of higher $\delta^{18}\text{O}$ identified at ca. 4.1 ka BP. A rather gradual increase in Ko-1 $\delta^{18}\text{O}$ values from -4.2‰ to -3.2‰ is exhibited from approx. 3.85 ka BP to 3.65 ka BP. Following this period of higher $\delta^{18}\text{O}$, two short intervals of more negative $\delta^{18}\text{O}$ values can be identified at ~3.6 ka BP and ~3.5 ka BP. From ca. 3.5 ka BP to around 3.4 ka BP, an increase in $\delta^{18}\text{O}$ values from approx. -4.2‰ to values of around -3.5‰ can be identified. Between 3.4 ka BP and 3.25 ka BP, a decrease in Ko-1 $\delta^{18}\text{O}$ can be identified, interrupted by a short excursion to back to values of approx. -3.5‰ at ~3.3 ka BP. A marked increase in Ko-1 $\delta^{18}\text{O}$ can be identified from ca. 3.25 ka BP (-4‰) to ca. 3.15 ka BP (-3.3‰). Between ca. 3.15 ka BP (-3.3‰) and 2.29 ka BP (-4‰), a long-term shift towards more negative values can be identified in the $\delta^{18}\text{O}$ profile. Several high-amplitude fluctuations in Ko-1 $\delta^{18}\text{O}$ can also be seen superimposed over this multi-centennial trend towards more negative $\delta^{18}\text{O}$ values. For example, isotopic fluctuations can be identified at ca. 3.05 ka BP (-3.95‰), ca. 2.96 ka BP (-4.03‰) and 2.91 ka BP (-4.14‰). Smaller isotopic fluctuations can also be seen after 2.7 ka BP, including a decrease in $\delta^{18}\text{O}$ values at ca. 2.55 ka BP (-3.6‰).

As seen in the $\delta^{18}\text{O}$ profile, an abrupt and significant increase in Ko-1 $\delta^{13}\text{C}$ values from around -8‰ to -3‰. can also be seen around 4.2 ka BP. The $\delta^{13}\text{C}$ record, however, presents a short deviation from the $\delta^{18}\text{O}$ signal towards higher values (-3‰) at ca. 3.9 ka BP. From around 3.85 ka BP to ca. 2.29 ka BP, the $\delta^{13}\text{C}$ profile generally presents similar variability to the $\delta^{18}\text{O}$ profile. An increase in Ko-1 $\delta^{13}\text{C}$ values can be identified from ca. 3.85 ka BP (-6.20‰) to 3.7 ka BP (-2.36‰). Following this period of higher $\delta^{13}\text{C}$, a decrease in $\delta^{13}\text{C}$ values can be seen until approx. 3.58 ka BP (-7.34‰), although two short intervals of higher $\delta^{18}\text{O}$ can also be identified at 3.64 ka BP (-4.68‰) and 3.6 ka BP (-4.71‰). From ca. 3.6 ka BP to around 3.53 ka BP, an increase in $\delta^{13}\text{C}$ values can be identified from approx. -7.13‰ to -3.35‰, though this increase in isotopic values is also briefly interrupted by a short depletion in values at ca. 3.58 ka BP. Between 3.53 ka BP and 3.5 ka BP, a short episode of lower $\delta^{13}\text{C}$ can also be identified (around -6.5‰). An increase in $\delta^{13}\text{C}$ values from -6.5‰ to -3.4‰ can be seen from ca. 3.5 ka BP to ca. 3.39 ka BP. However, this interval also sees a high amplitude excursion towards more negative $\delta^{13}\text{C}$ values (-6.3‰) at around 3.42 ka BP. Between 3.39 ka BP and 3.31 ka BP, there is a shift towards more negative $\delta^{13}\text{C}$ values (-7.16‰ at 3.31 ka BP). From ca. 3.31 ka BP to ca. 3.28 ka BP, a sharp increase in $\delta^{13}\text{C}$ values can be identified (-4.16‰ at 3.28 ka BP). Following this period of more positive $\delta^{13}\text{C}$, $\delta^{13}\text{C}$ values become more negative between 3.28 ka BP and 3.23

ka BP (-4.16 ‰ to -6.7‰). As also seen in the Ko-1 $\delta^{18}\text{O}$ signal, a marked reduction can also be identified in the $\delta^{13}\text{C}$ signal from ca. 3.23 ka BP (-6.7‰) to 3.16 ka BP (-3.37‰). A long-term trend towards lower isotopic values can be identified in the $\delta^{13}\text{C}$ signal from ca. 3.16 ka BP to 2.29 ka BP (-3.37‰ to -9‰), which is also seen in the $\delta^{18}\text{O}$ profile. Whilst the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles of Ko-1 generally present similar isotopic variability, the magnitude of isotopic fluctuations is less pronounced in the $\delta^{13}\text{C}$ profile. Isotopic fluctuations in the $\delta^{13}\text{C}$ signal can be identified at ca. 3.05 ka BP (-6.6‰), ca. 2.96 ka BP (-6.2‰) and 2.81 ka BP (-6.8‰). Additionally, unlike the $\delta^{18}\text{O}$ signal, an increase in $\delta^{13}\text{C}$ values can be seen between ca. 2.44 ka BP (-9.5‰) and 2.33 ka BP (-6.9‰). A return to more negative $\delta^{13}\text{C}$ values can be seen from ca. 2.33 ka BP until the end of the record at 2.29 ka BP (-9‰).

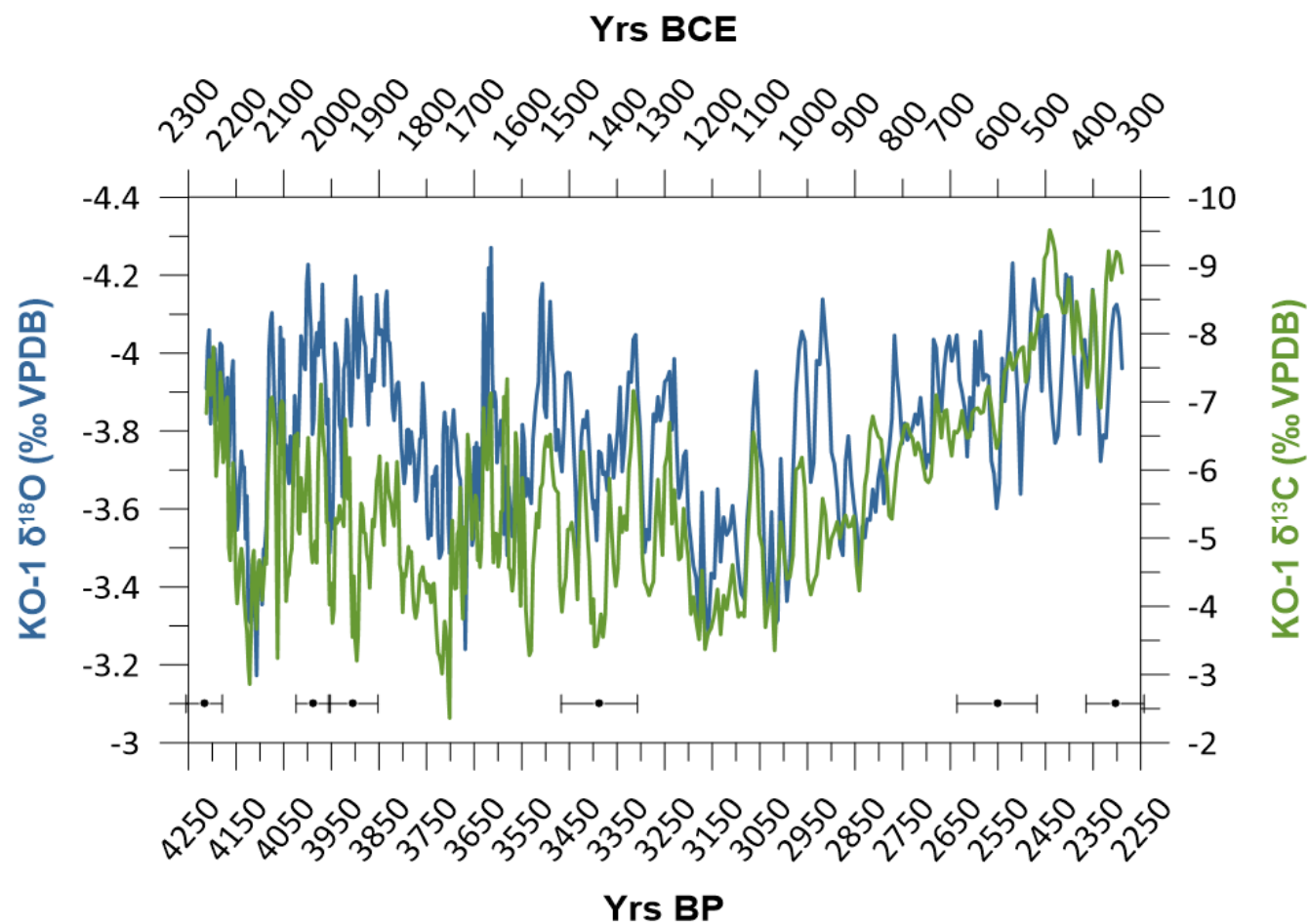


Figure 33. Ko-1 Stable isotopes plotted against years BP and BCE. The Ko-1 $\delta^{18}\text{O}$ profile is presented in blue, whilst the $\delta^{13}\text{C}$ profile is presented in green. Ko-1 U-Th ages and their associated errors (2σ) are also presented. Source: Author's original.

5.1.2.1. Interpretation of the Ko-1 Record

As kinetic fractionation can obscure the primary climate signal preserved in speleothem calcite, testing the degree of isotopic equilibrium in speleothems is important (Lachniet, 2009). Due to the low growth rate and difficulty of extracting isotope samples from a single growth layer from Ko-1, the ‘Hendy Test’ could not be applied to Ko-1 (Hendy, 1971). At the time of writing, stalagmite comparisons could not be made due to the absence of additional stalagmite datasets in the nearby vicinity of the cave.

A strong positive correlation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles ($r = 0.6$, $p < 0.01$) reflects the deposition of Ko-1 calcite under non-equilibrium conditions, which is common for stalagmites forming in caves in semi-arid environments as summarized in Chapter 4 (e.g., Fleitmann et al. 2004).

To understand the main factors influencing Ko-1 drip water $\delta^{18}\text{O}$, GNIP data from the nearby Antalya meteorological station (IAEA/WMO, 2023) have been examined, as at the time of writing, cave monitoring data from Kocain loggers could not be accessed during COVID-19 years. The strong negative correlation between GNIP monthly averages of precipitation amount ($\delta^{18}\text{O}_p$) and $\delta^{18}\text{O}$ ($r = -0.94$, $p < 0.0001$) is indicative of the “amount effect” (Dansgaard, 1964), whilst the strong positive correlation between monthly averages of air temperature and $\delta^{18}\text{O}_p$ across Antalya is indicative of temperature effects ($r = 0.88$, $p < 0.0001$). Therefore, fluctuations in $\delta^{18}\text{O}$ in Ko-1 drip water are likely related to climatic conditions above the cave. Ko-1 $\delta^{18}\text{O}$ is also most likely influenced by the seasonal distribution of rainfall above the cave, as the isotopic composition of rainfall differs across the seasons, with the precipitation of isotopically lighter $\delta^{18}\text{O}$ in winter rainfall compared to the summer months. The influence of seasonality on Ko-1 $\delta^{18}\text{O}$ values has also previously been suggested by Jacobson (2021: 52).

A positive correlation between Mg/Ca and Sr/Ca in the existing Ko-1 record of Jacobson et al. (2021) ($r = 0.57$, $p < 0.0001$) also appears to demonstrate the influence of Prior Calcite Precipitation (PCP) on the Ko-1 record. During periods of increased aridity, enhanced Prior Calcite Precipitation (PCP) increases $\delta^{13}\text{C}$ ratios and trace element ratios (Mg/Ca, Sr/Ca) due to the preferential deposition of Ca^{2+} and fractionation of ^{12}C due to enhanced degassing (Fairchild and Treble, 2009). Higher $\delta^{13}\text{C}$ values in Ko-1 due to PCP, therefore, suggest more arid conditions. As discussed in Chapter 4, vegetation and/or soil activity above the cave can also have a large influence on

speleothem $\delta^{13}\text{C}$. For example, periods of low effective moisture can induce sparse vegetation and reduced CO_2 production, resulting in higher $\delta^{13}\text{C}$ values (Cheng et al. 2015). P/Ca for Ko-1 was also analysed previously by Jacobson et al. (2021). Whilst the interpretation of P is less certain than other speleothem proxies, P is also considered a proxy for hydrological variability, as there appears to be a link between increases in rainfall and the increased release and transport of P during intensive soil infiltration (Johnson et al. 2006; Treble et al. 2003; Fairchild et al. 2007). Lower ratios of P are thought to be linked to cooler and drier conditions, which reduce vegetation and soil biological activity (Fairchild and Treble, 2009). As demonstrated by Jacobson et al. (2021), the influence of effective moisture on P/Ca is supported by strong correlations with Mg/Ca ($r=-0.60$, $p<0.0001$) and Sr/Ca ($r=-0.87$, $p<0.0001$). Changes in Ko-1 $\delta^{13}\text{C}$ and Ko-1 trace element ratios previously examined by Jacobson et al. (2021), therefore, also indicate the influence of effective moisture on stalagmite Ko-1.

Based on the above, including corroborating Ko-1 analysis undertaken by Jacobson et al. (2021), the strong agreement between high-magnitude changes in the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles suggests that Ko-1 isotopic variability generally reflects hydrological changes. The interpretation of Ko-1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ as proxies for hydroclimate changes supports previous studies of speleothem $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in the EM, as introduced in Chapter 4 (e.g., Bar Matthews et al. 2003; Fleitmann et al. 2009; Cheng et al. 2015).

Summary

As highlighted above, the variability of Ko-1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles can be attributed to hydrological changes and changes in effective moisture. The new Ko-1 record of this thesis can, therefore, be used to inform our understanding of hydroclimatic changes in the Antalya region of Türkiye during the Late Holocene and, more specifically, across the LBA-EIA transition period. It is, however, also important to recognize that the variability of Ko-1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values may be amplified by kinetic effects, which can enhance climatic signals. It is also important to recognize that temperature and seasonality across Antalya, as demonstrated by the local GNIP data, may also influence the Ko-1 record. However, at the time of writing, the influence of temperature and seasonality on the Ko-1 record cannot be proven due to the absence of cave monitoring data for Kocain Cave. Therefore, further monitoring of Kocain Cave is required for further research (see Chapter 7).

5.1.2.2. Palaeoclimatic Inferences from the Ko-1 Record

As Ko-1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ signals are predominantly thought to reflect changes in hydroclimatic conditions, higher isotope values indicate a shift towards drier conditions, likely reflecting a reduction of rainfall. Notable climatic variability is discernible across the Ko-1 record, as reflected by distinctive multidecadal to centennial-scale intervals of wetter and drier conditions (see **Figure 34**). Towards the start of the Ko-1 record, both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles present rapid and high magnitude positive shifts of values (-4‰ to -3.2‰ and -8‰ to -3‰ respectively) indicative of a dry event between 4.15 and 4.1 ka BP (2200-2150 BCE). This dry interval deserves further analysis and discussion as it falls around 4.2 ka BP but will not be discussed here due to the LBA-EIA focus of this thesis. An increase in both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values can also be identified between ca. 3.85 ka BP (1900 BCE) and 3.65 ka BP (1700 BCE), indicative of a multi-centennial trend of increasing aridity, which was followed by a multi-decadal period of wetter conditions around 3.6 ka BP (1650 BCE). Following this period of wetter conditions, an increase in $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ can be identified until ca. 3.39 ka BP (1440 BCE) with values of -3.52‰ and -3.42‰ indicative of drier conditions. A return to wetter conditions can be seen from 3.39 ka BP (1440 BCE) as indicated by lower $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values (-4.04‰ and -7.16‰). This was, however, followed by more positive $\delta^{18}\text{O}$ (-3.49‰) and $\delta^{13}\text{C}$ (-4.16‰) at ca. 3.29 ka BP (1340 BCE), indicative of a short but pronounced dry event. A marked dry event can also be seen in Ko-1 between ca. 3.25-3.15 ka BP (1250-1200 BCE) identified in both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles, as reflected by a shift from values of approx. -4.1‰ to -3.3‰ in $\delta^{18}\text{O}$ and approx. -6.5‰ to -3‰ in $\delta^{13}\text{C}$. This dry event was followed by a long-term shift towards wetter conditions from 3.15 ka BP (1200 BCE) onwards. Whilst this almost millennial scale trend towards wetter conditions can be observed in the $\delta^{18}\text{O}$ profile, it is much more pronounced in the $\delta^{13}\text{C}$ record, with the lowest $\delta^{13}\text{C}$ values (between -9‰ and -10‰) observed towards the youngest part of the record from ca. 2.45 ka BP. Decadal to centennial periods of variability are also superimposed within this long-term trend towards wetter conditions, including a decrease in isotope values around 3.05 ka BP (1100 BCE). After 3.05 ka BP, greater variability is exhibited in Ko-1 $\delta^{18}\text{O}$ compared to $\delta^{13}\text{C}$, which may reflect noise within the proxy signal.

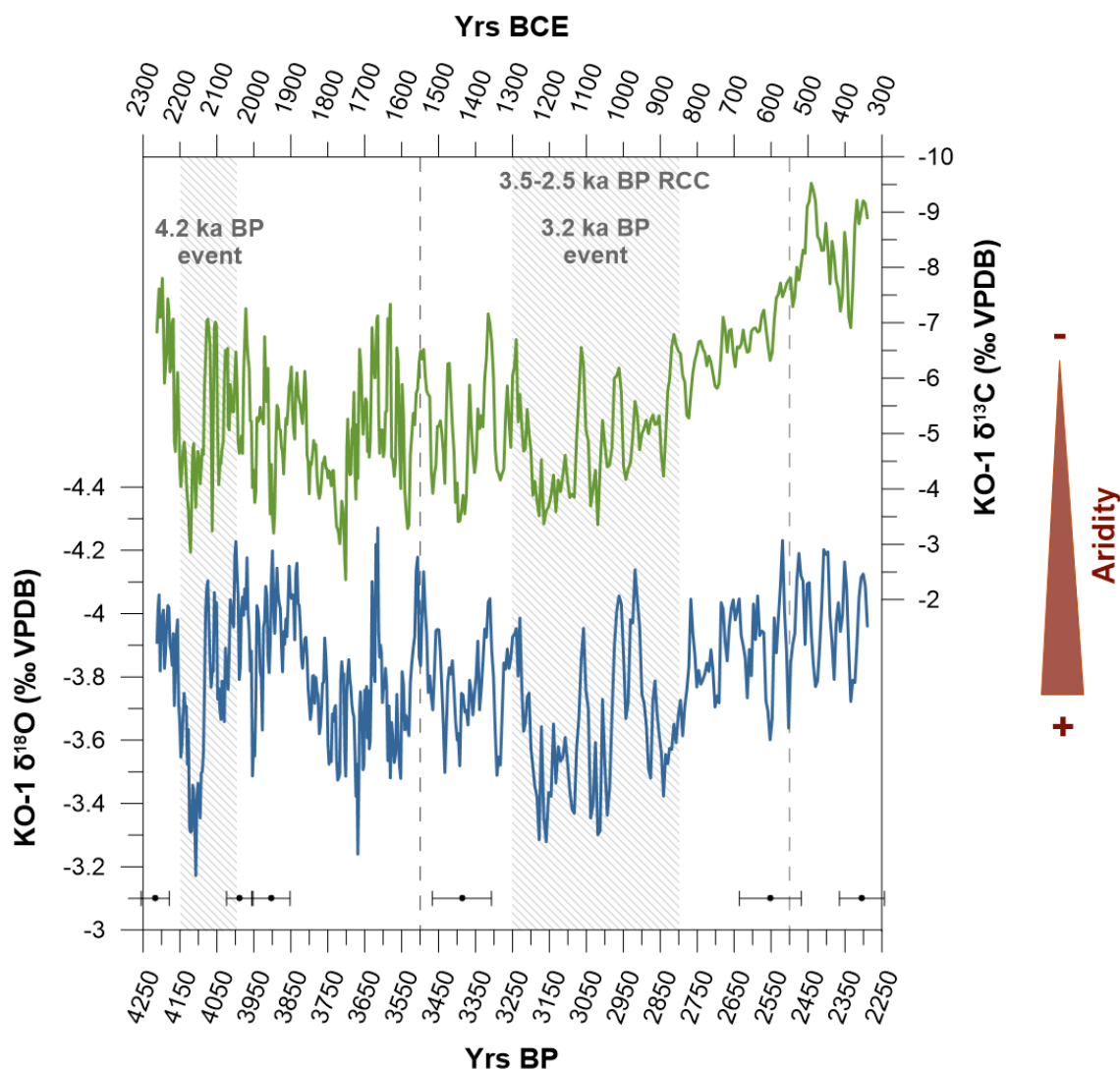


Figure 34. Hydroclimatic variability in Ko-1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles, demonstrating major changes and trends between 4.21 ka BP to 2.29 ka BP. Ko-1 U-Th ages and their associated errors (2σ) are also presented. Grey shaded bars indicate the 4.2 ka BP and 3.2 ka BP events, whilst dashed lines indicate the 3.5-2.5 ka BP RCC event. Source: Author's original.

