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Master Thesis

Provenance and Technological Analysis of Selected Cuneiform Tablets from the Late Second Millennium BC

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Summary

The aim of the present study is to examine a group of clay tablets by thin-section petrography and thermogravimetric analysis in order to assess specific problems related to their provenance and manufacture technology. Two sets of documents dating to the fourteenth-thirteenth centuries BC will be considered separately throughout the thesis, with different research questions in mind for each case study. The petrographic data will be compared when possible with the chemical composition of the tablets, determined by pXRF and/or INAA in previous studies. On the whole, this dissertation is an attempt to combine textual, archaeological, petrographic, chemical and thermogravimetric information in order to get a better understanding of the materiality and the historical implications of the objects under examination.

Resumo

O objetivo do presente estudo é examinar um grupo de tabuletas de argila por petrografia e análise termogravimétrica, a fim de avaliar problemas específicos relacionados com a sua proveniência e tecnologia de fabricação. Dois conjuntos de documentos que datam dos séculos XIV-XIII a.C. serão considerados separadamente ao longo da tese, com diferentes questões de pesquisa em mente para cada estudo de caso. Os dados petrográficos serão comparados quando possível com a composição química das tabuletas, determinada por pXRF e/ou INAA em estudos anteriores. No seu conjunto, esta dissertação é uma tentativa de combinar informação textual, arqueológica, petrográfica, química e termogravimétrica a fim de obter uma melhor compreensão da composição material e das implicações históricas dos objetos em análise.

Contents

Acknowledgments

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Abbreviations

AO	Inventory number for tablets in the Musée du Louvre
BLMJ	Inventory number for tablets in the Bible Lands Museum
BM	Inventory number for tablets in the British Museum
CTH	Laroche 1971
EA	Tablets from el-Amarna (Knudtzon 1915; Rainey 1978)
Emar VI	Arnaud 1986
KBo	Keilschrifttexte aus Boghazköi
KL	Kāmid el-Lōz inventory number
KUB	Keilschrifturkunden aus Boghazköi
MzP	Mainzer Photoarchiv (Hethitologie Portal Mainz)
SMEA-45	Salvini and Trémouille 2003
VAT	Inventory number for tablets in the Vorderasiatisches Museum

Conventions

- Approximate absolute dates for regnal periods follow the “Appendix: King Lists” in Van De Mieroop 2007b: 255-260.

- A slash (/) is used in toponyms to indicate the modern name of a given site followed by the ancient one (e.g., Boğazköy/Ḫattuša), and in personal names when an individual is known by two different names (e.g., Piyassili/Šarri-Kušuḫ).

1.
Introduction

1.1. Research goals

The aim of the present study is to examine a group of clay tablets by thin-section petrography and thermogravimetric analysis in order to assess specific problems related to their provenance and manufacture technology. These objects date to the fourteenth-thirteenth centuries BC and are currently kept at the Vorderasiatisches Museum (Berlin) and the Bible Lands Museum (Jerusalem). Two sets of tablets will be considered separately throughout the thesis, with different research questions in mind for each case study:

1. Seven fragments (VAT 6156, 6161, 6168, 6169+7669, 6172, 7677, 13067) of letters sent from Egypt to Ḫatti during the reigns of Ramses II and Ḫattušili III will be analyzed in order to: a) characterize the type of clay employed by the scribes, as well as its treatment and maximum firing temperature; b) compare these materials with other cuneiform tablets made in Egypt (namely, the Egyptian tablets found at Tell el-Amarna and the fragment known as Jerusalem 2) and with the Egyptian tradition of pottery production in general, considering functional and aesthetic aspects in the selection/processing of clay.

2. Five different Hittite diplomatic texts and one letter will be examined in order to determine their provenance and the possible historical implications of a non-local origin. These in turn can be subdivided into three "dossiers": 1. VAT 13008 (treaty between Šuppiluliuma I of Ḫatti and Piyassili/Šarri-Kušuḫ of Karkemiš) and VAT 7420 (edict of Muršili II of Ḫatti recognizing the status of Piyassili/Šarri-Kušuḫ of Karkemiš), which will be studied along with BLMJ 1143 (letter from a king of Karkemiš to Alziyamuwa) in order to compare their fabrics; 2. VAT 7423 and VAT 13024, two fragments of the diplomatic agreement between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni; 3. VAT 7421, a fragment from the so-called "Text A" of the treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru.

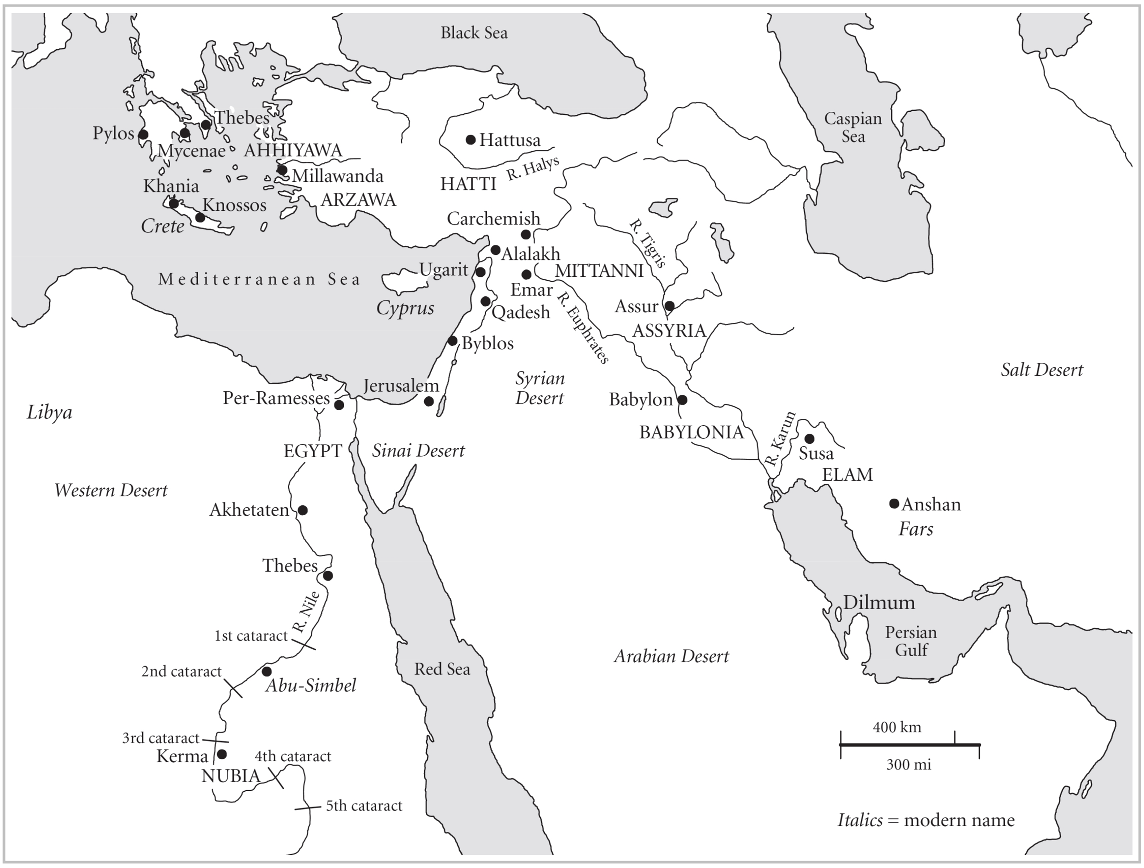
The petrographic data will be compared when possible with the chemical composition of the tablets, determined by pXRF and/or INAA in previous studies. On the whole, this dissertation is an attempt to combine textual, archaeological, petrographic, chemical and thermogravimetric information in order to get a better understanding of the materiality and the historical implications of the objects under examination.

1.2. Historical context

The tablets studied in this dissertation date to the Late Bronze Age, a period characterized by a high degree of connectivity between many different polities in the Near East. Between c. 1600-1200 BC, the relatively balanced distribution of political, economic and military power across the whole area shaped what M. Liverani (2014: 278-282) has defined as a "regional system." This system was dominated by a few territorial states (namely, Egypt, Ḫatti, Mittanni, Assyria, Babylonia and Elam, and to a lesser extent Mycenae and Cyprus) that interacted with each other and exercised varying degrees of control over smaller centers within their sphere of influence. Among this group of hegemonic states (which H. Tadmor [1979: 3] described as the "club of the great powers"), two are of particular relevance for the present study.

New Kingdom Egypt, on the one hand, was a powerful actor in Late Bronze Age inter-regional politics. Especially during the eighteenth and nineteenth dynasties, the Egyptian state developed an aggressive policy of territorial expansion beyond its traditional southern and northern limits (Spalinger 2005). The military campaigns conducted by Thutmose III (c. 1479-1425) in Syria-Palestine resulted in a relatively formalized political and administrative control over the region, which his successors would struggle to maintain and enlarge. This area functioned as a buffer zone between the dominant powers and was fragmented into a constellation of minor kingdoms such as Amurru or Ugarit (Van De Mieroop 2007a: 133-134).

The Hittite kingdom, on the other hand, had achieved its political cohesion only in the first half of the second millennium BC and was therefore a rather new state. However, in the fourteenth century BC the Hittites were able to expand their dominion from central Anatolia to the Upper Euphrates and further south into the Levant. When Šuppiluliuma I (c. 1350-1322) defeated and conquered the kingdom of Mittanni, he created a new administrative structure by installing his sons Telipinu and Piyassili/Šarri-Kušuḫ as subsidiary kings in the cities of Aleppo and Karkemiš, respectively (Bryce 2005: 51). Many of the local Syrian rulers concluded treaties of subordination with the Hittite sovereign, and thus Ḫatti became Egypt's main rival for the supremacy of this region. After many years of intense competition, with a major military encounter in Qadeš, Ramses II (c. 1279-1213) and Ḫattušili III (c. 1267-1237) finally reached a peace agreement.



§ Figure 1. The Near East in the fourteenth-thirteenth centuries BC (after Van De Mieroop 2007b: 10).