5.2. Examination of Existing Eastern Mediterranean Proxy Records

Over 70 proxy records located across the EM and areas beyond the EM were obtained from an extensive literature search (see Appendix A2). Hydroclimate and temperature records that met the selection criteria outlined in Chapter 4 are considered key records and will be examined here. As

introduced in 4.3, several proxy records from the North Atlantic and Europe will also be examined in this chapter against the key temperature records. For a map of all proxy records discussed in this section, see **Figure 35**.

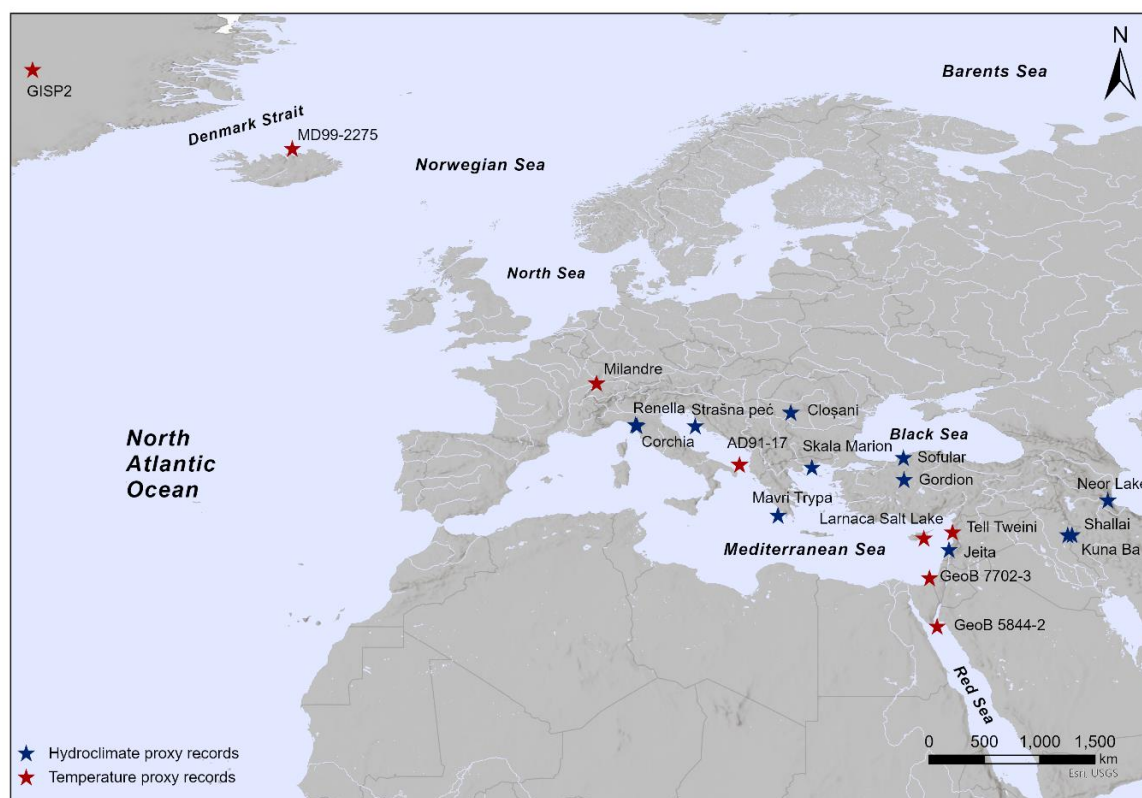


Figure 35. Map of hydroclimate and temperature proxy records discussed in this chapter across the North Atlantic, Europe and the eastern Mediterranean. Source: Author's original.

5.2.1. Hydroclimate Conditions

Of all existing hydroclimate proxy records which cover the LBA-EIA transition across the EM and bordering areas, 15 records pass the selection criteria outlined in Chapter 4. Each record is resolved to around 30-35 yrs between samples and possesses at least one radiometric date between 3.5-2.5 ka BP (see **Table 9**).

Table 9. Key hydroclimatic proxy records from the Adriatic to the Middle East.

Record	Location	Archive type	Proxy type	Temporal resolution in yrs (3.5-2.5 ka BP)	Reference
Renella	Italy	Speleothem	$\delta^{18}\text{O}$	8	Drysdale et al. 2006; Zanchetta et al. 2016
Corchia	Italy	Speleothem	$\delta^{18}\text{O}$, $\delta^{13}\text{C}$, Mg/Ca (CC26)	17 (CC26)	Zanchetta et al. 2007; Regattieri et al. 2014
			$\delta^{18}\text{O}$ (CC27)	26 (CC27)	Isola et al. 2019
Strašna peć	Croatia	Speleothem	$\delta^{18}\text{O}$, $\delta^{13}\text{C}$	10	Lončar et al. 2019
Cloșani	Romania	Speleothem	Mg/Ca	Annual	Warken et al. 2018
Mavri Trypa	Greece	Speleothem	$\delta^{18}\text{O}$	5	Finné et al. 2017
Skala Marion	Greece	Speleothem	$\delta^{18}\text{O}$	26	Psomiadis et al. 2018
Sofular	Türkiye	Speleothem	$\delta^{13}\text{C}$	5.4	Göktürk et al. 2011

Gordion	Türkiye	Tree ring	$\delta^{13}\text{C}$	Annual	Manning et al. 2023
Larnaca Salt Lake	Cyprus	Lacustrine	Pollen-based precipitation reconstruction	35	Kaniewski et al. 2020
Tell Tweini	Syria	Lacustrine	Pollen-based precipitation reconstruction	21	Kaniewski et al. 2019b
Jeita	Lebanon	Speleothem	$\delta^{13}\text{C}$	13	Cheng et al. 2015
Neor	Iran	Lacustrine	Ti	3.5	Sharifi et al. 2015
Kuna Ba	Iraq	Speleothem	$\delta^{18}\text{O}$, $\delta^{13}\text{C}$	3	Sinha et al. 2019
Shallai	Iraq	Speleothem	$\delta^{18}\text{O}$, $\delta^{13}\text{C}$, Mg/Ca	6	Bosomworth, 2021; Fleitmann et al. (in review)

Chronology of Proxy Records

The construction of accurate age-depth relationships is essential for the comparison and correlation of climate proxy records (Trachsel and Telford, 2017). A brief consideration of the established chronologies for the key hydroclimatic proxy records from the EM is presented below.

Firstly, we should consider the dating density of the 15 hydroclimate proxy records examined in this thesis. Whilst each record does possess at least one date between 3.5-2.5 ka BP it is evident

that dates are missing over significant time intervals, notably including the LBA-EIA transition period. Therefore, the density of radiometric ages surrounding the LBA-EIA transition needs to be improved.

Secondly, it is important to highlight that a range of different age-depth modelling approaches have been employed by the 15 hydroclimate proxy records examined here. For example, age models have been created using, e.g., linear interpolation (Strašna peć; Neor), linear regression, and Bayesian statistics, including Bchron (Cloşani Cave), Bacon, StalAge (Mavri Trypa, Sofular) and COPRA (Kuna Ba, Shallai). Whilst the results of the various age-depth modelling approaches differ due to the differences in their underlying assumptions, the differences in model outputs between each key proxy record are not substantial enough to invalidate the use of these key proxy records examined here. It is also beyond the scope of this thesis to re-calibrate any radiometric dates or recalculate age-depth models for any of these key records. It is, however, important to consider the impact of differing chronology on our understanding of any palaeoclimate changes identified by these proxy records.

For further chronological information for each proxy record, please refer to the original publications (see references in **Table 9**).

5.2.1.2. Hydroclimate Variability Between ca. 3.5-2.5 ka BP

Hydroclimatic conditions inferred from each proxy record from the EM and surrounding areas from the west to the east are examined below. The proxy signals of all records examined here can be seen in **Figures 36-38**.

The Adriatic and the Aegean

Across this region, the stable isotope and trace element records of the Renella, Corchia, Strašna peć, Cloşani, Mavri Trypa and Skala Marion stalagmite records from central Italy, Croatia, Romania and Greece are interpreted to reflect hydrological changes, as can be seen in **Figure 36** (Drysedale et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Isola et al. 2019; Lončar et al. 2019; Warken et al. 2018; Finné et al. 2017; Psomiadis et al. 2018).

From around 3.3 ka BP, with the exception of Skala Marion, more positive $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values can be identified in the Renella, Corchia, Strašna peć and Mavri Trypa cave records (Psomiadis et al.

2018; Drysdale et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Isola et al. 2019; Lončar et al. 2019; Finné et al. 2017). An increase in Corchia and Cloşani Mg/Ca can be identified until approx. 3 ka BP, reflecting a long-term shift in hydroclimatic conditions from more humid conditions to more arid conditions (Zanchetta et al. 2007; Regattieri et al. 2014; Warken et al. 2018). A short climatic perturbation can also be identified in the Renella and Mavri Trypa records at 3.2 ka BP and around 3.1 ka BP in the Cloşani record, which may reflect a short period of drier conditions, superimposed on the longer-term trend of increasing aridity (Drysdale et al. 2006; Zanchetta et al. 2016; Finné et al. 2017; Warken et al. 2018). A short dry interval between 3.22 ka BP and 3.2 ka BP can also be identified by an increase in Skala Marion $\delta^{18}\text{O}$ values from approx. -6.24‰ to -5.48‰ (Psomiadis et al. 2018).

From around 3-2.9 ka BP onwards, however, the variability in these proxy signals differs. For example, the Renella, stalagmite CC26 (Corchia) and Cloşani records appear to present a shift to wetter conditions after 3 ka BP whilst the Strašna peć and Mavri Trypa records appear to indicate drier conditions (Drysdale et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Warken et al. 2018; Lončar et al. 2019; Finné et al. 2017). Notably, a growth hiatus in the Mavri Trypa record can be seen from ca. 2.95 ka BP, indicative of a notable period of aridity (Finné et al. 2017).

Türkiye and the Levant

Across Türkiye, two high-resolution proxy records from the Black Sea coast (Sofular) and central Türkiye (Gordion) are understood to reconstruct hydroclimatic conditions across the LBA-EIA transition period (Göktürk, 2011; Manning et al. 2023), as can be seen in **Figure 37**. Between approx. 3.3 ka BP and 3.2 ka BP, an increase in Sofular ^{13}C values can be identified (from approx. -11.3‰ to -10.3‰), reflective of a reduction in effective moisture (Göktürk, 2011). Following this decline in effective moisture, ^{13}C values remain higher than those seen previously between 3.5-3.3 ka BP. The $\delta^{13}\text{C}$ Gordion record of Manning et al. (2023) also shows a shift towards drier conditions between ca. 3.22 ka BP (1230 BCE) and ca. 3.14 ka BP (1192 BCE). Manning et al. (2023) have also suggested that the Gordion record presents a severe three-year drought from ca. 3.15 ka BP (1198-1196 BCE).

In Cyprus, the pollen-based reconstruction of precipitation amount from Larnaca Salt Lake suggests a reduction of approx. 40mm of spring and winter precipitation around 3.3 ka BP

(Kaniewski et al. 2020). Further south, the Tell Tweini and Jeita Cave records from the northern Levant also indicate hydroclimate changes surrounding the LBA-EIA period (Kaniewski et al. 2019b; Cheng et al. 2015). Whilst the Jeita record may reflect a short period of aridity around 3.2 ka BP, the most significant change in climatic conditions is seen from approx. 3 ka BP to approx. 2.85 ka BP, indicative of a multi-centennial trend towards arid conditions (Cheng et al. 2015). From ca. 2.85 ka BP to 2.5 ka BP, conditions appear to remain arid (Cheng et al. 2015). Due to its well-constrained chronology (reflected by six high-precision U-Th dates across the LBA-EIA), there is confidence in the timing of this shift in hydroclimatic conditions seen in the Jeita record. In contrast to other Levantine records, reconstructed winter precipitation from Tell Tweini does not show a decline in precipitation amount around 3.2 ka BP, instead, a reduction in precipitation of over 20mm can be seen from ca. 3 ka BP (Kaniewski et al. 2019b). However, it is important to recognize the large chronological error associated with the calibrated age range of 3260-3000 yrs BP (Beta-229048) at 2σ (see **Figure 37**), as climatic changes seen around this time could shift.

The Middle East

In this thesis, only three proxy records from Iran and Iraq present LBA-EIA hydroclimatic conditions across the Middle East, as can be seen in **Figure 38**, as further examination of conditions in this region is beyond the scope of this research.

Around 3.2 ka BP, an increase in Ti, which is understood to reflect a high dust flux and drier conditions, can be identified in the Neor Lake record in Iran (Sharifi et al. 2015). An increase in Ti can also be identified around 3 ka BP and 2.8 ka BP in the Neor record (Sharifi et al. 2015). No dry episodes or events around 3.2 ka BP can, however, be seen in the Kuna Ba or Shallai stalagmite records (Sinha et al. 2019; Bosomworth, 2021). Wetter conditions can be identified from 3.25 ka BP in the Mg/Ca record from Shallai Cave, with several short dry events identifiable around 3 ka BP, 2.9 ka BP, 2.7 ka BP (Bosomworth, 2021). No major climatic changes can be identified in the Kuna Ba record until approx. 2.8 ka BP (Sinha et al. 2019).

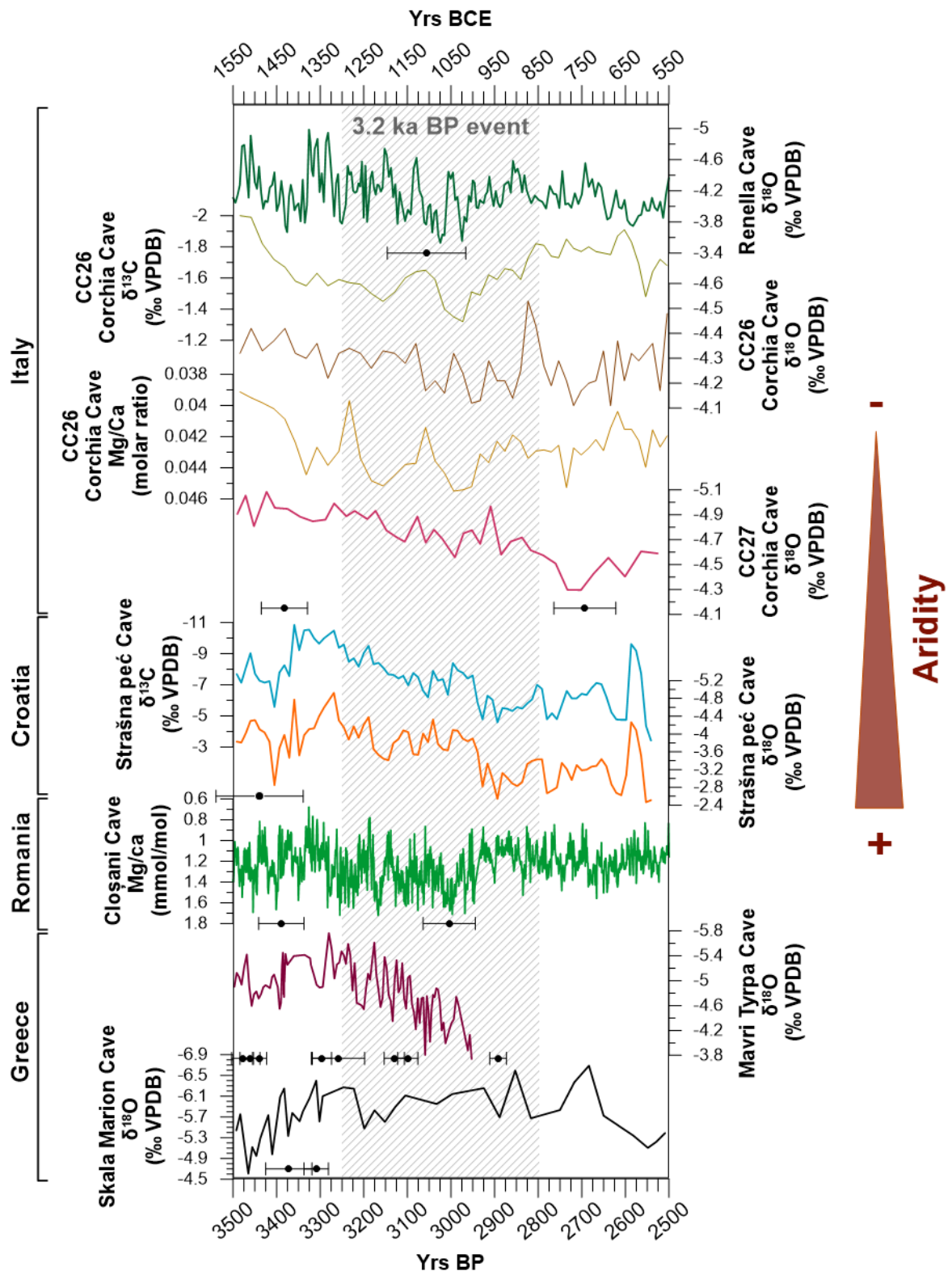


Figure 36. Highly resolved hydroclimate proxy records of the Adriatic and the Aegean. U-Th ages and associated uncertainties of each record can be seen as error bars below the proxy signal, reported to 2σ . The grey shaded bar indicates the 3.2 ka BP event. Source: Author's original.

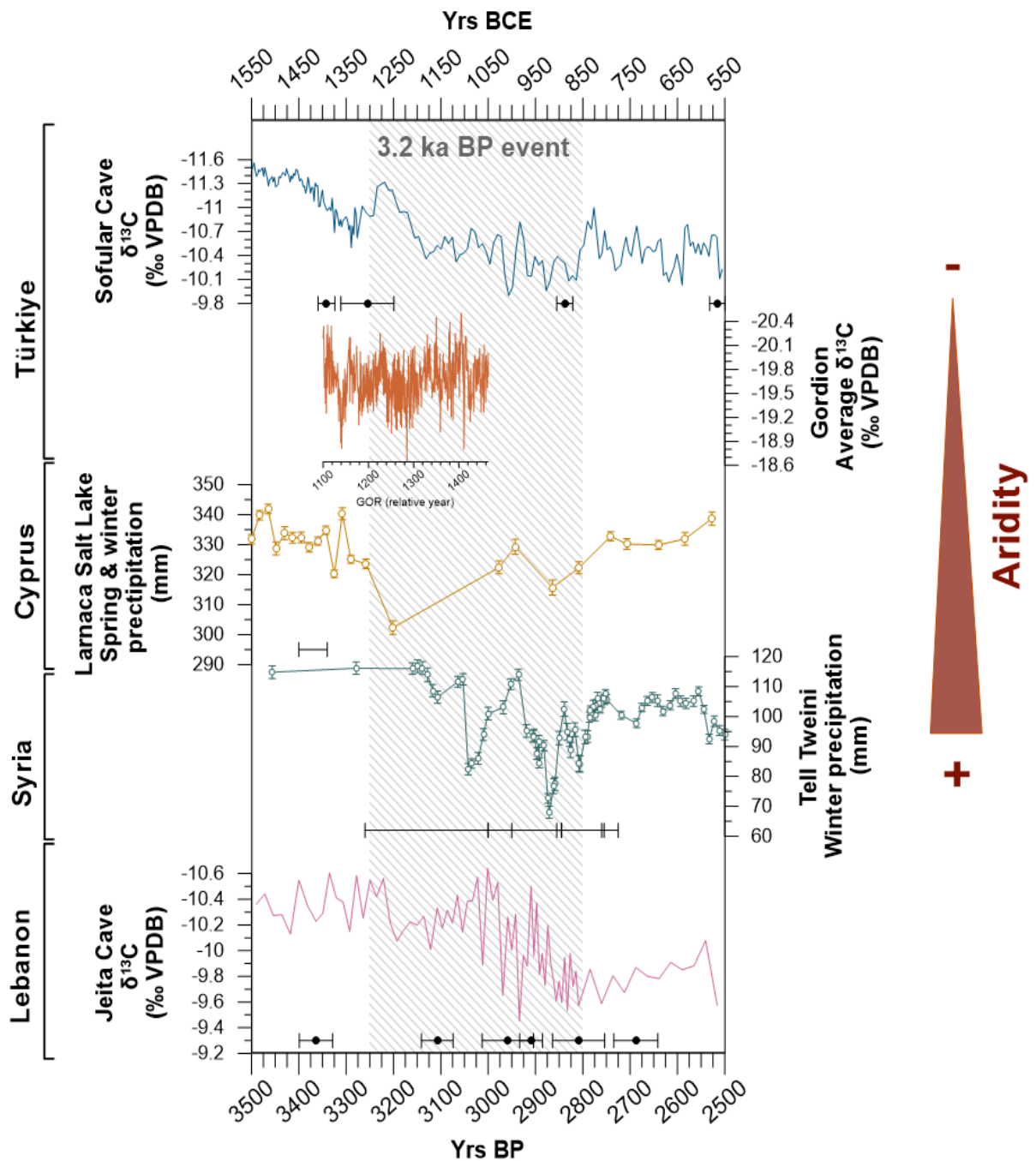


Figure 37. Highly resolved hydroclimate proxy records from Türkiye and the Levant. ^{14}C and U-Th ages and associated uncertainties for each record can be seen as error bars below the proxy signal, reported to 2σ . The grey shaded bar indicates the 3.2 ka BP event. Source: Author's original.