Communication between royal courts was well articulated during the Late Bronze Age, as evidenced by the vast corpus of inter-regional correspondence available to us (e.g., the famous Amarna letters from the reigns of Amenhotep III and Amenhotep

IV/Akhenaten).[1] In the diplomatic jargon, political relations were formally conveyed through household-derived notions (Schloen 2001: 255-262): thus, the horizontal interaction between one "great king" (*šarru rabû*, in Akkadian) and another of the same status was seen in terms of "brotherhood" or "friendship", whereas the vertical relationship established with a "small king" (*šarru ṣiḫru*, in Akkadian) was usually described as a master/servant or father/son bond. Even though the range of subjects covered by the epistolary corpus from this period is broad, many documents are devoted to two central issues: the exchange of gifts (Zaccagnini 1973) and the exchange of people—especially women, through arranged inter-dynastic marriages (Pintore 1978), and different kind of experts such as physicians, exorcists, musicians or craftsmen (Zaccagnini 1983). Akkadian is usually referred to in scholarly literature as the *lingua franca* of Late Bronze Age inter-regional written diplomacy, and in many royal courts across the Near East (e.g., in Egypt and Ḫatti) it was an external language alien to the local linguistic environment.[2]

1.3. Clay tablets

From a long-term perspective of human occupation, writing can be considered a relatively new technology in the Near East: while anatomically modern humans reached the region ~120-90 thousand years ago (Mann 1995; Osborne et al. 2008), the first evidence of a coherent writing system dates only to the late fourth millennium BC. This technical innovation developed out, at least in part, of a number of graphic and pseudo-graphic recording systems based on non-linguistic communicative devices such as tokens, seals, clay envelopes and numerical tablets (Woods 2010).

The earliest examples of "proto-cuneiform" signs are recorded in documents found at Uruk, in the southern Mesopotamian alluvial plain, and were mostly pictographic representations initially incised on clay with a pointed implement (Englund 1998). This notational system became gradually more standardized, while in turn the signs were simplified. Curvilinear lines were eventually straightened, and strokes were no longer incised but created by means of a stylus with a triangular cross-section. Due

[1] On diplomacy and inter-regional contacts during this period, see Cohen and Westbrook 2000; Liverani 2001.

[2] See the discussion on Akkadian as *lingua franca* in von Dassow 2004; Márquez Rowe 2006: 140-166; Mandell 2015: 70-79.

to the distinctive wedge-shaped impressions produced with such a device, which continued to be in use during three millennia, this writing system came to be known as "cuneiform" among modern scholars. Cuneiform script spread along with literacy and numeracy across a vast geographic area (from Anatolia to Egypt, and from the Levantine coast to Iran; see Figure 1)[3] and was adapted to represent many different languages such as Akkadian, Eblaite, Elamite, Hittite, Hurrian, Luvian, Old Persian, Palaic, Sumerian, Urartian and Ugaritic (Gragg 1996; Seri 2010).

The number of cuneiform tablets kept in different public and private collections around the world amounts to hundreds of thousands.[4] Due to the sheer quantity, diversity and linguistic complexity of the texts inscribed in these objects, the traditional approach to study them has been essentially philological. However, a clay tablet can be described in at least four distinct analytical levels:

1. Text: usually studied with photographs and/or hand copies of the cuneiform signs, which are subsequently transliterated into Latin characters. Some attempts have been made recently to scan, reconstruct and analyze tablets with 3D technology (e.g., Mara et al. 2010; Cammarosano et al. 2014; Collins et al. 2014; Fisseler et al. 2014).

2. Seal impressions and other graphic/non-textual features: sealing tablets was a widespread practice which had specific legal, economic and symbolic connotations (Charpin 1985; Radner 2010). Other non-textual elements can also occur in cuneiform tablets, e.g., drawings, fingernail marks, footprints and textile impressions (Finet 1969; Leichty 1989; Wagensonner 2009; Tsouparopoulou 2013).

3. Context: the archaeological context of an inscribed object (site, stratum, area, building/structure, horizontal and vertical position, association with other artifacts, etc.) is a vast source of information, not only in terms of chronology and geographic origin, but also to understand how certain groups of texts cohere

[3] A fragment of an agate artifact was discovered in 2010 at tas-Silg, Malta (Cazzella et al. 2011; Mayer 2011). However, the inscription is probably not of local origin and might have been produced in Nippur (southern Mesopotamia). Another short cuneiform inscription, probably in Ugaritic, was found in the Argolid at Tiryns (Cohen et al. 2010).

[4] Around 320.000 cuneiform inscriptions have been already catalogued in the Cuneiform Digital Library Initiative (CDLI), an online open access database (http://cdli.ucla.edu/).

as “archives” or “libraries” (Zettler 2003; Zimansky 2005; Rutz 2013; Kersel and Rutz 2014). Other functional or symbolic aspects can also be better understood when the artifacts have a well-documented context (e.g., administrative records or votive inscriptions), which is not always the case for cuneiform tablets since many of them come from the antiquities market or were excavated with unsuitable methods by early Near Eastern archaeologists.