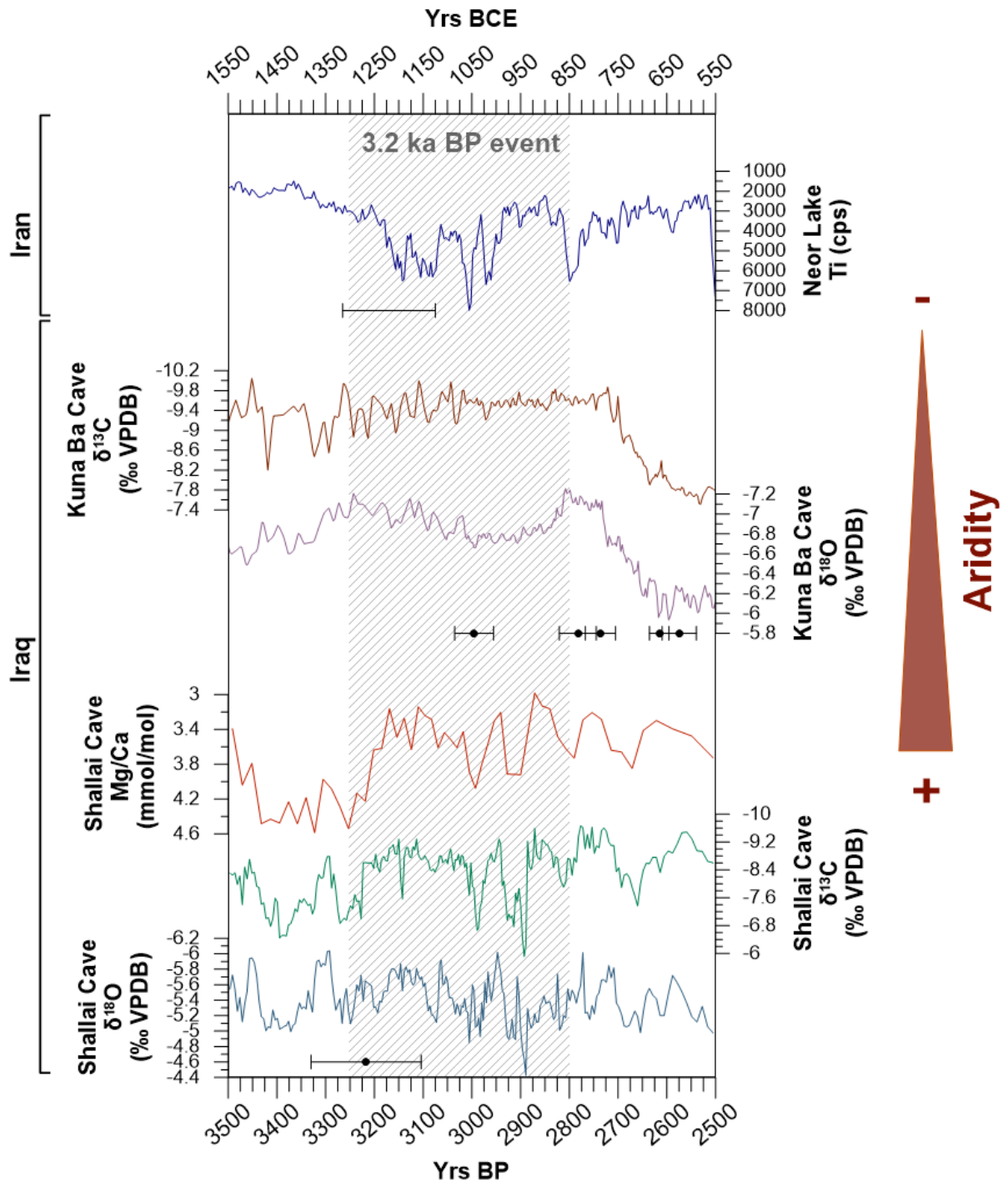


Figure 38. Highly resolved hydroclimate proxy records from the Middle East. ^{14}C and U-Th ages and associated uncertainties for each record can be seen as error bars below the proxy signal, reported to 2σ . The grey shaded bar indicates the 3.2 ka BP event. Source: Author's original.

5.2.2. Temperature Conditions

Of all published EM temperature records which cover the LBA-EIA, only the data of a few proxy records can be accessed. Due to the limited accessibility and resolution of temperature reconstructions across the EM, significant uncertainty surrounds our understanding of temperature variability during the Late Holocene and LBA-EIA transition.

To identify any significant cooling from northerly sources, several proxy records from the North Atlantic and Europe are also examined here. For all temperature records examined here, see **Table 10** and **Figure 39**.

Table 10. Key temperature proxy records examined in this thesis. Records are located across the North Atlantic, Europe and the Mediterranean, as can be seen in **Figure 35**.

Site location	Temperature record	Archive type	Proxy type	Temporal resolution in yrs (5000-0 BP)	Reference
Greenland	GISP2	Ice core	$\delta^{18}\text{O}$	10	Stuiver et al. 1995
Icelandic shelf	MD99-2275	Marine	Alkenone SST	4	Sicre, 2008

Switzerland	Milandre Cave	Speleothem	δD_{fi} -based transfer function	31	Affolter et al. 2019
Adriatic Sea	AD91-17	Marine	Alkenone SST	207	Sangiorgi et al. 2003
Cyprus	Larnaca Salt Lake	Lake	Pollen-based transfer function	7	Kaniewski et al. 2020
Syria	Tell Tweini	Lake	Pollen-based transfer function	14	Kaniewski et al. 2019b
Levantine Basin	GeoB 7702-3	Marine	Alkenone SST	231	Castañeda et al. 2010
	GeoB 5844-2	Marine	Alkenone SST	302	Arz et al. 2003

Temperature Variability across the North Atlantic and Europe

Between approx. 3.5 ka BP and 3.3 ka BP a cooling event can be identified in the GISP2 record from Greenland (Stuiver et al. 1995). From ca. 3.3 ka BP to ca. 2.97 ka BP, a multi-centennial trend towards cooler conditions can be identified in the GISP2 record, as reflected by an increase in $\delta^{18}O$ values (Stuiver et al. 1995). As identified in the GISP2 record, SST cooling can also be identified from ca. 3.5 ka BP to 3.27 ka BP in the MD99-2275 record (Sicre, 2008). Following this apparent drop in SST in the MD99-2275 record, a temperature rise can be identified between ca. 3.27 and

3.16 ka BP (Sicre, 2008). A drop in SST in the MD99-2275 can also be identified around 3.15 ka BP and between ca. 3.1-2.9 ka BP (Sicre, 2008). Whilst temperature conditions between 3.5-2.5 ka BP in the Milandre Cave record fall within the longer-term variability in temperature conditions seen from 5 ka BP, the record does also display a drop in temperature of approx. 1°C between 3.15 ka BP and 3 ka BP (Affolter et al. 2019). A 1°C drop in temperature can also be identified in the Milandre record from approx. 2.96 ka BP (8.5°C) to ca. 2.45 ka BP (7.5°C) (Affholter et al. 2019).

Temperature Variability across the Mediterranean

In the AD 91-17 record from the Adriatic, a multi-centennial episode of warming of around 1.2°C can be identified between ~3.5 ka BP and 3.3 ka BP, which is superimposed on a long-term shift towards cooler conditions between ca. 4.25 ka BP and 3 ka BP (Sangiorgi et al. 2003). Between ca. 3.3 ka BP to ca. 3 ka BP SST drops from approx. 15.6°C to 13.8°C. Following this cooler episode, the AD 91-17 record suggests a 500-year warming period (reaching SST values of around 15.9°C) until ca. 2 ka BP, when a return to cooler conditions can be identified. This apparent long-term cooler episode may, however, appear more pronounced due to the low temporal resolution of this record.

In the Levant, the Larnaca record of Cyprus presents a relatively rapid cooling episode of nearly 3°C from ca. 3.25 ka BP following several centuries of temperatures falling between ~12-13°C (Kaniewski et al. 2020). Around ca. 2.5 ka BP temperatures return to values of around 12°C, as seen before the cooling interval. In the Levantine Basin, the poorly resolved GeoB 7702-3 record exhibits a cooling episode from ~3.35-3.2 ka BP (Castañeda et al. 2010). Following an apparent cool period between ~3.5- 3 ka BP, the GeoB 5844-2 record an increase in alkenone SST can be identified until after 2.5 ka BP (Arz et al. 2003). Notably, a cooling episode around 3.2 ka BP cannot be identified in the Tell Tweini record from Syria (Kaniewski et al. 2019b). The Tell Tweini record does, however, present a major shift towards cooler conditions from around 3.05 ka BP until approx. 2.85 ka BP as reflected by a dramatic drop in temperature from ~10°C to 3°C (Kaniewski et al. 2019b). Cooler conditions are, however, interrupted by a ~80-year episode of warming from approx. 3 ka BP (Kaniewski et al. 2019b). From ca. 2.85 ka BP, an increase in temperatures of around 8°C can be seen in the Tell Tweini record.

In sum, the few temperature proxy records from the Mediterranean region generally appear to indicate cooling across the LBA-EIA transition period around ca. 3.3 ka BP, though the duration of cooling appears to differ between records. However, the Tell Tweini record does not show significant cooling until ca. 3 ka BP.

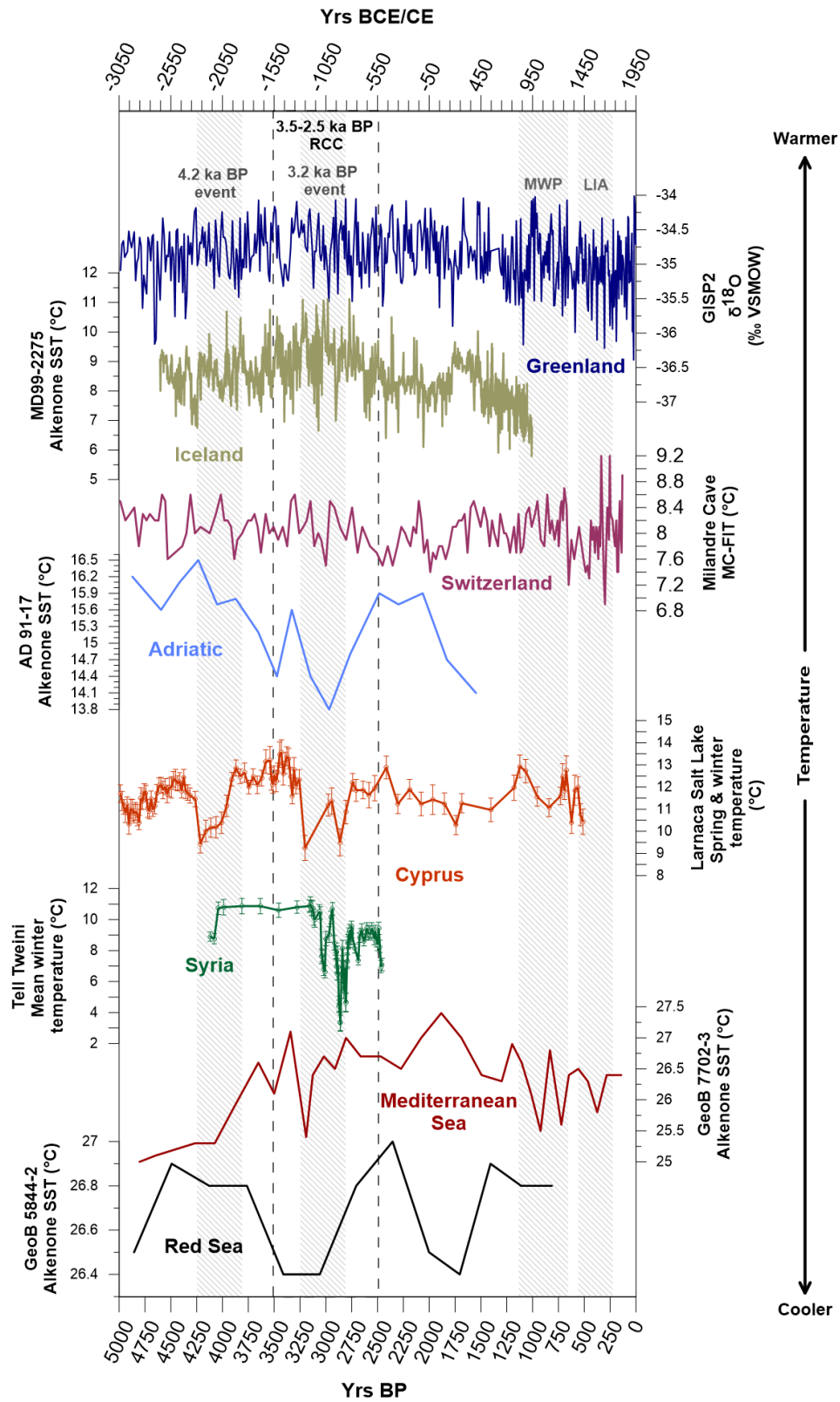


Figure 39. Temperature proxy records from the North Atlantic, Europe and the Mediterranean.

GISP2 (Stuiver et al. 1995), MD99-2275 (Sicre, 2008), Milandre Cave (Affolter et al. 2019), AD 91-17

(Sangiorgi et al. 2003), Laranca Salt Lake (Kaniewski et al. 2020), Tell Tweini (Kaniewski et al. 2019b), GeoB 7702-3 (Castañeda et al. 2010), GeoB 5844-2 (Arz et al. 2003). Source: Author's original. Grey shaded bars indicate the 4.2 ka BP and 3.2 ka BP events, the Medieval Warm Period and the Little Ice Age. Dashed lines indicate the 3.5-2.5 ka BP RCC event.

5.3. Key Results

Key hydroclimate and temperature proxy records from the EM and bordering areas examined in this chapter reveal significant and potentially impactful changes in climatic variability surrounding the LBA-EIA transition period. The results of this examination from each sub-region of the EM and surrounding areas are summarized below.

The North Atlantic and Europe

- A multi-centennial cooling episode can be identified between ca. 3.5-3.3 ka BP (1550 BCE) in both the GISP2 and MD99-2275 SST proxy records from Greenland and Iceland (Stuiver et al. 1995; Sicre, 2008).
- The GISP2 record also records a period of cooler conditions from ca. 3.3 ka BP (1350 BCE) to ca. 2.97 ka BP (1020 BCE) (Stuiver et al. 1995).
- This period of apparent cooling is not seen in the MD99-2275 record, which instead shows an increase in temperature between 3.27-3.16 ka BP (1320-1210 BCE) (Sicre, 2008).
- A reduction in MD99-2275 SST can also be identified around 3.15 ka BP and between ca. 3.1-2.9 ka BP (1150- 950 BCE) (Sicre, 2008).
- A drop in temperature can be identified between 3.15-3 ka BP (1200-1050 BCE) of around 1°C in the Milandre cave record in Switzerland (Affholter et al. 2019).
- A 1°C drop in temperature can also be seen from approx. 2.96 ka BP (1010 BCE) to ca. 2.45 ka BP (500 BCE) in the Milandre record (Affholter et al. 2019). surrounding areas are summarized below.

The Adriatic

- A long-term shift to drier conditions can be identified between ca. 3.3-2.9 ka BP (ca. 1350-950 BCE), as seen in the Renella, Corchia, Strašna peć and Cloşani records (Drysedale et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Isola et al. 2019; Lončar et al. 2019; Warken et al. 2018).
- From ca. 2.9 ka BP (950 BCE) onwards the climatic variability across these proxy records differs.
- An episode of SST cooling of around 1.8°C can also be identified in the AD 91-17 temperature record of the southern Adriatic Sea between ca. 3.25 ka BP to 3 ka BP (1300 to 1050 BCE) (Sangiorgi et al. 2003).

The Aegean

- The proxy signals of the Mavri Trypa and Skala Marion records appear to differ across the LBA-EIA transition period (Finné et al. 2017; Psomiadis et al. 2018).
- However, a small dry event around 3.2 ka BP (1250 BCE) can be identified in both the Mavri Trypa and Skala Marion records (Finné et al. 2017; Psomiadis et al. 2018).
- This short dry event around ca. 3.2 ka BP (1250 BCE) in the Mavri Trypa record is superimposed on a wider trend towards increasingly arid conditions from ca. 3.25 ka BP (1300 BCE) until ca. 2.95 ka BP (1000 BCE) (Finné et al. 2017).

Türkiye

- A marked reduction in precipitation can be identified in the new Ko-1 isotopic record presented in this thesis, indicating an important ~100 yr drying event between ca. 3.25 ka BP (1300 BCE) and 3.15 ka BP (1200 BCE).
- This pronounced dry event seen in the Ko-1 record was consequently followed by a shift to wetter conditions between ca. 3.15 ka BP (1300 BCE) and 2.25 ka BP (300 BCE), as reflected by higher rainfall amounts.
- Sofular and Gordion $\delta^{13}\text{C}$ records from northern and central Türkiye also identify a marked decrease in precipitation between ca. 3.3-3.2 ka BP (1350-1250 BCE) (Göktürk, 2011; Manning et al. 2023).

- A pronounced dry event can also be identified in the Gordion record around 3.15 ka BP (1198-1196 BCE) (Manning et al. 2023).

The Levant

- The reconstructed precipitation record Larnaca Salt Lake indicates a period of drier conditions between ca. 3.3-3.2 ka BP (1350-1250 BCE) (Kaniewski et al. 2019b).
- The Larnaca temperature record of (Kaniewski et al. 2020) also suggests a relatively rapid cooling episode of almost 3°C from ca. 3.25 ka BP (1300 BCE).
- A cooling episode can also be identified in the GeoB 7702-3 record from ~3.35-3.2 ka BP (1400- 1250 BCE) (Castañeda et al. 2010).
- The Tell Tweini and Jeita records do not indicate drier conditions around 3.2 ka BP (1250 BCE). A shift towards drier conditions can however be identified from ca. 3 ka BP (1050 BCE) (Kaniewski et al. 2019b; Cheng et al. 2015).
- Cooler conditions around 3.2 ka BP (1250 BCE) are also not apparent in either the Tell Tweini record from Syria, or the GeoB 5844-2 SST record of the Red Sea (Kaniewski et al. 2019b; Arz et al. 2003).
- A dramatic shift towards cooler conditions can be seen in the Tell Tweini temperature record from approx. 3.05 ka BP (1100 BCE) to ca. 2.85 ka BP (900 BCE) (Kaniewski et al. 2019b).

The Middle East

- Of the Middle Eastern records examined in this thesis, only the Neor record of Sharifi et al. (2015) appears to record an arid episode around 3.2 ka BP (1250 BCE), as reflected by an increase in Ti.
- Two short abrupt dry episodes can also be identified in the Neor Ti record around 3 ka BP (1050 BCE) and 2.8 ka BP (850 BCE) (Sharifi et al. 2015).
- No major climatic changes can be identified in the Kuna Ba record until approx. 2.8 ka BP (850 BCE) (Sinha et al. 2019).

- Interestingly, the Mg/Ca and $\delta^{13}\text{C}$ records of Shallai suggest a shift towards wetter conditions from 3.25 ka BP (1300 BCE) (Bosomworth, 2021). However, several short dry events can be identified around 3 ka BP (1050 BCE), 2.9 ka BP (950 BCE) and 2.7 ka BP (750 BCE) (Bosomworth, 2021).

5.4. Chapter Summary

This chapter has presented the results of the analysis of over 23 hydroclimate proxy records and temperature proxy records across the EM and surrounding areas, including the new Ko-1 record, to understand palaeoclimatic conditions during the LBA-EIA transition, and to contextualise the results from the new Ko-1 record.

The results of Ko-1 stable isotope analysis undertaken in this thesis identify a marked reduction in precipitation from ca. 3.25 ka BP (1300 BCE), indicative of a ~100 yr drying event during the LBA. Notably, a period of drier conditions can also be identified in several existing EM proxy records from the Aegean, Cyprus, and Türkiye from approx. 3.2-3.1 ka BP (1250-1150 BCE) (Finné et al. 2017; Kaniewski et al. 2019b; Göktürk et al. 2011; Manning et al. 2023). More arid conditions can also be identified in several Adriatic proxy record signals during the LBA and into the EIA (Drysdales et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Isola et al. 2019; Lončar et al. 2019; Warken et al. 2018), whilst drier conditions can be seen in the Neor Lake record of Iran (Sharifi et al. 2015). A shift to cooler conditions can also be identified in the Larnaca Salt Lake temperature record around 3.2 ka BP (Kaniewski et al. 2020).

Climatic heterogeneity is, however, also notably evident across the EM and surrounding areas. For example, whilst conditions across Aegean and Türkiye at ca. 3.2 ka BP appear to have been more arid, drier conditions cannot be seen in the important Levantine records of Tell Tweini and Jeita Cave at this time (Finné et al. 2017; Kaniewski et al. 2019b; Cheng et al. 2015). Instead, these Levantine records suggest that a shift to drier conditions occurs later, into the Levantine IA around ca. 3 ka BP (1050 BCE) (Kaniewski et al. 2019b; Cheng et al. 2015). The Tell Tweini temperature record also indicates a shift to cooler conditions from ca. 3 ka BP (Kaniewski et al. 2019b).

To determine the nature of climatic changes during the LBA-EIA as identified in this chapter and their possible societal impacts, the results of this proxy examination will be discussed further in

Chapter 6. Proxy findings will also be compared to the archaeological evidence of the LBA-EIA transition.

Chapter 6 - Discussion

6.1. Introduction

Given the contention and uncertainty surrounding the cogency of the popular climate hypothesis, this thesis has sought to re-examine the role of climate change on the end of the LBA and the transition to the EIA across the EM. Through an interdisciplinary and multi-scalar examination of climate and societal dynamics during the LBA and EIA, this research has demonstrated a complex picture of LBA-EIA climate and society across EM, as will be summarized and discussed in this chapter.

By exploring the key palaeoclimate and archaeological findings of this thesis, this chapter will address the role of climate on the LBA-EIA in the EM and interrogate the cogency of the existing climate hypothesis.