4. Material: all the physico-chemical features of a tablet, including macroscopic attributes (shape, perforations/“firing” holes, presence of ink or pigments, etc.) as well as the distinctive mineralogical and chemical properties of the raw materials.

These four dimensions are intrinsically connected, and each of them can amplify and enrich our knowledge of the rest. Thus, for example, the provenance of a given tablet can be ascertained taking into account different elements: archaeological information, content of the text, language and paleography, petrographic and chemical features, etc. Likewise, relative or absolute dating can be established by means of the chronological marks supplied by the text, stratigraphic correlations or archaeomagnetic dating.

The present dissertation is focused on, but not limited to, the material aspect of cuneiform tablets. Therefore, our research questions are mostly approached with scientific methods, but rely heavily on textual and archaeological data. This methodological perspective can be considered part of a growing effort to study the materiality of cuneiform tablets in particular (Cooper 1985; Charpin 2002; Eidem 2002; Goren et al. 2004; Taylor 2011; Taylor and Cartwright 2011; Selz 2011; Matthews 2013; Waal 2015; Balke and Tsouparopoulou 2016) and of ancient inscriptions in general (Piquette and Whitehouse 2013; Meier et al. 2015).

1.3.1. Manufacture process

The process of making a clay tablet involved at least four stages, namely: (1) procurement of the raw materials, (2) preparation of a suitable paste, (3) shaping of the object and (4) drying/firing. Goren et al. (2004: 5) highlight the fact that our reconstruction of these technological procedures cannot be supported by any ethnographic parallels, as in the case of ceramic production. Even though it is possible to establish some comparisons of technical nature between pottery and clay tablets manufacture, there are substantial differences between these two activities both in quantitative and qualitative terms. The social background of the scribal profession and the specific functionality of clay tablets should be acknowledged as decisive factors in such a comparative task (Goren et al. 2004: 5-6).

1.3.1.1. Procurement of the raw materials

By far the most common writing medium for cuneiform texts was clay, even though other materials were occasionally employed (e.g., stone, metal, glass, wooden or ivory boards with waxed surfaces, papyrus and parchment or leather rolls). "Clay" is a rather generic expression, and its precise meaning differs among various scientific fields.[5] This term has been employed to characterize a complex assemblage of materials by means of different parameters such as depositional situation, size of the particles, chemical composition, mineralogy and even commercial usage (Rice 2015: 40-59). In 1995, the Nomenclature Committees of the Association Internationale pour l'Étude des Argiles (AIPEA) and the Clay Minerals Society (CMS) attempted to formulate a standard definition:

> The term 'clay' refers to a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden when dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that do not impart plasticity and organic matter (Guggenheim and Martin 1995: 257).[6]

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[5] In fact, F. Bergaya and G. Lagaly point out in their introduction to the *Handbook of Clay Science* that "the quest for a unifying terminology that is acceptable to all disciplines, users, and producers would be a fruitless exercise" (2006: 3).

[6] According to this report, the specific meaning of the expression "fine-grained" cannot be quantified since there is not one universally accepted particle size for all disciplines: common values are <1 µm in colloidal chemistry, <2 µm in geology and <4 µm in sedimentology (Guggenheim and Martin 1995: 258).

In any case, as noted by P. Rice (2015: 60), for the study of ancient archaeological ceramics it is also possible to define clay on the basis of its plasticity/workability, since this was the primary operational criterion used by traditional potters to select the adequate material (rather than other factors such as granulometry or chemical/mineralogical[7] composition).

According to Goren et al. (2004: 6), the preferred clay for making tablets should be bright enough to highlight the script, have a low shrinkage rate and include some fine temper without large grits or fibers. This material could be obtained from the sediments in watercourses (such as rivers or canals) or from inland outcrops. The choice of particular sources was certainly influenced by relative proximity to the place of manufacture, but varying degrees of selectivity are to be expected according to the context of production, the scribe and the purpose of the tablet (Taylor 2011: 7). One Neo-Babylonian colophon, for instance, informs us that the clay to produce a tablet came "from the Garden of the Apsû" (a sacred area in the city of Babylon), while in another document one individual recalls that he went out of the city to pick up clay from the "holy clay-deposit" (George 2010).

1.3.1.2. Preparation, shaping, drying and firing

It has often been assumed that clay for tablets was levigated; i.e., mixed with water and left to stand so that the coarser particles would sink to the bottom while the water and the organic impurities would rise to the top, leaving a middle layer of fine textured clay (Taylor and Cartwright 2011: 298). However, it is evident that this process was not always carried out since many tablets contain large inclusions such as rock fragments, mollusk shells or plant remains (Taylor and Cartwright 2011: 315).