6.2. Late Bronze Age-Early Iron Age Climate across the Eastern Mediterranean

The climate hypothesis first introduced several decades ago (Carpenter, 1966; Weiss 1982), has seen a reemergence of research interest in recent decades due to the apparent synchronism between climate perturbations and the LBA-EIA transition in the EM. Through the analysis and examination of several EM proxy records, including the Larnaca Salt Lake record from Cyprus and Tell Tweini in Syria, Kaniewski et al. (2019a; 2019b; 2020) have proposed the existence of a widespread climatic event at approx. 3.2 ka BP in the EM. More recently, Kaniewski et al. (2019b; 2020) have suggested that a cooling event at 3.2 ka BP was responsible for drier conditions across the EM, which may have also been further amplified by drought.

To determine whether the EM witnessed an abrupt climate event ca. 3.2 ka BP, the nature of any major changes in rainfall and temperature variability across the region and surrounding areas will be discussed below. A brief introduction of the possible climate mechanisms behind climate variability will also be discussed.

6.2.1. Hydroclimate Conditions

In the Aegean, a small dry event around 3.2 ka BP (1250 BCE) can be identified in both the Mavri Trypa and Skala Marion records (Finné et al. 2017; Psomiadis et al. 2018). However, the proxy signals of these records generally differ across the LBA-EIA transition period (Finné et al.

2017; Psomiadis et al. 2018). It is also evident that the small dry event around ca. 3.2 ka BP (1250 BCE) in the Mavri Trypa record is superimposed on a wider trend towards increasingly arid conditions from ca. 3.25 ka BP (1300 BCE) until ca. 2.95 ka BP (1000 BCE) (Finné et al. 2017). A growth hiatus in the Mavri stalagmite record is also seen at ca. 2.95 ka BP (1000 BCE) reflecting a notable period of aridity (Finné et al. 2017).

In southwestern Türkiye, a significant reduction in precipitation can be identified in the new Ko-1 isotopic record (this thesis), indicating an important ~100 yr drying event between ca. 3.25 ka BP (1300 BCE) and 3.15 ka BP (1200 BCE). This pronounced dry event in the Ko-1 record was consequently followed by a shift to wetter conditions from ca. 3.15 ka BP (1200 BCE) as reflected by higher rainfall amounts. A marked decrease in precipitation between ca. 3.3-3.2 ka BP (1350-1250 BCE) can also be identified in the Sofular and Gordion $\delta^{13}\text{C}$ records from northern and central Türkiye (Göktürk, 2011; Manning et al. 2023). A pronounced dry event can also be identified in the Gordion record around 3.15 ka BP (1198-1196 BCE) (Manning et al. 2023). Notably, the drying event seen in the Ko-1 record is followed by a long-term shift towards wetter conditions from 3.15 ka BP (1200 BCE) onwards.

No significant changes in mean climatic state or increased variability can be identified in the Tell Tweini record of Syria nor the Jeita record of Lebanon around 3.2 ka BP (1250 BCE) (Kaniewski et al. 2019b; Cheng et al. 2015). A notable shift in hydroclimatic conditions is, however, apparent from ca. 3 ka BP (1050 BCE) in both records (Kaniewski et al. 2019b; Cheng et al. 2015).

Beyond the Eastern Mediterranean

A multi-centennial trend towards more arid conditions can be identified across the Adriatic between approx. 3.3 ka BP and 2.9 ka BP (ca. 1350-950 BCE), as seen in the Renella, Corchia, Strašna peć and Cloşani stalagmite records (Drysdale et al. 2006; Zanchetta et al. 2016; Zanchetta et al. 2007; Regattieri et al. 2014; Isola et al. 2019; Lončar et al. 2019; Warken et al. 2018). After 2.9 ka BP (ca. 950 BCE) climatic variability across these proxy records differs.

Of the three ME records examined in this thesis only the Neor Lake record (NW Iran) presents a shift towards drier conditions around 3.2 ka BP (1250 BCE), as indicated by a rise in Ti which is reflective of high dust flux (Sharifi et al. 2015). Two short abrupt dry episodes can also be identified in the Ti record around 3 ka BP (1050 BCE) and 2.8 ka BP (850 BCE) (Sharifi et al. 2015). Across the Iraqi records examined no other significant changes in mean climatic state or

increased variability can be identified around 3.2 ka BP (Sinha 2019; Bosomworth, 2021). The Mg/Ca and $\delta^{13}\text{C}$ records of Shallai cave suggest a shift towards wetter conditions from 3.25 ka BP (1300 BCE) (Bosomworth, 2021). Additionally, several short dry events can be identified around 3 ka BP (1050 BCE), 2.9 ka BP (950 BCE) and 2.7 ka BP (750 BCE) in the record (Bosomworth, 2021). No major climatic changes can be identified in the Kuna Ba record until approx. 2.8 ka BP (850 BCE) (Sinha et al. 2019).

6.2.2. Temperature Conditions

In Cyprus, the pollen-based temperature reconstruction from Larnaca Salt Lake appears to reflect dramatic cooling of around 2.6 °C from ca. 3.25 ka BP (1300 BCE) (Kaniewski et al. 2020). A cooling episode can also be identified in the GeoB 7702-3 SST record in the Levantine basin from approx. 3.35-3.2 ka BP (1400- 1250 BCE) (Castañeda et al. 2010). Cooler conditions around 3.2 ka BP (1250 BCE) are, however, not apparent in either the Tell Tweini record from Syria, or the GeoB 5844-2 SST record of the Red Sea (Kaniewski et al. 2019b; Arz et al. 2003). Instead, the Tell Tweini proxy signal indicates a drop in temperature of around 7°C from ca. 3.05 ka BP to 2.85 ka BP (1100-900 BCE) (Kaniewski et al. 2019b). This cooling episode is also interrupted by a ~80 yr period of warmer conditions around 3 ka BP (1050 BCE).

Beyond the Eastern Mediterranean

Beyond the EM region, a period of cooler conditions can be identified from ca. 3.3 ka BP (1350 BCE) to ca. 2.97 ka BP (1020 BCE) in the GISP2 record of Greenland (Stuiver et al. 1995). Between 3.27-3.16 ka BP (1320-1210 BCE) an increase in temperature can be identified in the MD99-2275 record from (Sicre, 2008). Two periods of reduced SST seen in MD99-2275 can also be identified from around 3.15 ka BP (1200 BCE) and between approx. 3.1-2.9 ka BP (1150- 950 BCE) (Sicre, 2008). A drop in temperature can also be identified between 3.15-3 ka BP (1200-1050 BCE) of around 1°C in the Milandre cave record in Switzerland (Affholter et al. 2019). A 1°C drop in temperature can also be seen from approx. 2.96 ka BP (1010 BCE) to ca. 2.45 ka BP (500 BCE) in the Milandre record (Affholter et al. 2019). An episode of SST cooling of around 1.8°C can also be identified in the AD 91-17 temperature record of the southern Adriatic Sea between ca. 3.25 ka BP to 3 ka BP (1300 to 1050 BCE) (Sangiorgi et al. 2003).

6.2.3. Is there Evidence for a 3.2 ka BP Event?

Based on the assessment of proxy records presented in this thesis, a shift towards more arid and cooler conditions during the LBA-EIA transition can be identified in several proxy records

from across the EM and beyond (see **Figure 40**), including the new Ko-1 stable isotope record, but do these changes reflect a widespread and abrupt climatic event at ca. 3.2 ka BP? It is important to examine the nature of climatic change recorded in proxy signals, as the environmental and societal impact of climatic variability depends on the magnitude, timing and spatial extent of any perturbation. A long-term shift in mean climate over several centuries, for example, would provide societies with a greater opportunity to respond and adapt to their changing environment over time compared to the sudden onset of high climatic variability. Additionally, whilst it is beyond the scope of this thesis, it is also possible to speculate on the processes driving the climatic changes seen in each of these proxy signals.

Magnitude, Timing and Spatial Extent of Climate Change

The apparent synchronicity of hydroclimatic variability changes identified in proxy records across the Aegean, Türkiye and Cyprus around ca. 3.2 ka BP (1250 BCE) seemingly indicates a strong drying signal that coincides with the events of the LBA-EIA transition. This drying signal, however, cannot be identified in Levantine records of Tell Tweini and Jeita Cave at this time (Kaniewski et al. 2019b; Cheng et al. 2015). Whilst drier conditions are not seen around 3.2 ka BP (1250 BCE) in both the Tell Tweini and Jeita Cave records, a shift to drier conditions can be identified from ca. 3 ka BP (1050 BCE), which cannot be identified in other EM records. This apparent climatic heterogeneity between the Aegean and Türkiye and the southern Levant appears to demonstrate the EM tendency towards anti-phased hydroclimatic variability, as demonstrated by Cook et al. (2016) (see Chapter 2). As presented in Chapter 5 and above, the Larnaca Salt Lake proxy record identifies cooling around 3.25 ka BP (1300 BCE) whilst the Tell Tweini temperature reconstruction suggests a shift towards cooler conditions from ca. 3.05 ka BP (1100 BCE) (Kaniewski et al. 2020; Kaniewski et al. 2019b). If the EM experienced a shift to cooler conditions, we would expect to see amplified cooling at higher latitudes (the North Atlantic and Europe) as cooler air masses in the EM originate from northerly sources. Whilst several proxy records from the North Atlantic and Europe presented in this thesis support the incidence of cooling around 3.2 ka BP (see Chapter 5, 5.2.2), they do not demonstrate amplified cooling at this time. Therefore, whilst the EM may have experienced some degree of cooling around 3.2 ka BP, this was not a major widespread event.

Based on these findings, it does indeed appear that the EM experienced a drying and cooling event during the LBA-EIA transition. Whilst climatic perturbation around 3.2 ka BP can be identified across several proxy records located beyond the EM (see Chapter 5), climatic changes generally appear to be regional in their extent, though research into climate changes

around 3.2 ka BP has also been undertaken for Europe (see Molloy, 2023). Finally, it is important to recognize that due to dating uncertainties and limitations over the spatiotemporal coverage of existing EM proxy records, the nature and timing of the 3.2 ka BP is still associated with uncertainty.

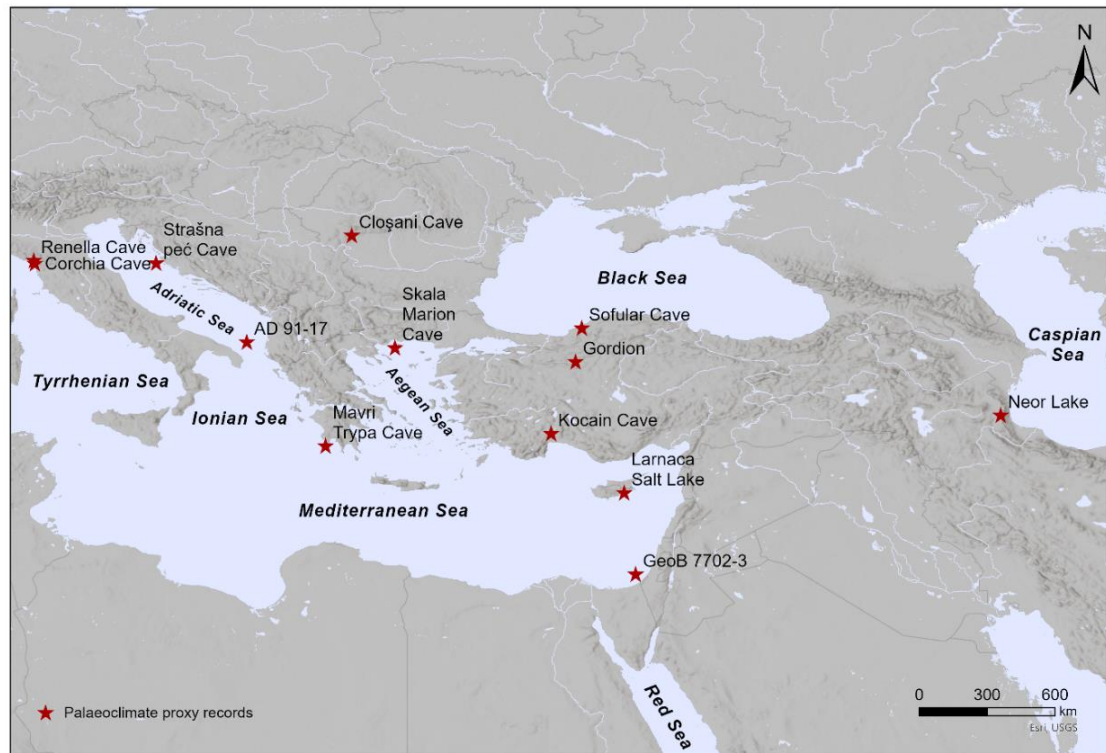


Figure 40. Map of all key palaeoclimate proxy records showing major changes in precipitation and temperature around 3.2 ka BP across the eastern Mediterranean and surrounding areas. Source: Author's original.

Driving Mechanism/s of Climate Changes Seen across the Late Bronze Age and Early Iron Age

Centennial and multi-decadal climate fluctuations during the Holocene have commonly been thought to have been related to changes in total solar irradiance (TSI) (Bond et al. 2001). However, no significant covariance can be identified between proxy records and solar activity around 3.2 ka BP. As the spatial extent of climate changes identified across the LBA-EIA transition appears to have been largely contained to the EM, the shift to more arid and cooler conditions was likely driven by internal climate variability. Internal climatic variability, which

arises naturally from the complex interaction of the atmosphere and the oceans, can lead to changes in large-scale teleconnections, such as the NAO, which influence climatic conditions across the EM (Cook et al. 2016). As highlighted by Cook et al. (2016) and Jones et al. (2019) EM hydroclimatic anti-phasing, as also identified in this study, bears a strong resemblance to hydroclimatic patterns expected from variability in the NAO. As seen in **Figure 41**, the NAO index of Olsen et al. (2012) suggests that the NAO was in a positive phase for around three centuries from approx. 3.3 ka BP until 3 ka BP (1350-1050 BCE), which therefore appears to coincide with the climatic changes seen across the EM. The possible influence of changes to the NAO may also explain why similar climatic variability is not reflected in ME proxy records, as the influence of the NAO is thought to be negligible across much of this region, except for the southern Zagros (Evans et al. 2004). However, the NAO alone does not explain the climatic patterns we see across the EM, as the climate of the region is also influenced by several other large-scale climate mechanisms and teleconnection patterns such as the North Caspian Pattern (NCP) and the East Atlantic (EA) pattern (Kutiel and Benaroch 2002; Dünkeloh and Jacobeit, 2003; Xoplaki et al. 2004; Finné et al. 2019; Hatzaki et al. 2007; 2009; Ulbrich et al. 2012).

Summary

Several EM proxy records presented in this thesis identify changes in precipitation and temperature around 3.2 ka BP, which appear to reflect a climate event. However, climatic variability can also be seen across the EM, reflecting the high degree of spatial variability in precipitation and temperature across the EM.

Whilst the onset of drier and cooler conditions appears to coincide with the LBA-EIA transition, including the end of the Mycenaean palatial period and the demise of the Hittite Empire, the timing and duration of this shift in EM climatic variability remain ambiguous. Additionally, whilst it is most likely that changes seen across the EM are due to internal climatic variability, the exact mechanisms behind Holocene climatic variability, including the changes seen around 3.2 ka BP, are still largely not understood. Therefore, several important questions surrounding the timing, duration and drivers of climate changes during the LBA-EIA transition period remain, highlighting the need for further research.

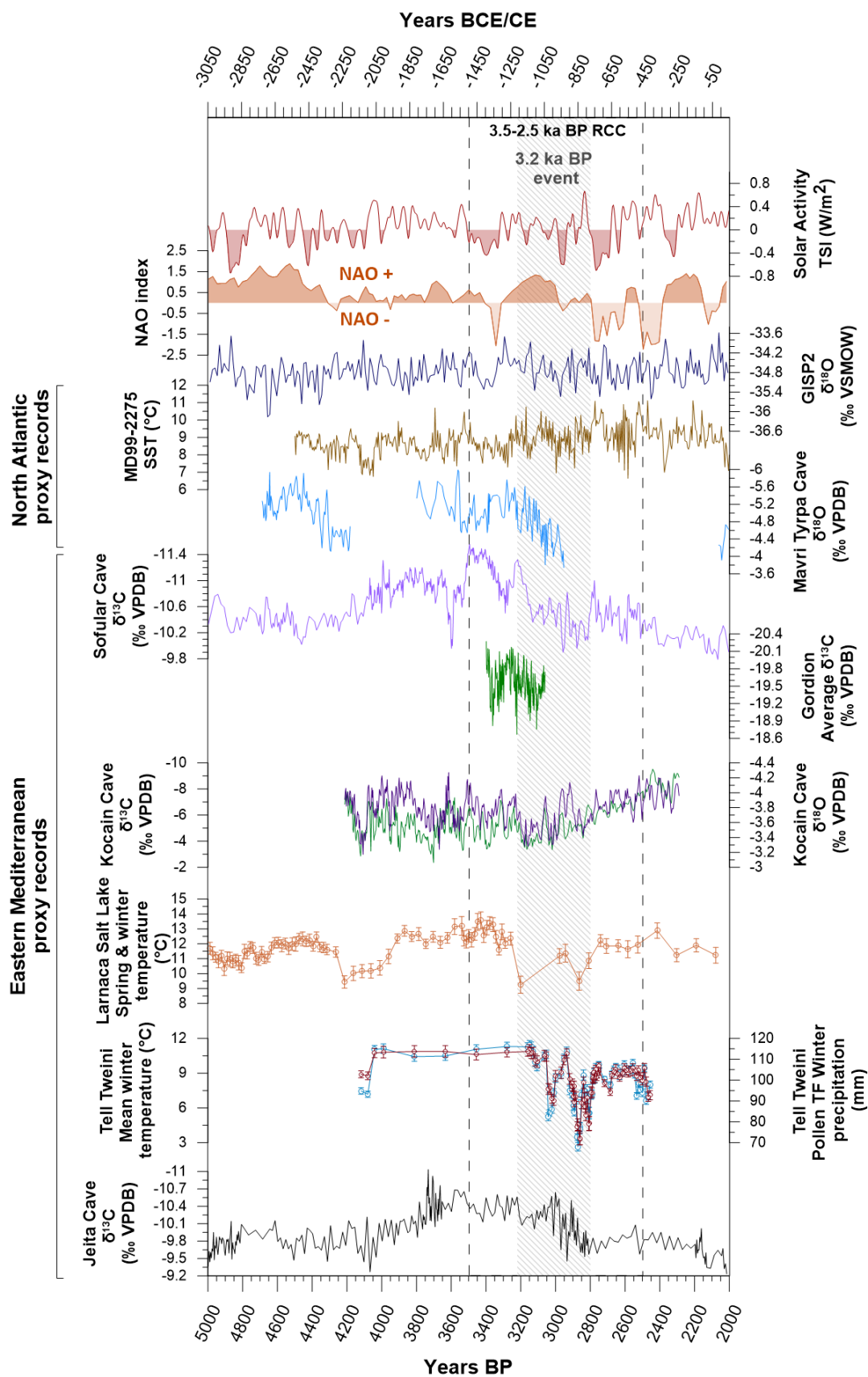


Figure 41. Hydroclimate and temperature records of the eastern Mediterranean and the North Atlantic. Total Solar Irradiance (TSI) and the North Atlantic Oscillation (NAO) index of

Steinhilber (2009) and Olsen (2012) are also presented. The grey shaded bar indicates the 3.2 ka BP event, whilst dashed lines indicate the 3.5-2.5 ka BP RCC event. Source: Author's original.

6.3. Climate and Society During the Late Bronze Age-Early Iron Age Transition in the Eastern Mediterranean

As can be seen in **Figure 42**, the onset of drier and cooler conditions seen across much of the EM appears to coincide with the LBA-EIA transition. If conditions became drier and cooler at the end of the LBA, we might expect to see an impact on agricultural production as climate is a pivotal factor that significantly influences the performance of agricultural regimes (Weiberg and Finné, 2021). Reduced rainfall and cool temperatures can affect crop productivity, leading to poor harvest and food insecurity. Significantly, the climate hypothesis proposes that a climate change event at 3.2 ka BP led to food insecurity and famine, which ultimately contributed to the end of the LBA across the EM. However, interactions between climate change and human societies are complex, multifaceted and multi-scalar (Manning, 2013: 104). Therefore, it is important to consider how EM societies responded to changes in climate variability. To understand the vulnerability, resilience, and response of LBA-EIA societies to the impact of climate change, we must consider societal dynamics and agricultural practices across the LBA and EIA in the EM, as presented in Chapter 3 against palaeoclimate evidence.

A summary of LBA-EIA society and economy, including agricultural conditions, is provided below against palaeoclimate proxy data from Türkiye, the western Aegean, and the Levant. Due to this thesis's microregional focus on Türkiye, it is important to highlight that the analysis of societal and climate dynamics across this region is more detailed to address variabilities and diversity.