After levigating and/or kneading the clay, the scribe would manually shape it. J. Taylor (2011: 11) notes that tablets could be made by hand molding a lump of clay into a rough shape, or with a more sophisticated system by which an outer layer was

[7] There are many types of clay minerals, which have been classified into different categories according to their crystalline structure and distinctive properties (Rice 2015: 45-58). Most of the major clay minerals are phyllosilicates, i.e., they have a layered arrangement of sheets of silica tetrahedrons and alumina octahedrons. The main sub-divisions within this category include the kaolin, smectite, illite and chlorite groups; each of them has specific traits that affect certain properties of the clay (e.g., plasticity, shrinkage and color). Besides, the clay fraction of soils and sediments often contains other associated non-phyllosilicate minerals such as carbonates, feldspars and quartz together with the (hydr)oxides of iron and aluminium (Bergaya and Lagaly 2006: 9).

wrapped around an irregular core. One tablet made with the latter method consists of a strip of clay folded almost in half and an external sheet folded over this core (BM 26783; Taylor 2011: 11-12); similarly, in a document from the Neo-Babylonian period the inner part is composed of several lumps of clay stuck together in a grid, covered with a layer of fine clay (Taylor and Cartwright 2011: 300).[8] Even though the shape and size of cuneiform artifacts changed across time and space (see Figure 2), most of the tablets available to us are rectangular and fit in the palm of the hand. Typological features were also influenced by the purpose, length and genre of the text, as well as by scribal preferences.

Once an object was inscribed and sealed, clay was left to dry and in some cases it was subsequently fired. A few Neo-Babylonian texts refer to the firing of tablets, and some first millennium documents exhibit along their surfaces a number of marks referred to as "firing" holes in scholarly literature, but their function is not certain (Taylor 2011: 15-16). Taylor claims that "only rarely in antiquity were tablets baked" (2011: 16; see also Taylor and Cartwright 2011: 300), but he does not offer explicit evidence to support such an assertion. As a matter of fact, it is difficult to determine if a clay artifact was fired or not without analyzing the changes in its mineralogy and/or its microstructure by different scientific techniques such as thin-section petrography, thermal analysis (e.g., thermogravimetric analysis [TGA], differential thermal analysis [DTA], differential scanning calorimetry [DSC], dilatometry [DIL]), X-ray diffraction (XRD), scanning electron microscopy (SEM) or Mössbauer spectroscopy (Rice 2015: 376-387).[9] Some visual criteria based on the color of tablets have been suggested by C. Walker (1987: 22), but they are not always valid since this property varies according to the composition of the clay, the soaking time and the type of firing atmosphere (oxidizing or reducing), and can also be affected by post-depositional events (Palmiter and Johnson 1988: 135). In any case, it should be noted that research on ancient technological practices is hampered by the fact that many cuneiform documents were accidentally fired in the past when their storage context was destroyed, or deliberately baked in modern times by museum staff, archaeologists and dealers for conservation purposes.

[8] Taylor (2011: 12) notes that in some cases the core is made from a different type of clay; further scientific research can shed new light on the production process of these composite objects.
[9] Goren et al. (2004) have analyzed by thin-section petrography the firing temperature of several Late Bronze Age tablets.

§ **Figure 2.** A sample of the variety of shapes/sizes of clay documents (after Taylor 2011: 9-10).

1.3.2. Ceramic ecology

One of the most significant theoretical trends in pottery studies is known as "ceramic ecology." This approach, formulated by F. Matson, attempts to "relate the raw materials and technologies that the local potter has available to the functions in his culture of the products he fashions" (1965: 203). Ceramic production is considered within the potter's ecological setting, including different aspects such as geology, hydrology, soils, vegetation and climate (Rice 2015: 209). The quality and the availability of clay/temper are also regarded as essential factors to understand the manufacture process.

Following the criteria adopted by Goren et al. (2004: 6), we will apply the term "local" to those artifacts made with raw materials that have been obtained within the exploitable range of a given site. According to D. Arnold (1985: 32-60), who gathered ethnographic data from traditional potters around the world, this territory can be tentatively defined as the entire surface in a radius of 10 km from the place of production. However, the time/distance required to obtain certain resources could be amplified or reduced by natural barriers (e.g., swamps and cliffs) and watercourses (e.g., the Nile or the Euphrates, which could be sailed in order to reach remote areas). The selection of raw materials may have also been affected by other constraining factors such as territorial conflicts, or even religious stipulations (Goren et al. 2004: 6-7).

2.
Materials and methods

2.1. Materials

This thesis is focused on the analysis of 13 fragments of clay tablets from the Vorderasiatisches Museum and the Bible Lands Museum; throughout the work each item is referred to with its respective VAT (Vorderasiatische Abteilung Tontafeln) or BLMJ (Bible Lands Museum Jerusalem) inventory number (see Table 1). The samples from the Vorderasiatisches Museum, discovered in the modern site of Boğazköy (ancient Ḫattuša, the capital of the Hittite kingdom), were taken by Y. Goren in different research visits between 2009 and 2014. The tablet from the Bible Lands Museum, which lacks a defined archaeological context, was sampled by the author and Y. Goren in June 2016.

§ *Table 1.* Tablets sampled at the Vorderasiatisches Museum and the Bible Lands Museum.