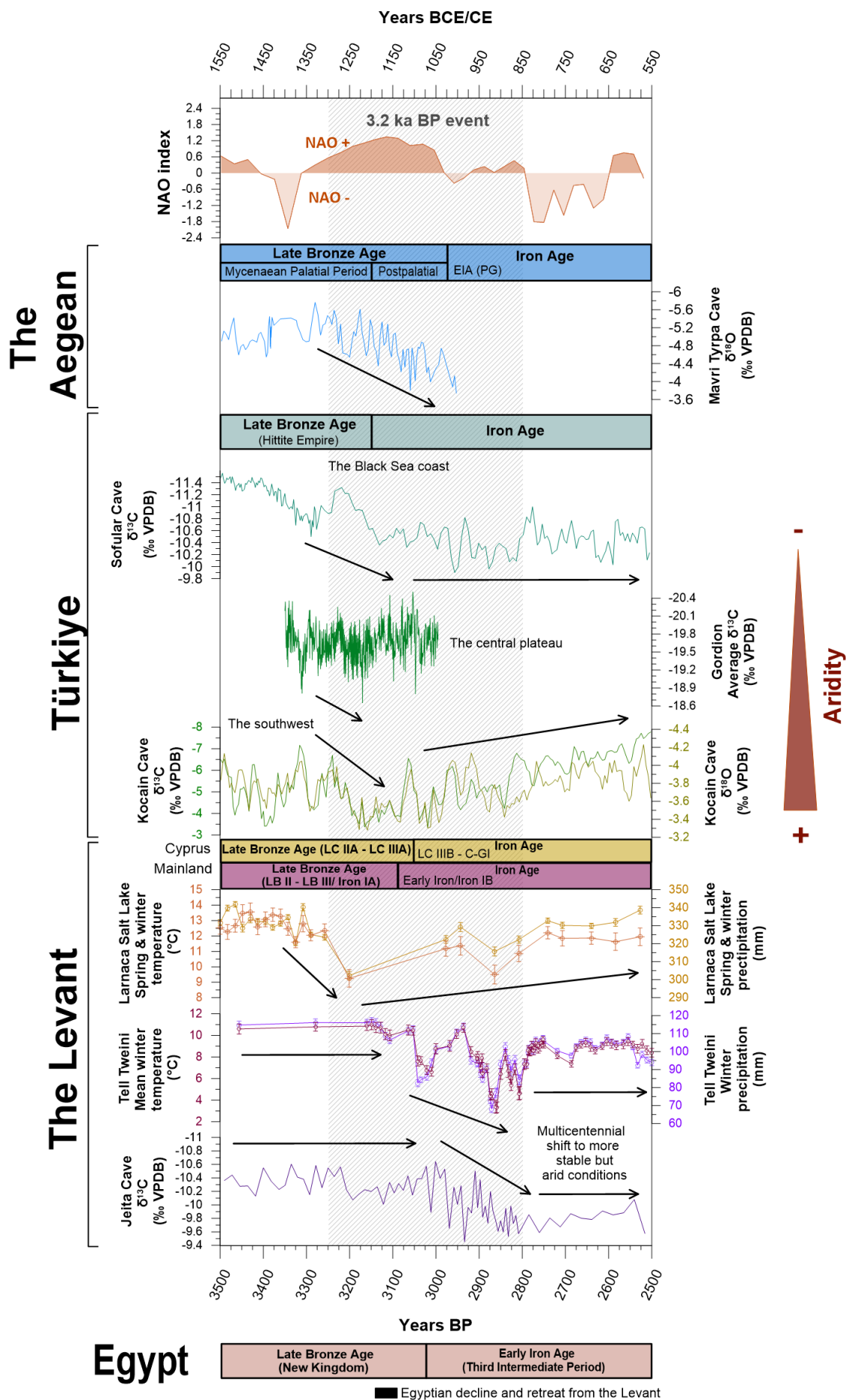


Figure 42. Eastern Mediterranean hydroclimatic and temperature proxy signals shown against Late Bronze Age-Early Iron Age chronologies of Türkiye, the western Aegean and the Levant. The grey shaded bar indicates the 3.2 ka BP event. Source: Author's original.

6.3.1. The Late Bronze Age and Early Iron Age across Türkiye

During the LBA, Türkiye was home to the Hittite Empire, which is recognized as one of the great powers of the ancient world. To support their vast Empire, which extended from the central plateau into northern Syria, the Hittite state relied on intensive agricultural production and the accumulation of substantial agricultural surplus (Sagona and Zimansky, 2009: 253; Bryce, 2002: 72; Dörfler et al. 2011; Castellano, 2018: 278). As introduced in Chapter 1, the Hittite Empire depended on large grain supplies to feed their general population and maintain their substantial army to keep and consolidate their position within the EM world (Bryce, 2002: 72; Dörfler et al. 2011). In the LBA, direct imperial control is evident across the central plateau, as reflected by monumental and fortified urban centers (e.g., Hattuša, Çadır Höyük) and a centralized and standardized economy. For example, within the Hittite sphere of influence, ceramics were largely mass-produced (Seeher, 2011). However, as presented in Chapter 3, socio-political and cultural differences are also evident across Türkiye during the LBA. Notably, the Hittites did not control the north, which was home to the likely semi-nomadic Kaška in the Black Sea region (Glatz and Matthews, 2005; Yakar, 2008; Hammer and Arbuckle, 2017). Additionally, whilst the western lands were under the vassalage of the empire, there is no evidence of direct Hittite control or involvement in this region (Bryce, 2011: 363; Sagona and Zimansky, 2009; Mac Sweeney, 2010: 8). As proposed by Mac Sweeney (2010: 8), western groups may have been distant from the Hittites who may have been a relatively minor consideration in the context of their wider world-view.

Despite their power and military successes, Schachner (2020: 394) suggests that the economic, political and social system of the Hittites was fragile, due to geographical obstacles. As introduced in Chapter 2, the topography and landscape of Türkiye is complex and fragmented. Significantly, the Hittite heartland was landlocked and isolated from northern and southern seas (Alparslan and Doğan-Alparslan, 2015: 97). The Hittites also faced numerous conflicts during the LBA. For example, the Hittites clashed with Egypt over the control of the northern Levant, culminating in the battle of Qadesh. The Hittite Empire is also understood to have been at constant odds with the Kaška and western states (Glatz, 2020: 40; Matthews and Glatz, 2009; Mac Sweeney, 2010). Thus, whilst the Hittite Empire was powerful, it was also subject to

a number of fragilities and vulnerabilities before its dissolution in the late 12th century BCE (ca. 1200-1180 BCE). Following a gradual decline seen across the empire towards the end of the LBA, by the late 12th century BCE (ca. 1200-1180 BCE), Türkiye had witnessed the disintegration of Hittite power and the disappearance of all traces of the Hittite Empire, marking the end of BA Türkiye (Glatz, 2020: 40). Following the demise of the Hittite Empire, significant societal transformation can be seen into the EIA. Significantly, the north-central plateau witnessed a widespread return to simpler socio-political systems and smaller domestic settlements (Mora and d'Alfonso, 2012: 388; Genz, 2004; Henrickson and Voigt, 1998; Matsumura, 2008). For example, during the EIA Hattuša and Gordion were occupied by small village communities (Genz, 2004, 7-10; Kealhofer et al. 2019; Henrickson and Voigt, 1998). In contrast, continuity in settlement pattern and occupation can be seen across the south-central plateau at the sites of Türkmen-Karahöyük and Kınık Höyük (Massa et al. 2020: 66; d'Alfonso 2010: 36-38). Additionally, whilst less is known about socio-political, economic and cultural conditions of the LBA-EIA transition period in northern and western Türkiye, as these areas were not under the direct control or influence of the Hittites, it is likely that societies would have been impacted by the events of the transition significantly less than those in the heartland. Therefore, whilst profound transformation can be seen across the heartland, there is no evidence of widespread civilizational collapse across all of Türkiye.

As can be seen in **Figure 43**, a marked reduction in precipitation can be identified in several highly resolved palaeoclimate proxy signals from the region during the LBA (Göktürk, 2011; Manning et al. 2023; this thesis). Significantly, the Ko-1 record presents a ca. 100 yr drying event from ca. 1300 BCE to ca. 1200 BCE, whilst the Gordion record appears to present a severe three-year drought from ca. 1198-1196 BCE (this thesis; Manning et al. 2023), which appears to coincide with the dissolution of the Hittite Empire. Notably, the Ko-1 record appears to demonstrate an earlier trend towards aridity than the Sofular and Gordion records, which may reflect the regional diversity of climatic conditions across Türkiye. As introduced in Chapter 2, drier conditions can also be seen towards the end of the LBA in the Tecer, Eski Acigöl, and Nar Gölü proxy records from central Türkiye (Kuzucuoğlu et al. 2011; Roberts et al. 2001; Dean et al. 2015). During the LBA, Hittite subsistence shows some degree of risk aversion, which may demonstrate a degree of resilience. For example, cereal assemblages at a number of sites generally demonstrate diversified crop cultivation, with a range of cereals and legumes grown during the LBA. Additionally, barley, which is a dominant crop at most sites during the LBA, can produce a sufficient yield even during bad years (Dörfler et al. 2011). Storage of surplus is also evident at sites (e.g., Oymağaç Höyük, Hattuša, Kuşaklı Höyük),

which suggests that the Hittites were accustomed to the challenging agricultural environment of the central plateau, as the storage of agricultural surplus can be used to ensure adequate food resources in bad harvest years, thus guarding against food shortages (Winterhalder, 1990; Marston, 2011). Such subsistence strategies appear to demonstrate societal knowledge of the risk of insufficient water availability and drought in the EM region. Across the LBA and EIA periods, several changes in crop cultivation and animal husbandry can be identified. For example, an increase in drought-resistant crops (e.g., barley and bitter vetch) and an increase in the ratio of sheep and goats to cattle at a number of sites (e.g., Gordion, Kaman-Kalehöyük) are often taken to reflect drought sensitivity and a potential shift to drier climate conditions into the EIA. Whilst there appears to be some evidence of adaptability, it is likely that consecutive dry years in areas such as southwestern Türkiye (as demonstrated by the Ko-1 record) would lead to successive years of low yield, which may have depleted stored grain. Whilst the Hittites were accustomed to drought and stress (Manning et al. 2023), it is likely that Hittites would have been vulnerable to prolonged aridity and multi-year drought towards the end of the LBA due to their reliance on significant grain supplies. Significantly, multi-year drought and, consequently, bad agricultural years can overwhelm agricultural production and prevent the production of surplus needed to sustain the substantial grain supply required to support the functioning of the empire (Manning, 2018). As stated in Chapter 1, several texts allude to food shortages at the end of the LBA, such as *KUB 21.38*, a Hittite letter from the queen Puduhepa to Ramesses II stating that there is no grain in her lands (Kitchen, 1982; Knapp and Manning, 2016). Textual evidence also suggests that surrounding neighbours (e.g., Ugarit) withheld grain shipments to Hatti, due to their own difficulties (Divon, 2008; Knapp and Manning, 2016; Manning et al. 2023). Besides textual documents, there does not appear to be any other evidence at present that supports widespread famine across Türkiye. In light of these findings, it would appear that drier conditions may have likely contributed, in part, towards the dissolution of the Hittite Empire, alongside several other causal factors such as economic decline and rebellion or invasion from hostile neighbouring regions.

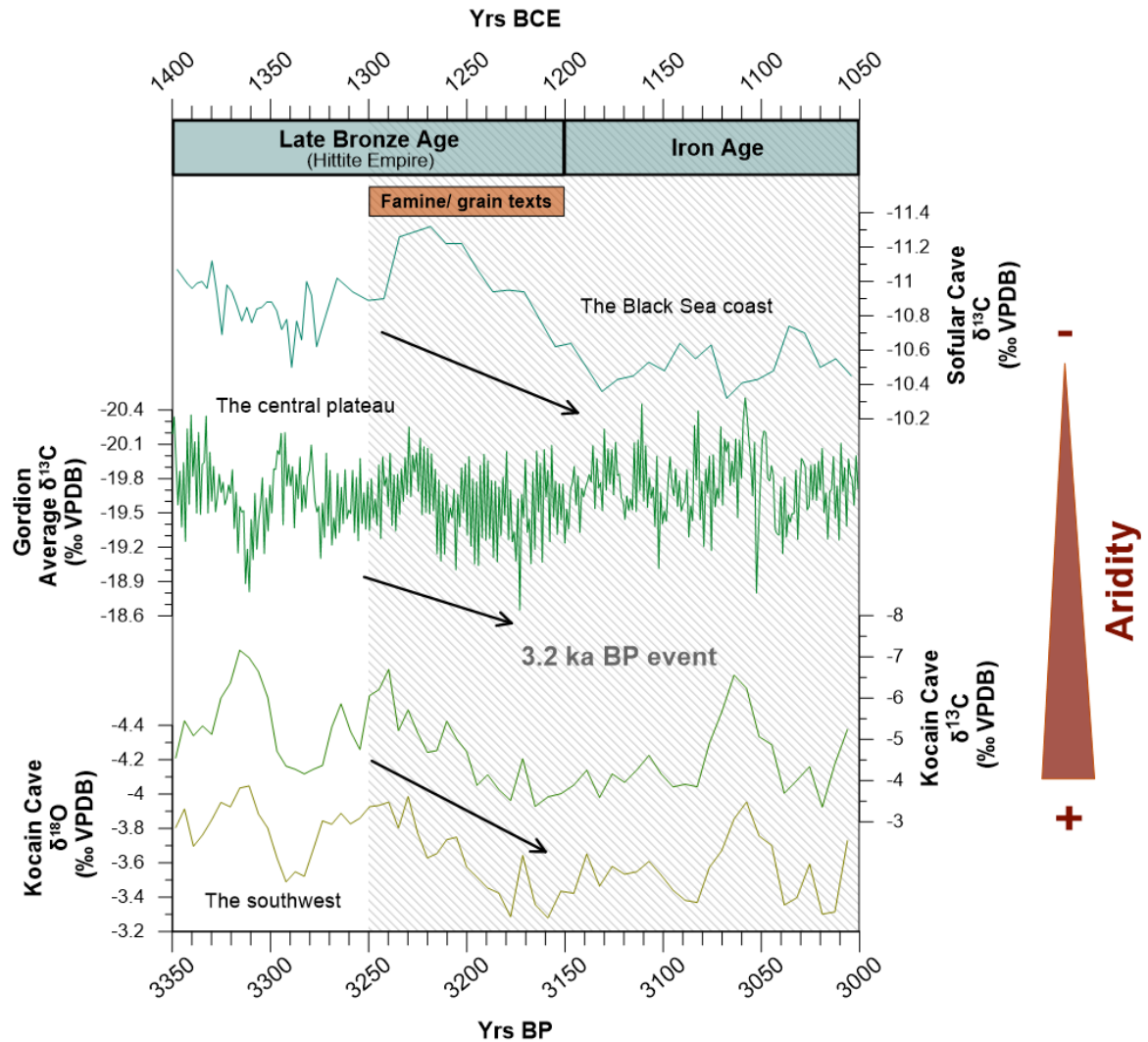


Figure 43. High-resolution hydroclimatic variability in Turkish proxy records across the LBA-EIA transition, from the north (the Black Sea) to the southwest (Antalya region). This figure is based on Figure 2 of Manning et al. (2023), with the addition of the new Ko-1 record. The grey shaded area indicates the 3.2 ka BP event. Source: Author's original.

6.3.2. The Late Bronze Age and Early Iron Age across the Western Aegean

During the LBA, the Aegean was home to the Mycenaean palatial system, which consisted of a highly connected network of monumental palaces and centres (e.g., Mycenae, Pylos). The palaces are understood to have controlled the economic, cultural and political spheres across the Aegean due to their power and influence (Shelton, 2012; Maran and Wright, 2019: 114). Whilst speculative, it is thought that the palaces were involved in agricultural production across the region including cereal production. For example, at Knossos, there is evidence for the provision of plough cattle to increase grain production (Bennet, 2007: 207). However, the

palaces did not maintain total control over food supply (Foxhall, 1995: 243). For example, whilst the palaces were directly involved in wheat production, a significant proportion of food staples came from independent producers (Foxhall, 1995: 243). It is also important to emphasize that whilst Mycenaean influence is generally thought to have been widespread throughout the western Aegean, evidence of palatial centres is not identifiable across several areas of the region, including Achaea, Corinthia, Locris and Phocis (Dickinson, 2006: 24; Middleton, 2020: 10). It is also important to highlight that whilst the Aegean LBA is generally considered a prosperous period, signs of decline and political instability can be identified during the later stages of the LBA (Deger-Jalkotzy, 2008).

At the end of the palatial period (LH IIIB), around ca. 1200 BCE, the Aegean significantly witnessed the destruction of the palaces. The breakdown of the palatial system across the Aegean notably led to the development of small and powerful competing groups and the emergence of a pronounced socio-political regionalism across the Aegean (Eder and Lemos, 2019; Maran and Wright, 2019). Significantly, the demise of the palatial system also led to the loss of palatial organization and traditions, including the use of monumental architecture (Deger-Jalkotzky, 2008). Whilst the Aegean witnessed the “collapse” of Mycenaean palaces this transformation did not involve complete breaks or straightforward continuities in societal conditions (Middleton, 2020; Eder and Lemos, 2019: 135). Notably, the end of the palatial period did not mark the end of the LBA, as it was followed by the post-palatial period (LH IIIC). During the post-palatial period and the EIA, diverse societal trajectories can be seen across the Aegean (Eder and Lemos, 2019). For example, whilst several palatial sites (e.g., Tiryns, Pylos, Mycenae) and non-palatial sites (e.g., Menelaion, Teichos Dymaion) were destroyed and abandoned, some sites devoid of palatial influence such as Lefkandi maintained their importance into the EIA (Thomatos, 2006: 252-260; Lemos, 2012; Maran and Wright, 2019: 119). By the end of the 11th century BCE, multiple sites across Crete also appear to have experienced prosperity (Dickinson, 2012: 487). For a comparison of palatial and post-palatial site and cemetery numbers across the Aegean, see **Figure 44**.

During the palatial and postpalatial periods, the Aegean also appears to have witnessed the onset of a long-term trend towards more arid conditions from ca. 1225 BCE until ca. 1000 BCE, as recorded by the Mavri Trypa record of the Peloponnese (Finné et al. 2017). A short dry episode of around two decades is also superimposed on this longer-term trend at around 1250 BCE. As summarized by Finné et al. (2017), aridity conditions appear to have developed during the post-palatial period, with the most arid conditions established in the EIA (after 3 ka BP). A

longer-term trend towards more arid conditions is also seen in several low-resolution records from the Aegean as referenced by Drake (2012) including the pollen record of Lake Voulkaria (Jahns, 2005) and the SST record, LC21 (Rohling et al. 2002).

Based on the up-to-date archaeological and palaeoclimate proxy data presented in this thesis and summarized above, it is evident that the Aegean experienced significant societal and climatic changes across the LBA-EIA transition. Whilst our understanding of agricultural conditions in the EIA is rather limited, due to the relative scarcity of archaeobotanical evidence, the end of the palatial period of the LBA is thought to have brought with it the end of more intensive production strategies. Pagnoux and Zurbach (2020) for example, suggest that intensive agricultural production was no longer tenable due to the high agricultural risk associated with this practice. Whilst crops grown at sites with EIA occupation are not strikingly different from those grown in the LBA, the EIA does see an increase in crops that require less water including barley, emmer wheat and einkorn wheat, which may reflect a shift to more arid climatic conditions across the region (Foxhall, 1995: 248; Pagnoux and Zurbach, 2020: 274). Zooarchaeological evidence also suggests that the EIA saw an increase in goats across areas of low rainfall which most likely presents an adaptive response to climatic changes across the transition (Dibble and Finné, 2021). Dibble and Finné (2021) also suggest that food production and animal husbandry became more diverse in the IA which also may reflect the adaptive response of EIA populations to challenging conditions. As suggested by Finné et al. (2017), dry conditions from 3.1 ka BP (1150 BCE) may have contributed to the instability and pressures of Mycenaean palaces which were already experiencing societal turbulence during their final stages. However, dramatic agricultural changes are unlikely to have been experienced at the levels of local settlements and small-scale farmers, who may have been able to return to more traditional smaller-scale subsistence practices associated with less risk in the face of climatic stress (Foxhall, 1995: 250). It is also important to highlight that there is no record of famine at ca. 1200 BCE in Greece (Middleton, 2020). Linear B records, for example, show that palaces distributed normal rations to those who worked for them and sent offerings to sanctuaries, which does not appear to suggest that the region was amid a grain shortage at this time (Lupack, 2011; Middleton, 2020).