Inventory n.	**Site**	**Language**	**Description**
VAT 6156	Ḫattuša	Akkadian	Letter from Ramses II of Egypt to Ḫattušili III of Ḫatti
VAT 6161	Ḫattuša	Akkadian	Letter from Ramses II of Egypt to Ḫattušili III and Puduḫepa of Ḫatti
VAT 6168	Ḫattuša	Akkadian	Letter of Ramses II of Egypt to Kupanta-Kurunta of Mira-Kuwaliya
VAT 6169 +7669	Ḫattuša	Akkadian	Letter from Ramses II of Egypt to Ḫattušili III of Ḫatti
VAT 6172*			(?)
VAT 7420	Ḫattuša	Hittite	Edict of Muršili II of Ḫatti recognizing the status of Piyassili/Šarri-Kušuḫ of Karkemiš
VAT 7421	Ḫattuša	Hittite	Treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru

VAT 7423	Ḫattuša	Akkadian	Sworn statement of Šattiwaza of Mittanni
VAT 7677	Ḫattuša	Akkadian	Letter from Ramses II of Egypt to Puduḫepa of Ḫatti
VAT 13008	Ḫattuša	Hittite	Treaty between Šuppiluliuma I of Ḫatti and Piyassili/Šarri-Kušuḫ of Karkemiš
VAT 13024	Ḫattuša	Akkadian	Treaty between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni
VAT 13067	Ḫattuša	Akkadian	Letter from Sutahapsap of Egypt to Ḫattušili III of Ḫatti
BLMJ 1143	Emar**	Hittite	Letter from a king of Karkemiš to Alziyamuwa

* VAT 6169+7669 and VAT 6172 do not join directly, but it has been suggested that they belong to the same tablet; see section 3.1.1.

** Tablet acquired in the antiquities market, but probably coming from Meskene Qadime/Emar.

2.1.1. Egyptian letters

The fragments examined here were sent from Egypt to Ḫatti in the thirteenth century BC. They represent only a small fraction of the corpus of Egyptian-Hittite correspondence discovered at Boğazköy/Ḫattuša, which has been studied in detail by E. Edel in a two-volume edition with commentary (1994a; 1994b).[10] This group of documents, dating for the most part to the reigns of Ramses II of Egypt and Ḫattušili III of Ḫatti, are essentially an exchange between two "great kings" and a few members of their respective courts, such as the Hittite queen Puduḫepa or the Egyptian prince Sutahapsap (Edel 1994b: 17-18).[11] One interesting exception studied here is a missive sent by Ramses to Kupanta-Kurunta of Mira-Kuwaliya (VAT 6168), a western Anatolian kingdom subject to Hittite dominion. The possible explanations as to why this letter was discovered in Ḫattuša may be related to the fact that it contains a reply to a previous inquiry from the king of Mira-Kuwaliya, who had asked Ramses whether he

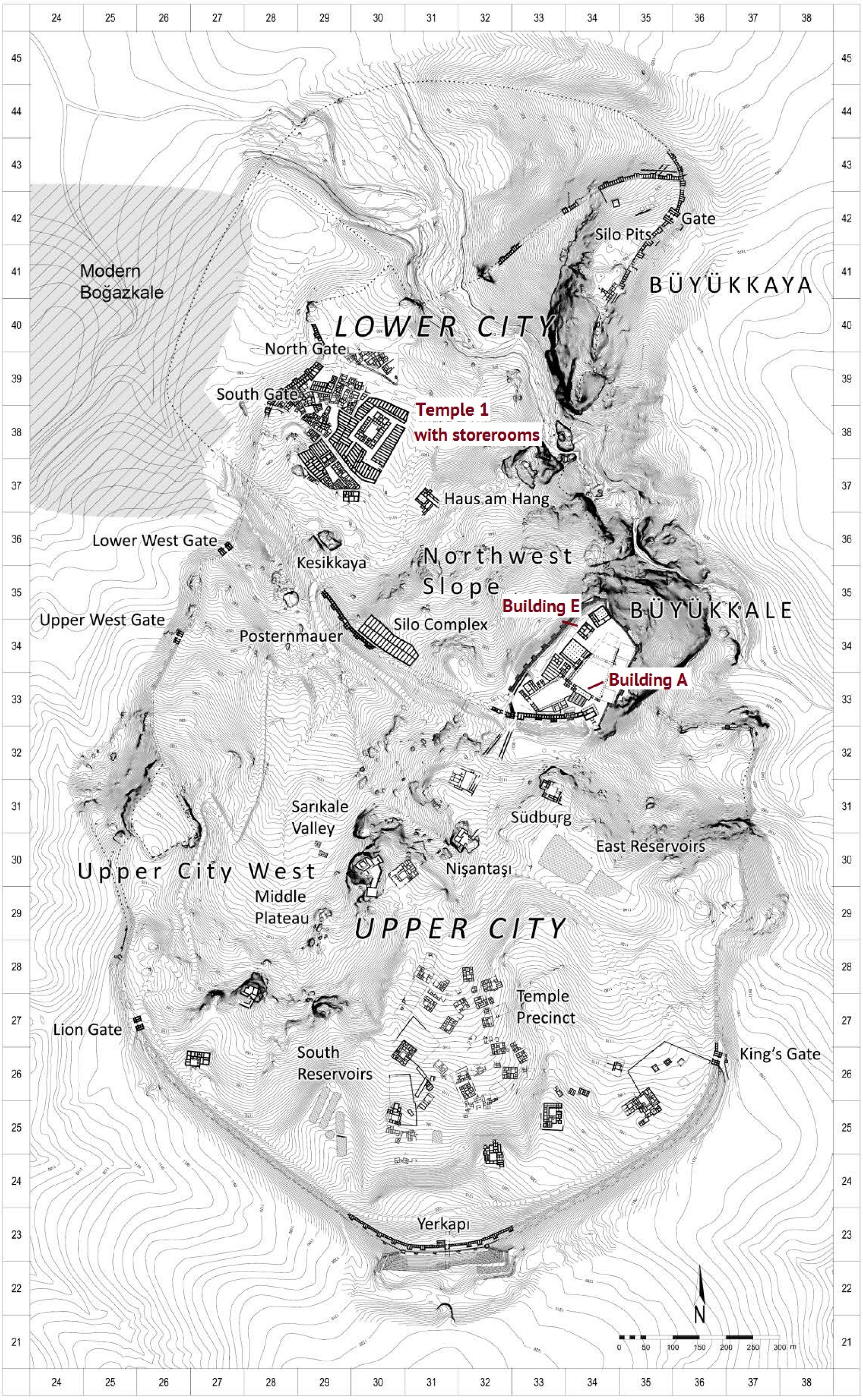
[10] More fragments were discovered or identified after this work was published; see e.g., Edel 1996; Pusch and Jakob 2003; cf. also Weeden 2014.

[11] This dossier follows the general thematic trends outlined above, including exchange of commodities, marriage arrangements and political negotiations: see Goelet 2001 (brief overview); Klengel 2002 (extensive study of Egyptian-Hittite relations under Ramses II and Ḫattušili III); De Vos 2007 (annotated bibliography).

supported Ḫattušili or his deposed nephew Urḫi-Teššub/Muršili III. G. Beckman (1996: 124) considers that it was sent via the Hittite capital because it would have been inappropriate for a subordinate of the king of Ḫatti to establish direct contact with another "great king." However, T. Bryce (2003: 85-86) points out that since Kupanta-Kurunta had apparently already done so in his original letter, this document should actually be understood as a message from Ramses to Ḫattušili where the former intended to expose how the latter's legitimacy was being contested by the ruler of Mira-Kuwaliya.

The dossier of Egyptian-Hittite letters was unearthed during the excavations conducted at Boğazköy/Ḫattuša by Hugo Winckler and Theodor Makridi Bey between 1906 and 1912.[12] There is no available information about the precise find-spot of these tablets/fragments, but Edel (1994b) provides a probable area of provenance by correlating the dates when Winckler copied some of the texts with the structures excavated during that year's season. According to this conjectural reconstruction, all the letters come either from Buildings A and E of Büyükkale, or from the storerooms surrounding Temple 1 in the Lower City (Edel 1994b: 19-21; see Figure 3).[13]

[12] On the initial archaeological work at Boğazköy, see Alaura 2006.
[13] Individual find-spots can also be consulted in the *Konkordanz der hethitischen Keilschrifttafeln*, an on-line database developed and maintained by Silvin Košak at the Akademie der Wissenschaften und der Literatur Mainz (http://www.hethport.uni-wuerzburg.de/hetkonk/hetkonk_abfrageF.php).



§ **Figure 3.** Plan of Boğazköy/Ḫattuša, with the location (in red) of the areas where the Egyptian-Hittite correspondence was discovered (modified after Lehner 2015: 109).

2.1.2. Hittite diplomatic texts and letters

During the fourteenth and thirteenth centuries BC, the Hittite state dominated a large portion of Anatolia and northern Syria. According to T. Bryce (2005: 44-51), in geo-political terms this kingdom can be described as the sum of four main components: (1) a core territory comprising Ḫattuša and other administrative centers; (2) the immediate periphery of the homeland, under direct control of the king and his officials; (3) the so-called "vassal" states, governed by local rulers subjected to the authority of the Hittite sovereign; (4) Aleppo and Karkemiš, two subsidiary kingdoms in northern Syria (from the reign of Šuppiluliuma I onward).

The king was the head of the entire administrative apparatus of the Hittite state, and also directed the foreign policy (Beckman 1995). In order to fulfill these duties, the relationship established with his subordinates and with his diplomatic partners was codified in written documents referred to by modern scholars as "treaties" and "instructions." Both categories actually belong to the same textual genre, which had a basic dual structure (Miller 2013: 1-6): the royal imposition of a set of "obligations" (Hittite *išḫiul*-; Akkadian *riksu*, *rikiltu*) upon the subordinate party, and the swearing of an "oath" (Hittite *lingai*-; Akkadian *māmītu*, *nīš* DINGIR-*LI*) as a commitment to these stipulations before the gods. Thus, a Hittite treaty may be defined as "an 'obligation and oath' text with the function of defining and regulating the relationships between the Hittite kingdom and political entities located outside the borders of the Hittite heartland" (Devecchi 2013: 90); the "instructions," on the other hand, were addressed to members of the state administration. Internal and external affairs were also managed by means of the so-called "edicts," which contain prescriptive statements dictated by the king but lack a formal commitment/oath imposed on the subordinate party.