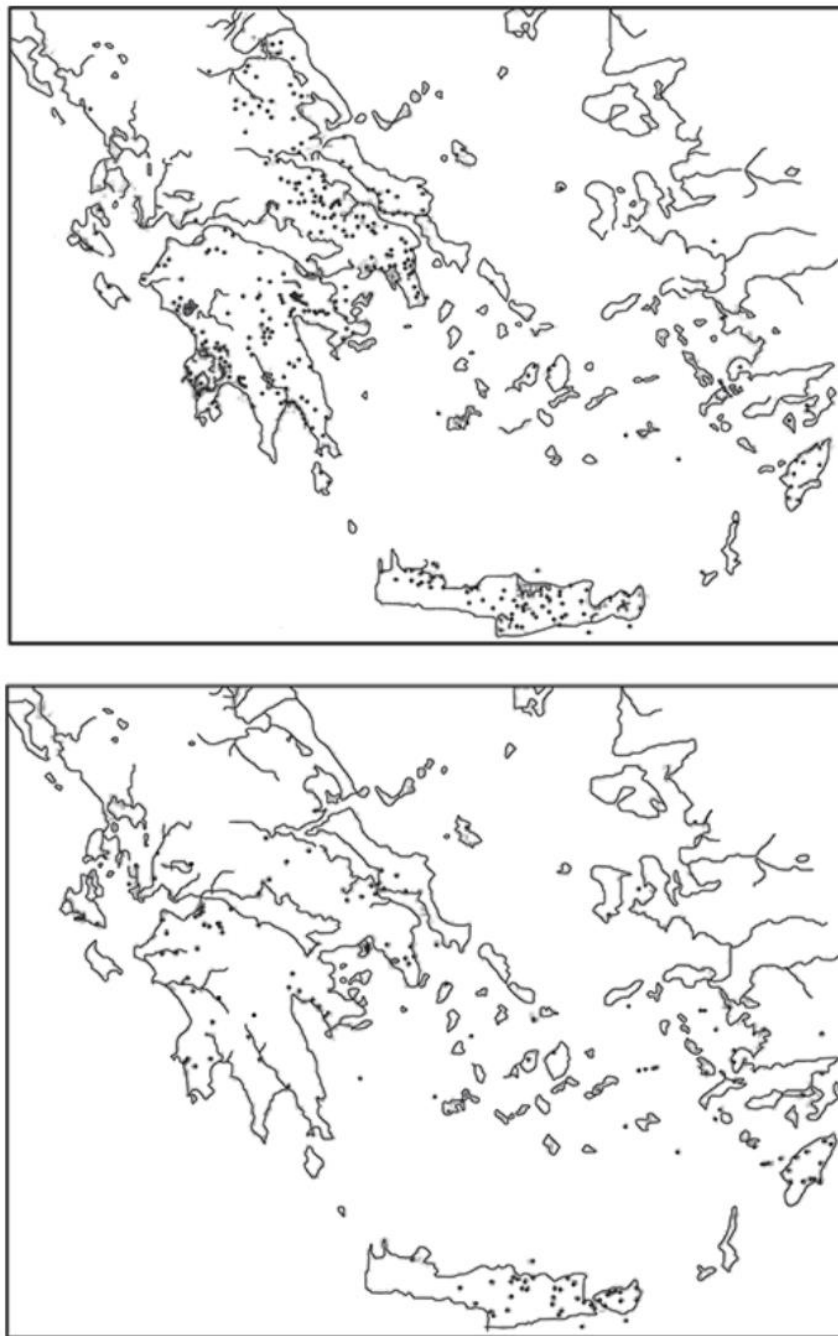


Figure 44. Sites and cemeteries of the Palatial (top) and Postpalatial (Bottom). Source: Middleton (2019, Figure 5), based on the original map from Popham (1994: 282-283). Copyright © 1994. Reproduced with permission of Oxford Publishing Limited through PLSclear.

6.3.3. The Late Bronze Age and Early Iron Age across the Levant

During the LBA city-states of the northern and southern Levant were under the vassalage of the Hittite and Egyptian Empires (as can be seen in **Figure 45**), who sought to control trade networks across the region whilst Cyprus was home to a number of regional polities. It is, however, important to emphasize that Egyptian control and influence was not uniform across the southern Levant, as reflected by its politically fragmented landscape and relative autonomy within the international trade network of the period (Panitz-Cohen, 2014; Manolova, 2019: 1186). During the LBA Levantine agriculture appears to have been integrated into palatial economies, with agricultural surplus production required to maintain Hittite and Egyptian vassalage. For example, sites such as Palioklichia in Cyprus are thought to have functioned to provide agricultural support for urban centres sustaining copper production (Webb and Frankel, 1994). At this time, the Levant was home to several important ports and urban centres located across coastlines and inland plains (e.g., Ugarit, Jaffa, Hala Sultan Tekke), though it is believed that most people lived in smaller villages that provided support for the larger cities. Generally, there appears to have been regional differences in cultural traditions across the Levant, though some homogeneity can be seen in the southern Levant reflecting Egyptian influence (Gonen, 1992b; Panitz-Cohen, 2014).

At the end of the LBA, the Levant like its EM neighbours also witnessed the destruction and abandonment of key sites including Ugarit and Emar in Syria, Hazor and Lachish across the southern Levant and several Cypriot sites such as Hala Sultan Tekke and Palaeopaphos. Significantly, the end of the LBA saw the demise and decline of Hittite and Egyptian influence and control, which brought about regional instability and fragmented polities in the northern and southern Levant (see **Figure 46**). Into the EIA the Levant also saw the end of the extensive economic networks of the LBA and shifts in settlement patterns. For example, settlements in the northern Levant are characterized by domestic dwellings rather than the urban features of the LBA. The EIA also saw the emergence of new cultural practices, including new burial practices (e.g., intra-muros chamber tombs in Cyprus) and ceramic traditions (e.g., the introduction of homemade pottery). However, the continuity of some LBA societal features can also be seen across the Levant into the EIA. For example, the size and location of most northern Levantine towns and cities remained the same in the EIA. Continuity in Hittite influence and tradition in the form of monumental religious architecture can also be seen in the EIA at several Syrian sites in the so-called Neo-Hittite tradition.

In Cyprus, a reduction in precipitation in the Larnaca Salt Lake record appears to indicate drier conditions during the LBA from 1350-1250 BCE, whilst the Jeita cave record in the northern Levant also presents a short period of aridity around 1250 BCE (Kaniewski et al. 2019b; Cheng et al. 2015). As presented in Chapter 2, several lower-resolution proxy records from the Sea of Galilee, Ein Gedi and the Dead Sea have also suggested drier conditions during the LBA (Langgut et al. 2013; Litt et al. 2012; Neugebauer et al. 2015). It is, however, important to highlight that the major changes in hydroclimatic and temperature conditions in the Jeita and Tell Tweini records of Lebanon and Syria are seen from ca. 1050 BCE, after the events of the terminal LBA, as can be seen in **Figure 42** (Kaniewski et al. 2019b; Cheng et al. 2015). Into the EIA, the end of Hittite and Egyptian dominance saw the end of state-level involvement in agricultural production. Instead, Levantine agropastoral strategies into the EIA appear to have been focused at a settlement level (Porter, 2016: 388-389). As suggested by Karakaya and Riehl (2019: 155) the end of state regimes and economies across the Levant may have led to a period of emancipation into the EIA, which freed local farmers from former economic ties which may have allowed the development of more versatile subsistence strategies and resilient agricultural production (Karakaya and Riehl, 2019: 155). It is important to emphasize that several letters have been taken to indicate a famine in the final decades of Ugarit (e.g., RS 94.2002+2003; RS 34.152), though there is uncertainty over the timing of events (Singer, 1999; 2000; Cohen and Singer, 2006; Divon, 2008: 103-104; Knapp and Manning, 2016). However, it is also important to highlight that there is no evidence to suggest that the entirety of the LBA and the IA Levant experienced widespread dearth and famine at the end of the LBA. For example, the cultivation of more drought-susceptible crops appears to have become more widespread into the IA (Karakaya and Riehl, 2019: 155).



Figure 45. Map showing the spheres of Hittite and Egyptian territory and influence across the Levant during the LBA. Source: Sauvage (2020: 99). Reproduced with permission of the author and Les Belles Lettres.



Figure 46. Map showing the Iron Age states and polities of the Levant and Mesopotamia.

Source: Sauvage (2020: 113). Reproduced with permission of the author and Les Belles Lettres.

6.3.4. What Were the Impacts of Climate Change on Late Bronze Age and Early Iron Age Societies of the Eastern Mediterranean?

As presented in Chapter 3 and summarized above, the EM appears to have witnessed significant socio-political and cultural transformations across the LBA-EIA transition period. The end of the LBA world system across the EM saw not only the destruction and abandonment of important sites such as Hattuša and Ugarit, but also the demise of the Mycenaean palatial system across the Aegean and the Hittite Empire in Türkiye (Eder and Lemos, 2019; Schachner, 2020: 396). Additionally, whilst Egypt did not experience the same fate as the Hittites, its Empire did experience a significant decline in the EIA and retreated from its well-established

Levantine territory (Killebrew, 2014: 599). In addition to the loss of major LBA socio-political systems and their high connectivity, which were replaced by smaller regionalized polities, many changes were also seen across the EM at the end of the LBA in settlement patterns and material culture. For example, in Türkiye, the end of the centralized and standardized economy of the LBA brought about the end of centralized mass production of ceramics, which was replaced by more handmade and variable ceramics, indicative of household-level production.

Whilst the dramatic events seen at the end of the LBA indicate a period of instability and crisis, the archaeological evidence also presents socio-political and cultural diversity across the EM. The events of the LBA-EIA transition and processes of change appear to have differed throughout the EM, as presented in this chapter and Chapter 3, whilst societal trajectories also appear to have differed. The end of the LBA would have likely caused significant upheaval for many such as those living in areas of direct imperial influence such as central Türkiye whose social, economic and ritual landscapes underwent profound transformation (Glatz, 2020: 300). However, the stresses and events of the terminal LBA may have been felt less by communities beyond direct imperial control, such as groups and polities in western Türkiye, who were able to make their own economic and agricultural decisions based on local traditions and knowledge, and thus would have been less likely to feel the impact of political and economic state “collapse”. Additionally, some communities and individuals may have benefitted from the collapse of political states, freed from their political and economic control. For example, the end of tax collection would have been a relief to former Hittite subjects (Glatz, 2020: 299).

It is also important to recognize that the impact of political “collapse” would be felt more severely by elites, reliant on imperial systems, compared to the majority of the EM population living in small villages, whose lives might have continued much as before. However, it is important to recognize that we still know very little about individual and household level agency and decision making during the LBA and EIA. As different groups and societies would have experienced different lived experiences across different environments during the LBA-EIA, it is important to recognize that societal vulnerability and resilience in the face of climate change would have also varied. As introduced in Chapter 1, the impacts of climate and environmental changes on societies are tied to social, economic and political circumstances, as well as societal attitudes (Middleton, 2020: 14). Different groups, guided by the decisions of key figures in the community, can pursue different coping strategies when faced with climate change (Hassan, 2016: 41).

During the LBA, large-scale agricultural decisions appear to have been largely under the control of LBA states. At this time, the Mycenaean palatial system and the Hittite Empire in the western Aegean and Türkiye appear to have been involved in intensive agricultural production to ensure stable crop cultivation. For example, large grain stores and traction animals used for ploughing can be identified at several LBA sites (see Chapter 3). The cultivation of crops appears relatively risk-averse during the LBA, with a range of cereals grown, including high frequencies of drought-resistant barley and bitter vetch, thus indicating some degree of societal resilience. In the EIA, several changes can be identified in agricultural production, which may indicate an adaptive response of EIA societies to changes in climate conditions. Significantly, the demise of the palatial system and Hittite Empire brought about the end of intensive agricultural production, as indicated by the end of high labour production and the absence of large-scale grain storage seen during the LBA. An increase in drought-resistant crops, most notably barley, can also be identified at several sites in the EIA, which may indicate concern over crop yields. Additionally, an increase in the ratio of goat to sheep seen in EIA assemblages across several sites across the western Aegean and Türkiye may reflect a shift to drier conditions, as goats require less water than sheep and tolerate lower quality pasture (Zeder and Arter, 1994: 1; Hongo, 1998: 253; Dibble and Finné, 2021). However, it is also important to recognize that changes in crop cultivation and animal husbandry may also reflect changes in economic practice and cultural preferences (Sapir-Hen et al. 2014; MacKinnon, 2014: 221).

As discussed in 6.3.1 and 6.3.2, climate change may have been a shock to the Mycenaean palatial system and an already vulnerable and maladaptive Hittite state. However, the impact of climate change may have differed across groups and communities that were peripheral to state systems across the western Aegean and Türkiye and may have possessed greater resilience and agency. Groups beyond state influence may have possessed more resilience to disturbances including climate change, as greater autonomy allows for local decision-making to change based on local environmental knowledge (Marston, 2015). For example, in more recent history, it is understood that some communities, e.g., indigenous peoples, possess a capacity to adapt to environmental changes and uncertainties when faced with local climate variation due to their in-depth understanding of the land as part of their traditional ecological knowledge (TEK) (Scaddan, 2008; Hosen et al. 2020). TEK can be defined as “a cumulative body of knowledge, practice and belief, evolving by adaptive processes” (Berkes, 2000: 1252). In the LBA it is believed that agricultural production operated with autonomy at the site of Kaymakçı in western Türkiye, employing diverse and extensive agricultural practices which can minimize

agricultural risk (Shin et al. 2021; Marston et al. 2022; Marston, 2011). For example, a diverse range of crops were cultivated at the site during the LBA, increasing agrobiodiversity and thus resilience. Additionally, the use of wild animals (e.g., fish and deer) is also evident at the site in the LBA. Semi-nomadic groups, such as the Kaška in northern Türkiye, may have also employed more risk-averse subsistence strategies such as crop and spatial diversification and mobility to meet their own local and community needs.

Notably, climate change can threaten food supply by lowering crop yields and reducing food availability (Jones et al. 2017). As introduced in Chapter 2, dry spells can shorten crop growing periods, which can result in lower crop yield, affecting food security (Mugalavai et al. 2008; Bahiru et al. 2020; Habte et al. 2023). As summarized by Jones et al. (2017), food insecurity is affected by state vulnerability, which varies according to economic and geographic features that may magnify the impact of food security and the capacity of a state to prevent or manage its ramifications. Based on texts understood to reflect famine and grain shortages (see Chapter 1), it is possible that the land of Hatti and Ugarit experienced food shortages during the terminal LBA due to the vulnerabilities of the Hittite state. However, there is no archaeological evidence of widespread food shortages or famine across the EM region. For example, there is no evidence of famine in the Aegean around ca. 1200 BCE (Middleton, 2020). Additionally, there is no archaeological evidence (e.g., osteological evidence of malnutrition or the presence of mass graves) that might indicate widespread famine across the EM (Morgan, 2013). Furthermore, it is important to emphasize that the detection of famine may not be possible from the archaeological record alone (Morgan, 2013).

In summary, it is evident from comparison of the palaeoclimate and archaeological evidence that whilst some areas of the EM did experience climate changes at the end of the LBA, there was no uniform societal impact of climate change across the region.

6.4. Did Climate Change Contribute to the End of the Late Bronze Age in the Eastern Mediterranean?

Whilst the EM does appear to have experienced a shift to drier and cooler conditions during the LBA in the western Aegean and Türkiye, we must remember that climate has always been a threat to ancient societies in the EM, and so it is likely that populations would have anticipated bad years. As summarized by Degroot et al. (2021) we know that communities and cultures can persist amid changing climates, as can be seen throughout the Holocene. For example, whilst the site of Kültepe, which was part of the Assyrian trade network, is thought to

have experienced climate change and aridity around 4.2 ka BP, Kültepe did not “collapse” (Haldon et al. 2020). Instead, the site continued for another 550 years after the shift to aridity. We, therefore, might expect some degree of resilience and adaptability in the face of climate challenges at the end of the LBA, as summarized above. We must also recognize that complex societies are not indefinitely adaptive to climate variability, as introduced in Chapter 1, as the adaptive capacity of a society can become overwhelmed by multiple poor harvest years (Weiberg and Finné, 2018; deMenocal, 2001; Izdebski et al. 2022). It is important to recognize that the resilience of societies will depend upon a number of factors (e.g., political, economic) and can therefore differ between groups. Whilst LBA-EIA agricultural evidence across the EM demonstrates an awareness and management of agricultural risk, there are limits to adaptation and societal resilience. For example, whilst the production of surplus grain, seen at many EM sites during the LBA, can ensure adequate food resources during bad harvest years and reduce the chance of subsistence failure, multiple bad years may overwhelm risk-buffering strategies including exhausting grain stores (Marston, 2011; Halstead, 2014; Manning, 2018). Additionally, complex and hierarchical societies are more interconnected and reliant on social connections, making them less flexible to changes (Coombes and Barber, 2005; Flohr et al. 2016). It is also important to highlight that societies are generally at their most vulnerable at their peak (Wright, 2004), and as presented in this thesis EM states were subject to numerous fragilities and vulnerabilities during the LBA which will have reduced their capacity to endure shocks such as climate changes.

If we consider the adaptive cycle framework introduced in Chapter 1, we can think of LBA states such as the Hittites and the Mycenaean palatial system as sitting within the conservation (K) phase, with maximum connectedness, but the lowest flexibility and potential for change. As posed by Halstead (1993: 68), domestic buffering is likely to have been undermined by rigid state systems reliant on intensive agricultural production. The Hittite Empire, for example, relied on intensive rain-fed agricultural production during the LBA due to their need to feed the general population and a large army. As discussed in Chapter 2, rainfall is a limiting factor for agriculture in central Türkiye and so it is possible that even small changes in rainfall had a significant agricultural impact (Marston, 2010: 457). A shift towards arid conditions at the end of the LBA likely overwhelmed agricultural production, which may have ultimately led to a reduction in tribute and taxation to palace leadership, who in turn may have lost the capacity to provide for their cities or maintain armies to ward off invaders or to support the wider populations who were providing grain taxation to the state, thus increasing the risk to a household’s inter-annual food supply. As summarized in Chapter 1, several text documents

have also suggested an incidence of food shortages and possible famine across Türkiye at the end of the LBA. Whilst intensive agricultural production would have served as an adaptation to maximize grain supply given the environmental challenges posed by the semi-arid central plateau and topological restrictions, this agricultural system would have been less resilient to shocks and disturbance due to its rigidity and reliance on substantial grain supplies. Climate may have therefore contributed in part to the eventual demise of BA states whose state policies reduced traditional mechanisms of risk management.

We must remember, however, that socio-economic conditions at the state level are unrepresentative of the vast majority of people living in the EM during the LBA and EIA periods. EM societies of the LBA-EIA were not a unified, homogenous entity. During the LBA and EIA, the EM was home to a diverse range of people who spoke different languages and had different traditions. At least six distinct languages are attested across the corpora of LBA Hittite texts, for example, indicative of significant linguistic and likely ethnic diversity within Hittite Türkiye (Collins, 2007). Critically, different societies and populations can vary in their capacity to respond to shocks and disturbances such as climate change. Whilst climate changes may have contributed to the difficulties and strains of the Hittite Empire and Mycenaean palatial system, the motivation and resilience of elites and their imperial networks would have differed from the majority of the population living in smaller rural settlements, particularly those living beyond state influence and control. Without the rigid pressures imposed by LBA states on agricultural production, we might hypothesize that groups may have possessed a greater adaptative capacity in the face of climate changes, from observing and responding to local climate change, as discussed in 6.3.4. For example, settlements and small-scale farmers once under imperial networks may have been able to return to more traditional smaller-scale and risk-averse subsistence practices in the EIA.

The variability and diversity in both palaeoclimatic and societal conditions during the LBA-EIA, demonstrated in this thesis indicates that there is no simple cause and effect relationship between climate change and the LBA-EIA transition across the EM. Climate alone cannot account for all of the changes seen at the end of the LBA and so cannot be considered the primary cause of societal trajectories across the transition period. This is unsurprising as climate is only part of the context in which individuals, groups and socio-political and economic entities make decisions, act and react to stressors (Butzer, 2012; Middleton, 2017b; Manning et al. 2020; Manning et al. 2023). As demonstrated in this thesis, the relationship between climate and society appears to be diverse across the EM during the LBA-EIA transition. Whilst

climate may have contributed to the instability of LBA states across the EM, climate is most likely only one of multiple contributory factors. As postulated for the end of ancient Maya (e.g., Douglas et al. 2016), it is likely that BA states suffered from weaknesses, which made them vulnerable to disturbance and political “collapse”, though climate change likely exacerbated conditions.

Whilst the existing climate hypothesis has presented the end of the LBA in the EM as a period of societal catastrophe, the range of socio-political and cultural changes and continuities seen across the region demonstrates significant complexity and diversity. The EM appears to have witnessed the political “collapse” of several BA states (the Ω phase of the adaptive cycle), including the Hittite Empire, whereby climate may have played some contributory role. However, there is no evidence of civilizational “collapse” across the whole of the EM region, as demonstrated by the diverse trajectories of EM societies during the LBA-EIA transition, nor climate-induced mass famine. Instead, we might be better placed to consider the socio-political and cultural changes and return to earlier traditions seen across the EM in the EIA as features of necessary societal reorganization and transformation (the α phase of the adaptive cycle). We must also emphasize that our understanding of climate and society during the LBA-EIA transition in the EM is impeded by several limitations associated with the palaeoclimate and archaeological evidence, as summarized in Chapters 2 and 3. For example, the chronological uncertainties of the palaeoclimate data and archaeological evidence discussed in this thesis cast uncertainty over the strength of a temporal correlation between a 3.2 ka BP climate event and the end of the LBA across the EM. Furthermore, whilst it seems highly probable that climate change will have likely contributed to some degree to the difficulties faced by LBA states, we do not currently have enough robust palaeoclimatic and archaeological evidence to confidently support a causal relationship between climate change and the end of the LBA in the EM as presented by the existing climate hypothesis. This is, however, unsurprising given that few studies can demonstrate causality, as first introduced in Chapter 1 (Contreras et al. 2018).

6.5. Testing the Climate Hypothesis: New Data, New Interpretations

As presented in Chapter 1, the theory that climate change was a causal factor behind the LBA-EIA transition in the EM has become popular over recent decades, reflecting contemporary concerns over climate change and sustainability. As part of the climate hypothesis, several studies have hypothesized that the onset of a major and abrupt climate event around ca. 3.2 ka BP contributed to the end of the LBA through widespread food shortages and famine, which

underpinned societal crises and decline (Drake, 2012; Langgut et al. 2013; Kaniewski et al. 2015; 2019a; 2019b; 2020). However, this prominent and prevailing theory is not supported by the palaeoclimate and archaeological evidence examined in this thesis. Through a nuanced and multi-scalar assessment of climate and society it is clear that there are several major weaknesses of the existing climate hypothesis, as summarized below:

Firstly, the climate hypothesis presents a narrative of dramatic and catastrophic widespread “collapse” across the EM at the end of the LBA, which focuses on widespread destruction and decline. However, this view of the LBA-EIA as a period of catastrophe and widespread societal “collapse” across the entire EM is too simplistic. By following the assumption that a loss of complexity and “collapse” reflects societal regression and failure, the climate hypothesis fails to recognize the complexity of socio-political, economic and cultural dynamics across the transition period. Whilst the climate hypothesis has presented “collapse” as detrimental for societies, as introduced in Chapter 1, several archaeologists suggest that highly connected states were fragile and anomalous, with smaller political units the historical norm (e.g., Tainter, 1999; Scott, 2017; Morris, 2019; Yoffee, 2019). Therefore, it could be argued that the demise of states and palaces at the end of the LBA across the EM was a necessary societal transformation that brought a return to more typical socio-political conditions, with smaller political units and communities in the EIA. Additionally, whilst there is evidence for dramatic and pronounced socio-political and economic transformations at the end of the LBA, including the political “collapse” of states, examination of the archaeological record demonstrates that survival and continuity is also evident across the EM, thus presenting a more variable and diverse picture of LBA-EIA society across the EM. It is also important to emphasize that the climate hypothesis fails to consider the majority of the LBA-EIA population who would have been less reliant on imperial structures and networks compared to elites. This is significant as the impact of state “collapse” would have been felt more or less keenly depending upon an individual’s social position. Ultimately, the existing climate hypothesis appears to demonstrate a lack of engagement with ongoing LBA-EIA archaeological research and theory, despite the contested and transient nature of archaeology.

Secondly, whilst several EM palaeoclimate proxy records suggest a shift to more arid conditions, and perhaps cooler conditions around 3.2 ka BP, the climate hypothesis seemingly fails to address the complexity and important limitations surrounding LBA-EIA palaeoclimatic reconstruction across the region. Whilst this thesis has sought to improve the network of highly resolved proxy records covering the LBA-EIA transition across the EM, through the

construction of a new stalagmite record from Türkiye, we still require more robust and highly resolved EM proxy records if we are to determine the onset and duration of climate changes and identify synchronicity in climate variability between proxy records. Furthermore, there are gaps in the spatial coverage of proxy records, despite the high spatial variability of climatic conditions across the EM. At present, there are only two highly resolved hydroclimatic records in the Aegean, three highly resolved records from Türkiye and three highly resolved records from Cyprus and the northern Levant whilst there are no highly resolved records from the southern Levant. Additionally, there are only two highly resolved palaeotemperature records covering the entire EM, Larnaca Salt Lake and Tell Tweini from Cyprus and the northern Levant (Kaniewski et al. 2020; Kaniewski et al. 2019b). As discussed in 6.2.3, it is also important to emphasize that whilst these records appear to present dramatic cooling of overall several degrees, there is no evidence of amplified cooling in northerly palaeotemperature records which casts doubt over the reliability and accuracy of these reconstructions.

Thirdly, the climate hypothesis fails to appreciate the complexity of LBA-EIA climate and society across the EM. The deterministic and top-down narrative posed by the existing climate hypothesis fails to recognize climatic and societal variability present across the EM and ultimately fails to recognize the differential societal impact of climate changes. By presenting a narrative of widespread climate-induced food shortages and famine the climate hypothesis seemingly ignores the inherent potential of humans to move beyond or adapt to challenges, instead presenting populations as passive victims of disaster (Nicholl and Zerboni, 2020; Haldon et al. 2020). LBA societies likely had an awareness of the challenges of aridity and poor harvest, as reflected by evidence of agricultural risk management, thus demonstrating a degree of societal resilience. It is also important to recognize that the vulnerabilities and resilience of societies differ. For LBA states reliant on intensive agricultural production, external shocks, including climate change, may have overwhelmed their adaptive capacity. As presented in this chapter, drier conditions leading to poor harvest years may have contributed, in part, to the challenges and demise of the Hittite Empire and Mycenaean palatial system. However, not all LBA groups and states were under the direct control or influence of LBA states and palaces. Whilst speculative, it is possible that such societies and communities, which would have greater autonomy, may have been able to employ more diverse and extensive subsistence strategies based on local decision-making and knowledge of local land. Additionally, whilst several grain texts appear to identify food shortages across the state of Hatti and Ugarit at the end of the LBA, there is no evidence of widespread food shortages and famine across the EM. Finally, whilst the climate hypothesis has asserted a strong causal

relationship between the 3.2 ka BP and the LBA-EIA transition in the EM, we do not currently have enough robust palaeoclimatic and archaeological evidence to confidently support a causal relationship. However, as demonstrated in this thesis it does appear highly probable that climate change around 3.2 ka BP did contribute to some degree to the political “collapse” of LBA states across the EM, which requires further research.

Summary

This thesis, therefore, disputes the existing climate hypothesis, as we cannot demonstrate a simple cause-and-effect relationship between climatic change and the LBA-EIA transition. Whilst there is evidence of climatic changes across the Aegean and Türkiye at the end of the LBA, there is no evidence for a widespread and uniform societal impact of climate changes at ca. 3.2 ka BP across the entire EM region. Significantly, the findings of this thesis support the arguments posed by several archaeologists and historians which have suggested that the LBA-EIA climate narrative, and climate narratives more generally, have oversimplified the role of climate in societal changes (see Chapter 1, 1.2.2.1).

Whilst the results of this thesis do not support the simplistic causal association between climate changes and LBA-EIA societal changes across the EM region as a whole, it is nevertheless possible that a shift towards arid conditions at the end of the LBA in Türkiye and the western Aegean may have in part contributed towards the demise of the Hittite Empire and Mycenaean palatial system. Climate may therefore be considered a contributory factor, alongside other primarily societal factors in the events of the LBA-EIA transition in Türkiye and the western Aegean. It is therefore important that we revise the climate narrative to reflect this position. When examining climate as a contributory factor future studies must avoid presenting simplistic notions of widespread and uniform societal impact of climate change, and instead seek to engage with a more nuanced and micro-regional examination of climate and society across the EM to understand the climatic and societal diversity of the region and the differential impact of any climate changes.

Chapter 7 - Conclusions

7.1. Summary of Main Findings

Given the issues and contention associated with the climate hypothesis (Chapter 1, 1.2.2.1), this thesis has sought to re-examine the role of climate on the LBA-EIA transition across the EM through an interdisciplinary and multi-scalar assessment of climate and society across the LBA-EIA transition in the EM. The key research questions of this thesis are summarized below.

- Did the eastern Mediterranean experience marked changes in hydroclimatic and temperature conditions surrounding the Late Bronze Age and Early Iron Age?
- Did the eastern Mediterranean experience an abrupt, synchronous and widespread climate event at ca. 3.2 ka BP?
- What were the impacts of climate change on Late Bronze Age and Early Iron Age societies of the eastern Mediterranean?
- Did climate change contribute to the end of the Late Bronze Age and the transition into the Iron Age across the eastern Mediterranean?
- How valid is the climate hypothesis in light of new evidence?

Key Findings

This thesis has undertaken a critical analysis of key palaeoclimate proxy records, including the new Ko-1 stalagmite record from southwestern Türkiye, and LBA-EIA archaeological evidence across the EM to answer the above research questions and re-examine the role of climate on the LBA-EIA transition in the EM. The key findings of this research are summarized below.

- 1) The new Ko-1 stalagmite record from Kocain Cave in southwestern Türkiye presents a significant 100 yr drying event between ca. 3.25 ka BP (1300 BCE) and 3.15 ka BP (1200 BCE), as reflected by high magnitude changes in $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$. This drying event, which seemingly coincides with the end of the Hittite Empire, is followed by a return to wetter conditions from ca. 3.15 ka BP (1200 BCE) to 2.25 ka BP (300 BCE).
- 2) Several highly resolved palaeoclimate proxy records from the EM and surrounding areas identify a shift towards drier and cooler climate conditions around 3.2 ka BP,

which appears to coincide with the end of the LBA across much of the EM. However, whilst a notable shift to more arid conditions can be seen in proxy records from the Aegean and Türkiye, this cannot be seen in proxy records from the mainland Levant, demonstrating hydroclimatic variability across the EM region. This is unsurprising given the high degree of spatial variability of precipitation and temperature in the EM. Existing EM proxy records are also subject to limitations surrounding spatiotemporal and chronological resolution. Notably, there are only two highly resolved EM temperature proxy records covering the LBA-EIA transition period. Additionally, there is some uncertainty over the exact timing and duration of hydroclimatic and temperature changes around 3.2 ka BP.

- 3) The EM region witnessed significant upheaval and socio-political transformation during the LBA-EIA transition, which would likely have affected swathes of the population. Notably, the end of the LBA saw the destruction and abandonment of major settlements and the demise and decline of the Hittite Empire of Türkiye and the Mycenaean palatial system of the western Aegean. Significantly, these socio-political systems of the LBA did not recover into the EIA and were replaced by smaller, more fragmented polities across the region. For example, during the EIA the northern Levant was home to several smaller states and kingdoms (**Figure 46**). A number of changes in settlement patterns and material culture can also be identified into the EIA, as reflected by major architectural changes and changes to ceramics and burial traditions. However, it is also important to emphasize that whilst this period is often viewed through a catastrophic lens, sub-regional and micro-regional examination of the archaeological record identifies diverse societal conditions and trajectories across the EM during the LBA and EIA. This is exemplified in this thesis by the socio-political and cultural diversity seen across Türkiye, particularly between the central plateau and the northern and western lands. It is also important to recognize that our understanding of LBA-EIA socio-political and cultural conditions is associated with several limitations. For example, our understanding of past societal dynamics is predominantly based on elites compared to rural populations due to a bias in archaeological investigation.
- 4) The societal impact of climate change at the end of the LBA was not uniform across the EM, reflecting the different vulnerabilities and resilience of states and communities throughout the region. During the LBA, the Mycenaean palatial system and the Hittite Empire were involved in agricultural production across the western Aegean and

Türkiye. Agricultural strategies employed at LBA sites generally demonstrate a degree of agricultural risk management and thus resilience, as states would have been accustomed to the risks of insufficient water availability and crop failures. However, the adaptive capacity and resilience of LBA states was likely overwhelmed by several shocks and disturbances at the end of the LBA, including climate change around 3.2 ka BP, due to their inflexibility. Importantly, however, not all groups and communities of the EM were under the influence and control of BA states in the LBA and were thus likely able to make their own decisions to mitigate agricultural risk. Additionally, a number of changes in subsistence can be seen at sites which indicate some degree of adaptation to drier conditions into the EIA, as without the influence of BA states communities may have been able to return to more traditional and resilient agricultural production strategies. Finally, whilst several texts suggest that Türkiye and Ugarit may have experienced food shortages at the end of the LBA, there is no archaeological evidence for widespread food shortages and famine across the EM at the end of the LBA.

- 5) Ultimately, the palaeoclimatic and archaeological findings of this thesis do not support the existing climate narratives posed by the likes of Kaniewski et al. (2015), Langgut (2013) and Drake (2012). The existing climate hypothesis, which is associated with several weaknesses, generally presents a deterministic and oversimplistic narrative of LBA-EIA climate and society and makes several outdated assumptions which cannot be supported by the palaeoclimatic and archaeological evidence. Whilst there is evidence of drying, and possible cooling around 3.2 ka BP in the Aegean, Türkiye and Cyprus, there is no evidence of widespread food shortages and famine. By focussing on catastrophe and civilizational breakdown at the end of the LBA, the climate hypothesis has seemingly overrepresented disaster, failed to emphasize the spatiotemporal heterogeneity of climate changes seen across the EM, and ultimately failed to recognize the complex relationships between climate and society. By presenting a catastrophic narrative, the climate hypothesis has effectively provided an explanation for the events of the LBA-EIA transition that downplays the highly complex and multicausal changes in climate and society across the EM during this time.
- 6) As a number of questions surrounding climate and the LBA-EIA transition remain, we must continue to examine the complex and multicausal changes in LBA-EIA climate and society across the EM. However, the climate hypothesis requires significant

amendments to address the nuance and heterogeneity of EM climate and society during the LBA and EIA. Additionally, to further develop our understanding of climatic and archaeological diversity during the LBA-EIA transition we require further local and regional studies across the EM. It must also be recognized that as there is still much that we do not currently understand about LBA-EIA climate and societal dynamics across the EM, attempting to determine the role of climate on the LBA-EIA transition with any certainty remains difficult.

Whilst there is an enduring appeal to provide tidy and dramatic narratives of climate and societal changes (Aimers and Ianonne, 2014), this thesis demonstrates a complex relationship between climate and society during the LBA-EIA transition across the EM, thus challenging the simple cause-and-effect relationship between climate change and the LBA-EIA transition posed by the climate hypothesis. The examination of climate and LBA-EIA society presented in this thesis demonstrates climatic and societal variability and diversity across the different regions of the EM, which is unsurprising given the micro diversity of the Mediterranean. Whilst areas of the EM do appear to have experienced changes in climate conditions, the societal impact of such changes appears to have varied, as demonstrated in 6.3.4 (Chapter 6). Furthermore, this thesis refutes the theory of widespread climate-induced food insecurity and famine across the EM at the end of the LBA, as there is no evidence to support this hypothesis.

Though this thesis provides support for a possible link between changes in hydroclimatic variability and the dissolution of the Hittite Empire, caution must be taken. We must recognize that our understanding of LBA-EIA climate conditions across the region is still limited by several uncertainties surrounding our palaeoclimatic and archaeological understanding. Therefore, it is important that the findings of this thesis should be viewed as provisional and subject to change following the publication of any new evidence and insight.

7.2. Significance and Contribution of this Research

This research provides valuable contributions to our understanding of climate and the LBA-EIA transition across the EM region through its re-examination of the palaeoclimate and archaeological evidence, which ultimately challenges the existing climate hypothesis. The complex relationship between climate and society presented in this thesis stresses the need to avoid deterministic and catastrophic narratives surrounding the examination of climate change and the LBA-EIA transition across the EM. This thesis indicates a need to further examine

climate and societal interactions of the LBA-EIA at a micro-regional level across the EM which will further enlighten our understanding of the LBA-EIA transition.

This thesis also presents implications for palaeoclimatologists. Notably, the new highly resolved palaeoclimate data from speleothem Ko-1 fills a spatiotemporal gap in our understanding of palaeoclimatic conditions across Türkiye, and the wider EM region. Significantly the new Ko-1 contributes to our understanding of conditions surrounding the LBA-EIA transition and more broadly, Late Holocene climate variability across Türkiye and the EM. The high-resolution hydroclimatic data of Ko-1 can also be used to support climate modelling for Türkiye and the wider EM region.

This thesis is also able to contribute to our modern concerns over climate change and societal impact. Significantly, the EM region has seen an increase in the frequency and severity of water scarcity and drought over the last several decades which poses notable risk to agricultural production and thus food security. As introduced in Chapter 1, there is recognition that strategies of human resilience and persistence in the deep past can inform current mitigation and adaptation strategies (Nicoll and Zerboni, 2020). This thesis contributes to this discourse through its interdisciplinary examination of the multi-scalar societal impact of climate changes in the EM region. The results of this thesis are important as they demonstrate the complexity and diversity of climate-societal interactions and provide insights into past societal vulnerabilities and factors affecting resilience.

7.3. Recommendations for Future Research

Whilst this thesis has provided key insights into climate and societal interactions in the EM across the LBA-EIA transition, further thorough and nuanced examination is necessary. The following recommendations would help deepen our understanding into the complex relationship between LBA-EIA climate and society across the EM.

- Additional highly resolved proxy records from the EM covering the transition period should be constructed to address the spatiotemporal gaps of the existing proxy network covering the EM, given the high degree of spatial variability in EM climate. In Türkiye, the microregional case study of this thesis, it would be beneficial to provide a highly resolved proxy record from the central plateau, if possible, to reconstruct palaeoclimate variability in the Hittite heartland. Additionally, whilst several proxy records suggest some degree of cooling around 3.2 ka BP, there is a scarcity of highly resolved temperature proxy records from the EM so it is important to develop new

proxy records that can provide high-resolution reconstructions of palaeotemperatures. For example, fluid inclusion analysis should be undertaken on the Ko-1 record. Our understanding of Ko-1 proxy signal variability will also be improved by cave monitoring, which could be not undertaken in this thesis as stated in Chapter 5. Examination into the internal mechanisms that have caused the apparent shift to drier, and perhaps cooler, conditions around 3.2 ka BP in several EM proxy records should also be undertaken to understand LBA-EIA climate variability.

- Whilst we know a lot about palatial economy during the LBA, we know very little about domestic economy and agriculture at community and individual level. Archaeological survey and excavation of smaller rural sites across the EM region is strongly encouraged to understand everyday life across the region better. By examining the archaeology at a local level, we can better understand how communities functioned within the larger political entities of the LBA. By collating more data on rural populations, we can ask important questions such as how autonomous were people under state rule and what were agricultural conditions like at smaller, rural sites?
- In order to better understand climate-human relationships at a community and individual level, future studies are encouraged to employ agent based modelling (ABM), which can provide a simulation of the complex interactions between human agents and their environment (Parker et al. 2003; Matthews et al. 2007; Barton et al. 2012). Critically, ABMs focus on the diversity of agents and their modes of interaction (Ferber, 2007; Matthews et al. 2007; Fontaine and Rounsevell, 2009).
- As agricultural archaeology is still in its relative infancy across the EM, it is important for further archaeological research to improve our understanding of cultivation and subsistence strategies across the LBA-EIA transition. Increasing our understanding of past subsistence conditions may also allow for the modelling of past crops and agricultural approaches against highly resolved palaeoclimate data (such as the Ko-1 record) to estimate potential agricultural yields under past climatic conditions, as has been undertaken in a study by Contreras et al. (2018).
- The palaeoclimatic and archaeological evidence examined in this thesis should also be considered against LBA-EIA demographic changes, reconstructed through archaeological settlement data and summed probability distributions (SPD) of radiocarbon dates, and changes in landscape cover the LBA-EIA, reconstructed through environmental proxies such as pollen (e.g., Palmisano et al. 2019). Examination of LBA-

EIA population changes may further aid our understanding of the impact of climate changes on LBA-EIA societies, as we might expect to see a decrease in EIA population sizes coupled with climate changes if we follow the assumption that populations reliant on rain-fed agriculture were vulnerable to climate shifts and strain on food resources. We can also examine ecological indicators to aid our understanding of land use and subsistence strategies, e.g., was the land being used for intensive agricultural production or pasture, to further improve our understanding of human-climate-environment interactions and societal resilience of the LBA-EIA across the EM.

- To establish a stronger and more reliable temporal correlation between changes in climatic conditions and societal changes at the end of the LBA, we require the refinement of the chronological resolution of EM palaeoclimate proxy records and archaeological chronologies, which would allow us to understand better the onset and duration of changes in climate variability around 3.2 ka BP and the timing of societal changes across the LBA-EIA transition.
- Further interdisciplinary and micro-regional examination of proxy records and sub-regional archaeological evidence should also be undertaken across the EM in order to further identify and understand the variability and diversity of climate conditions and societal dynamics and behaviours within the EM region.

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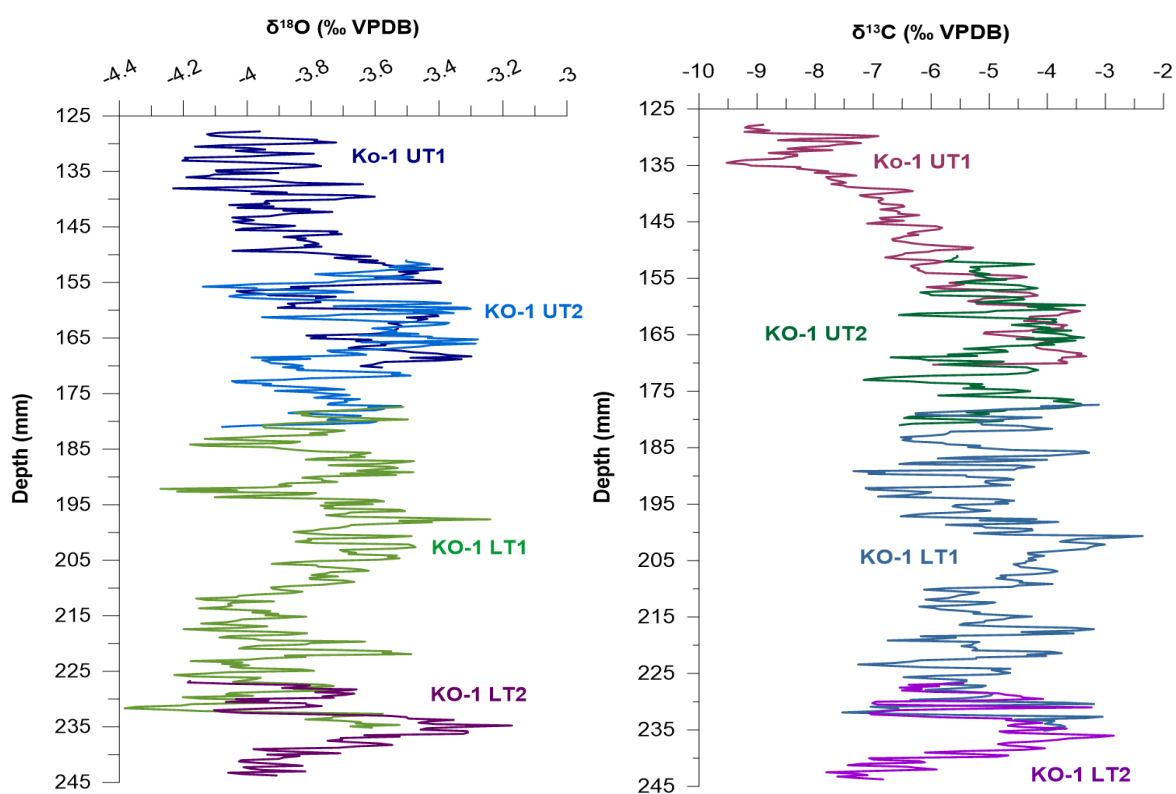
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Appendix

Appendix A1- Ko-1 drill track depth (mm) vs $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profiles.

Appendix A2- Palaeoclimatic proxy records from the Eastern Mediterranean and bordering areas.

*All sites in bold are considered key proxy records in this thesis

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
1	Grotta Savi	SV1	Northern Italy	45°37'N; 13°53'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	17,000-0	U-Th	Multi-decadal-Centennial (est.)	Frisia et al. 2005
2	Renella Cave	RL4	Central Italy	44°05'N; 10°11'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	7300-1000	U-Th	~8 yrs	Drysdale et al. 2006; Zanchetta et al. 2016
3a	Corchia Cave	CC26	Central Italy	43°59'N; 10°13'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Mg/Ca)	13500- 0	U-Th	~17 yrs	Zanchetta et al. 2007 Regattieri et al. 2014
3b	Corchia Cave	CC27	Central Italy	43°59'N, 10°13'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	6000-2000	U-Th	~15 yrs	Isola et al. 2019
4	Lake Preola	LPA, LPBC	Southern Sicily	37°37'N; 12°38'E	Lake	Sedimentology, Climate reconstruction of lake level (CA)	11,000-0	^{14}C AMS, Tephra	64 yrs (core LPA), 58 yrs (LPBC)	Magny et al. 2011
5	Gorgo Basso	GL3	Southwestern Sicily	37°37'N; 12°39'E	Lake	Pollen, Microcharcoal	10,200-0	^{14}C AMS	~65-173 yrs	Tinner et al. 2009

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
6	Lake di Pergusa	PRG1, PGR2	Central Sicily	37°31'N; 14°18'E	Lake	Pollen, Microcharcoal (PGR1) $\delta^{18}\text{O}$ (PGR2)	11,000-0	^{14}C AMS, Tephra	Multi-decadal- Multi-centennial (est.)	Sadori and Nacisi, 2001; Sadori et al. 2008
7a	Trifoglie-tti		Southern Italy	39°33'N; 16°01'E	Lake	Pollen, Precipitation reconstruction (Pollen), Magnetic susceptibility, Sedimentology	11,500-0	^{14}C AMS	~70 yrs	Joannin et al. 2012
7b	Trifoglie-tti		Southern Italy	39°33'N; 16°01'E	Lake	Temperature & Precipitation reconstruction (Pollen)	11,500-0	^{14}C AMS	~68 yrs	Peyron et al. 2013
8	Alimini Piccolo		Southern Italy	40°11'N; 18°26'E;	Lake	Pollen	5600- 0	^{14}C AMS	Multi-decadal (est.)	Di Rita and Magri, 2009
9		RL11	Ionian Sea	36°45'N; 17°43'E	Marine	Climate reconstruction: SSS (Foram $\delta^{18}\text{O}$), SST (Alkenones)	16,000-0	^{14}C AMS	~110-290 yrs	Emeis et al. 2000
10a		AD91-17	Southern Adriatic Sea	40°52'N; 18°38'E	Marine	Alkenone climate	11,500-2000	^{14}C AMS	Multi-cetennial (est.)	Giunta et al. 2003

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
						reconstruction (SST)				
10b		AD91-17	Southern Adriatic Sea	40°52'N; 18°38'E	Marine	SST reconstruction (Pollen), Magnetic susceptibility, Forams - Stable isotopes ($\delta^{18}\text{O}$), Dinocysts, Nanoplankton, Alkenones	11,500-1500	^{14}C AMS, Tephra	~223 yrs	Sangiorgi et al. 2003
11a		MD90-917	Southern Adriatic Sea	41°17'N; 17°37'E	Marine	Forams- Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Forams (SST)	12,500-0	^{14}C AMS, Tephra	~94 yrs	Siani et al. 2013
11b		MD90-917	Southern Adriatic Sea	41°17'N; 17°37'E	Marine	Forams and Alkenones (SST)	20,400-500	^{14}C AMS, Tephra	~40 yrs	Sicre et al. 2013
11c		MD90-917	Southern Adriatic Sea	41°17'N; 17°37'E	Marine	Pollen, Temperature & Precipitation reconstruction (Pollen), Sedimentology	12,500-2500	^{14}C AMS, Tephra	~140 yrs	Combourieu-Neubout et al. 2013

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
12		SA03-09	Southern Adriatic Sea	41°37'N; 17°28'E	Marine	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Forams	6000-0	^{14}C AMS	Multi-centennial (est.)	Piva et al. 2008
13		RF93-30	Central Adriatic Sea	42°40'N; 15°40'E	Marine	Pollen, Magnetic susceptibility, Sedimentology, Alkenones (SST)	7000-0	^{14}C AMS	Multi-decadal-Multi-centennial (est.)	Oldfield et al. 2003
14		AMC99-1	Central Adriatic Sea	42°52'N; 14°56'E	Marine	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Forams	6000-0	^{14}C AMS, Tephra	Multi-decadal-Multi-centennial (est.)	Piva et al. 2008
15	Strašna peć Cave	SPD-1	Eastern Croatia	44°00'N; 15°02'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	4400-1500	U-Th	~10 yrs	Lončar et al. 2019
16	Cloșani Cave	C09-2	Southwestern Romania	45°N; 23°E	Speleothem	Trace elements (Mg/Ca, Sr/Ca, Ba/Ca)	3600- 0	U-Th, lamina counting	Annual	Warken et al. 2018
17	Poleva Cave	PP10	Southwestern Romania	44°43'N; 21°45'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	11,000-2400	U-Th	~40-150 yrs	Constantin et al. 2007
18a	Lake Shkodra	SK13	Northern Albania	42°11'N; 19°17'E	Lake	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Pollen, Sedimentology	4500- 0	^{14}C AMS, Tephra	~30-50 yrs	Zanchetta et al. 2012

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
18b	Lake Shkodra	SK13	Northern Albania	42°11'N; 19°17'E	Lake	Ostracods, Charophytes	4500- 0	¹⁴ C AMS, Tephra	~14 yrs	Mazzini et al. 2015
18c	Lake Shkodra	SK13	Northern Albania	42°11'N; 19°17'E	Lake	Pollen	4500- 0	¹⁴ C AMS, Tephra	~80 yrs	Sadori et al. 2015
19	Ohrid	CO1262	Albania/ Macedonia	41°04'N; 20°40'E	Lake	Stable isotopes ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$), Geochemistry	12,000- 0	¹⁴ C AMS, Tephra, Cross-correlation	~10-40 yrs	Lacey et al. 2015
20a	Prespa	CO1215	Albania/ Macedonia	40°58'N; 20°58'E	Lake	Stable isotopes ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$), Geochemistry	80,000- 0	¹⁴ C AMS, Tephra	~125 yrs	Leng et al. 2010
20b	Prespa	CO1215	Albania/ Macedonia	40°58'N; 20°58'E	Lake	Sedimentology, Pollen, Ostracods	17,000- 0	¹⁴ C AMS, Tephra	~330-450 yrs	Aufgebauer et al. 2012
21	Butrint	BUT-12	Southern Albania	39°47'N; 20°01'E	Marine	Sedimentology, Geochemistry, Pollen	4500- 0	¹⁴ C AMS	Sub annual Geochemistry	Morellón et al. 2016
22	Dojran	Co1260	Macedonia/ Greece border	41°12'N; 22°44'E	Lake	Sedimentology, Geochemistry, Stable isotopes ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$)	12500- 0	¹⁴ C AMS	~4-35 yrs	Francke et al. 2013
23	Pamvoti-s	I-284	Northwestern Greece	39°45'N; 20°51'E	Lake	Ostracods, Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	500,000- 1200	¹⁴ C AMS	Multi-decadal-Millennial (est.)	Frogley et al. 2001

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
24	Voulkari-a	VOUL1	Western Greece	38°52'N; 20°50'E	Lake	Sedimentology, Geochemistry, Forams, Ostracods, Charophytes	8100- 0	¹⁴ C AMS	Multi-decadal (est.)	Jahns, 2005
25	Gialova		Southwestern Peloponnese	36°57'N; 21°40'E	Lake	Stable isotopes ($\delta^{13}\text{C}$ and δD), Geochemistry	3600- 0	¹⁴ C AMS	~70 yrs	Katrantsiotis et al. 2018
26	Mavri Trypa Cave	S1	Southwestern Peloponnese	36°44'N; 21°45'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	4700-1300	U-Th	~10 yrs	Finné et al. 2017
27	Agios Floros		Southwestern Peloponnese	37°10'N; 22°01'E	Lake	Stable isotopes ($\delta^{13}\text{C}$ and δD), Geochemistry, Diatoms	6000- 0	¹⁴ C AMS	~126 yrs	Katrantsiotis et al. 2016; Norström et al. 2018
28	Asea Valley	Asea-1	Central Peloponnese	37°22'N; 22°15'E	Lake	Sedimentology, Geochemistry	6500- 0	¹⁴ C AMS	~7 yrs	Unkel et al. 2014
29	Lerna		Northeastern Peloponnese	37°35'N; 22°44'E	Lake	Stable isotopes ($\delta^{13}\text{C}$ and δD), Geochemistry	5000-0	¹⁴ C AMS	~49-61 yrs	Katrantsiotis et al. 2019
30		SL148	Northwestern Aegean Sea	39°45'N; 24°06'E	Marine	Forams (Stable isotopes, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	12,000-0	¹⁴ C AMS	~150 yrs	Kuhnt et al. 2008
31		SL152	Northern Aegean Sea	40°05'N, 24°37'E	Marine	Pollen	20,000-0	¹⁴ C AMS	~128 yrs	Kothoff et al. 2008

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
32	Skala Marion Cave	MAR_L	Thassos, Greece	40°38'N; 24°31'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	5000-1500	U-Th	~18.2 yrs	Psomiadis et al. 2018
33	Messara Plain	Multiple cores	Southern Crete	35°02'N; 24°48'E	Lake	Magnetic Susceptibility, Sedimentology, Diatoms, Pollen	5000- 0	^{14}C AMS	N.A	Ghilardi et al. 2018
34		HCM2/22	Northern Levantine Sea	34°34'N; 24°54'E	Marine	Pollen, Biomarkers	20,000-2500	^{14}C AMS	~400 yrs	Kouli et al. 2012
35		LC21	Aegean Sea	35°39'N; 26°34'E	Marine	Forams (SST)	13,000-1300	^{14}C AMS	~125 yrs	Rohling et al. 2002
36		NS-14	Southeastern Aegean Sea	36°39'N; 27°00'E	Marine	Forams, Phytoplankton, Pollen, Geochemistry, SST climate reconstruction (Alkenones)	13,000-2500	^{14}C AMS, Tephra	~50-450 yrs	Triantaphyllou et al. 2009
37		GeoB76 22-2	Southwestern Black Sea	41°32'N; 31°10'E	Marine	Clay layers	7500- 0	^{14}C AMS, Tephra	~20-30 yrs	Lamy et al. 2006
38		GeoB76 25-2	Southwestern Black Sea	41°27'N; 31°04'E	Marine	Clay layers	7500- 0	^{14}C AMS	~20-30 yrs	Lamy et al. 2006
39	Sofular Cave	So-1	Northern Türkiye	41°25'N; 31°57'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$),	50000- 0	U-Th	~5 yrs & sub annual	Göktürk, 2011; Göktürk et al. 2011

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
						Trace elements (Mg/Ca)				
40	Gordion	GOR	Central Türkiye	40°05' N; 31°41' E	Tree ring	Tree ring width, Stable isotopes ($\delta^{13}\text{C}$)	3400-2800	Tree ring	Annual	Manning et al. 2023
41	Iznik	Multiple cores	Northwestern Türkiye	40°26'N; 29°32'E	Lake	Sedimentology, Magnetic susceptibility, Geochemistry, Pollen	4700- 0	^{14}C AMS, Radionuclide	N.A	Ülgen et al. 2012
42	Göhlisar	GHA & GHB	Southwestern Türkiye	37°8'N; 29°36'E	Lake	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Sedimentology, Diatoms, Precipitation reconstruction (Pollen)	10,500-0	^{14}C , Tephra	~15-295 yrs	Eastwood et al. 1999; 2002; 2007
43	Kocain Cave	Ko-1	Southwestern Türkiye	37°14'N; 30°42'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	3400- 0	U-Th	~4 yrs	Current study
44	Eski Acigöl	ESK92 & ESK95-3	Central Türkiye	38°33'N; 34°32'E	Lake	Sedimentology, Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Diatoms, Pollen	16,000-0	^{14}C , U-series	Multi-decadal-Multi-centennial (est.)	Roberts et al. 2001

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
45	Nar	NAR-10	Central Türkiye	38°20'N; 34°27'E	Lake	Magnetic susceptibility, Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Geochemistry, Diatoms	13,800-0	Varve counts, U-Th	~25-200 yrs	Dean et al. 2015; 2018; Roberts et al. 2016
46	Tuzla	TZL 16-01	Central Türkiye	36°42'N 35°02'E	Lake	Pollen	5000-0	^{14}C AMS	N.A	Şenkul et al. 2018
47	Amik Lake		Southern Türkiye	36°21'N; 36°21'E	Lake	Sedimentology, Geochemistry	4000-0	^{14}C	N/A	El Ouahabi et al. 2017
48	Tecer		Central Türkiye	39°25'N; 37°05'E	Lake	Sedimentology	6000-0	^{14}C AMS	N.A	Kuzucuoğlu et al. 2011
49a	Hazar	HZ11-P03	Southeastern Türkiye	38°31'N; 39°25'E	Lake	Magnetic Susceptibility, Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Geochemistry	17,500-0	^{14}C AMS	~27-177 yrs	Eriş, 2013; Eriş et al. 2018; Ön et al. 2018
49a	Hazar	HZ11-P03	Southeastern Türkiye	38°31'N; 39°25'E	Lake	Pollen	13,000-0	^{14}C AMS	~150-200 yrs	Biltekin et al. 2018
50a	Van		Southeastern Türkiye	38°38'N; 42°49'E	Lake	Stable isotopes ($\delta^{18}\text{O}$), Trace elements (Mg/Ca), Pollen	12700-0	Varve counts	Multi-decadal- Multi-centennial (est.)	Wick et al. 2003

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
50b	Van	V08G04	Southeastern Türkiye	38°21'N, 43°03'E	Lake	Magnetic susceptibility, Geochemistry, Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Ostracods	3500- 0	^{14}C AMS, Radionuclide, Varve counts	N.A	Barlas Şimşek and Çağatay, 2018
51	Neor Lake		Northwestern Iran	37°57'N; 48°33'E	Lake	Stable isotopes (δD), Trace elements, Geochemistry	13,350- 0	^{14}C AMS	~3 yrs (Ti) 35-340 yrs (all other analysis)	Sharifi et al. 2015
52	Zeribar		Western Iran	35°32'N; 46°07'E	Lake	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Pollen	13000- 1000	^{14}C	Multi-centennial (est.)	Stevens et al. 2001
53	Lake Mirabad		Iran	33°05'N; 47°43'E	Lake	$\delta^{18}\text{O}$	10000- 0	^{14}C AMS	Multi-centennial (est.)	Stevens et al. 2006
54	Kuna Ba Cave	NIR-1 & NIR-2	Northeastern Iraq	35°09'N; 45°38'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	4000- 0	U-Th	~3 yrs	Sinha et al. 2019
55	Shallai Cave	SHC-03	Northeastern Iraq	35°08'N; 45°17'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), Trace elements (Mg/Ca)	11000- 0	U-Th	~9-35 yrs	Bosomworth, 2021; Fleitmann et al. in review
56		ODP 967	Levantine Basin	34°04'N; 32°44'E	Marine	Climate reconstruction: SSS (Forams-	16,000- 0	Correlation with R11	Multi-decadal- Multi-	Emeis et al. 2000

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
						$\delta^{18}\text{O}$), SST (Alkenones)			centennial (est.)	
57	Larnaca Salt Lake	B ₂₂	Southeastern Cyprus	34°53'N; 33°36'E	Lake	Pollen, precipitation & temp reconstruction (Pollen)	5000-3500	¹⁴ C AMS	~7 yrs	Kaniewski et al. 2013; 2019a; 2020
58	Tell Tweini	TW-1 & TW-2	Syria	35°22'N; 35°56'E	Lake	Pollen, Precipitation & Temperature reconstruction (Pollen)	4100-2900	¹⁴ C AMS	~14 yrs	Kaniewski et al. 2010; 2019a; 2019b
59a	Jeita Cave	JeG-stm-1	Lebanon	33°57'N; 35°39'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	11,900-1100	U-Th	~10-180 yrs	Verheyden et al. 2008
59b	Jeita Cave	J-1	Lebanon	33°57'N; 35°39'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	20,000-0	U-Th	~13 yrs	Cheng et al. 2015
60	Tel Dan	TD-1	Northeastern Israel	33°15'N; 35°39'E	Lake	Pollen	4200-2000	¹⁴ C AMS	~15 yrs	Kaniewski et al. 2017
61a	Kinneret	KI10-I & KI10-II	Northeastern Israel	32°49'N; 35°35'E	Lake	Diatoms, Pollen, Geochemistry, Climate reconstruction: Lake level (Diatoms)	9000- 0	¹⁴ C AMS	~10-50 yrs (Diatoms)	Vossel et al. 2018

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
61b	Kinneret	KI10-I & KI10-II	Northeastern Israel	32°49'N; 35°35'E	Lake	Magnetic susceptibility, Pollen	9000- 0	¹⁴ C AMS	~124 yrs (Pollen)	Schiebel and Litt (2018)
62	Sea of Galilee		Northeastern Israel	32°49'N; 35°35'E	Lake	Climate reconstruction (Pollen)	4950-1450	¹⁴ C AMS	~40 yrs	Langgut et al. 2013
63a	Dead Sea	Ein Feshka, Ein Geidi, Ze'elim Gully	Southeastern Israel	31°30'N; 35°30'E	Lake	Sedimentology (Lake level)	10,000-0	¹⁴ C AMS	Multi-centennial (est.)	Migowski et al 2006
63b	Dead Sea	Ein Geidi	Southeastern Israel	31°30'N; 35°24'E	Lake	Pollen	10,000-0	¹⁴ C AMS	Multi decadal-Centennial (est.)	Litt et al. 2012
63c	Dead Sea	Ze'elim Gully	Southeastern Israel	31°21'N; 35°24"E	Lake	Climate reconstruction (Pollen)	4500-1400	¹⁴ C AMS	~35 yrs	Langgut et al. 2014
63d	Dead Sea	SN5	Southeastern Israel	31°04'N, 35°23'E	Tree	Stable isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$)	4200-3900	¹⁴ C AMS	~3 yrs	Frumkin, 2009
64	Soreq Cave		Central Israel	31°45'N, 35°01'E	Speleothem	Stable isotopes ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$)	58,300-0	U-Th	~40 yrs	Bar-Matthews et al. 1997; 1999; 2003; Orland et al. 2009; Bar-

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
										Matthews and Ayalon, 2004; 2011
65		V-4	Mediterranean Sea	34°81'N, 32°43'E	Marine	Sedimentology, Geochemistry, Forams, Pollen, Charcoal	4550-2600	¹⁴ C AMS	~45 (Sedimentology) ~45 yrs (Geochemistry) ~25 yrs (Pollen)	Avanaim-Katav et al 2019
66		GA-112	Mediterranean Sea	31°56'N; 34°22'E	Marine	Forams- Stable isotopes ($\delta^{18}\text{O}$ & $\delta^{13}\text{C}$)	3700- 0	¹⁴ C AMS	~73 yrs	Schilman et al. 2001; 2003
67		GA-110	Mediterranean Sea	31°57'N; 34°20'E	Marine	Forams- Stable isotopes ($\delta^{18}\text{O}$ & $\delta^{13}\text{C}$)	3750- 0	¹⁴ C AMS	~114 yrs	Schilman et al. 2001; 2003
68		GeoB 7702-3	Mediterranean Sea	31°39'N, 34°04'E	Marine	Alkenones (SST)	185,000-0	¹⁴ C AMS	~231 yrs	Castañeda et al. 2010
69a		GeoB58 04-4	Red Sea	29°30'N; 34°57'E	Marine	Sedimentology, Forams- $\delta^{18}\text{O}$ (SSS), Alkenones (SST)	~7300- 0	¹⁴ C AMS	~115 yrs	Arz et al. 2003
69b		GeoB58 04-4	Red Sea	29°30'N; 34°57'E	Marine	Sedimentology, Forams- $\delta^{18}\text{O}$	~7500- 0	¹⁴ C AMS	~25 yrs	Lamy et al. 2006

Map ID	Site Name	Core/ ID	Location	Coordinates	Archive Type	Proxy Type	Approx. Time Interval	Dating technique	Average Temporal Resolution Across record	Reference
70		GeoB5844-2	Red Sea	27°43'N; 34°41'E	Marine	Sedimentology, Forams- $\delta^{18}\text{O}$ (SSS), Alkenones (SST)	10,000-0	^{14}C AMS	~123 (Sedimentology & SST) ~300 yrs ($\delta^{18}\text{O}$)	Arz et al. 2003

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