Around 35 Hittite treaties are available to us, representing over half of the preserved documents of this type from the ancient Near East (Beckman 2006; Devecchi 2015). Most of them are written in Akkadian, although the Hittite language was also employed. The materiality and production process of these texts is significant for our study: "vassal" treaties were normally engraved on a metal tablet (of silver or bronze), which was presented to the junior partner; however, apart from one exceptional case (Otten 1988), all the texts at our disposal are clay copies (or perhaps drafts resulting from different compositional stages).

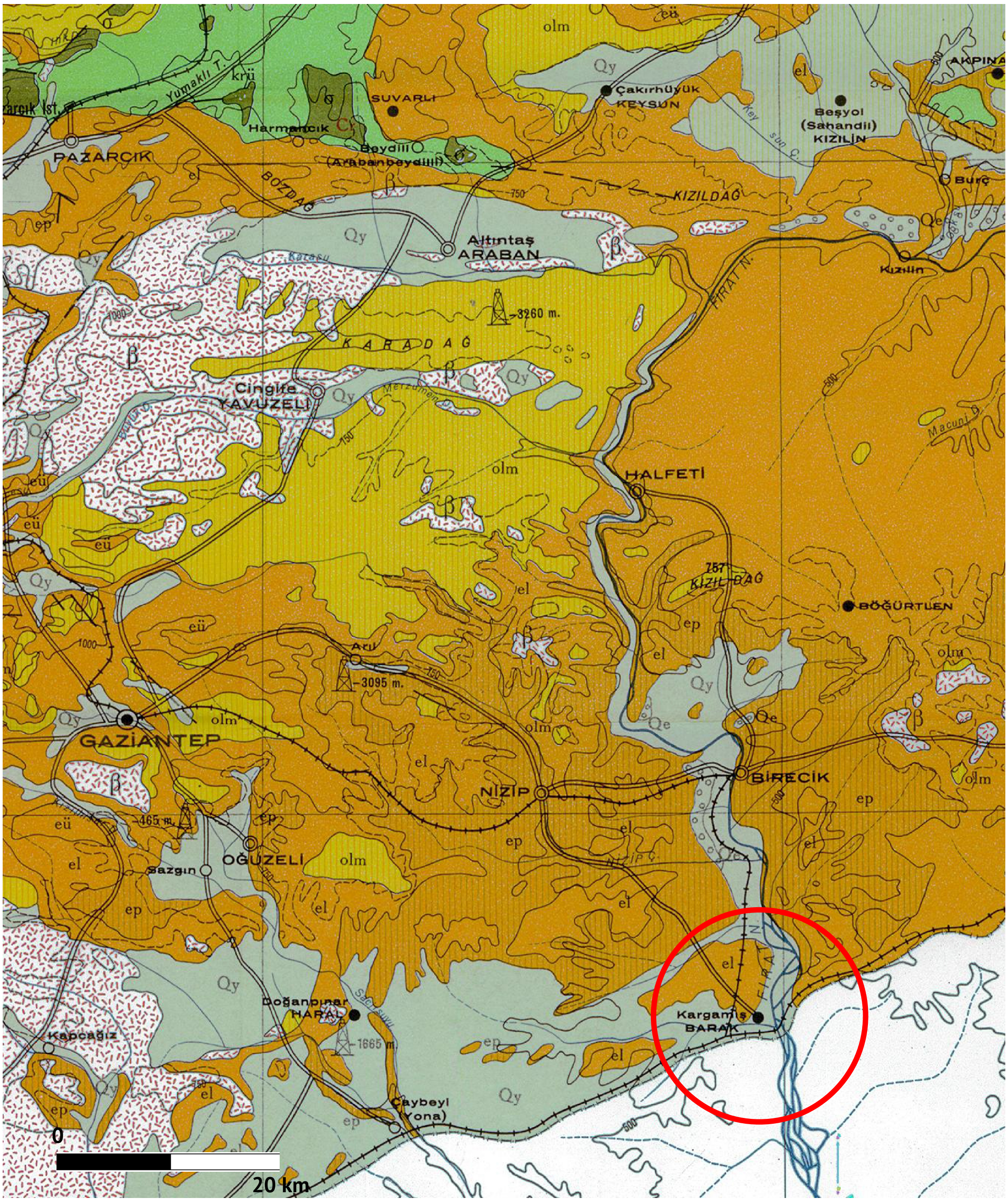
In this dissertation we will examine four treaties and one edict found at Boğazköy/Ḫattuša, as well as two letters discovered in different cities under Hittite dominion (AO 19.955, from Ras Shamra/Ugarit, and BLMJ 1143, from Meskene Qadime/Emar), in order to determine their provenance and the potential implications of a non-local origin.

2.1.2.1. Four documents related to Karkemiš

The site of Karkemiš is located on the west bank of the Euphrates, about 60 km southeast of Gaziantep (Turkey). In the second half of the fourteenth century BC, Šuppiluliuma I conquered the city and appointed his son Piyassili/Šarri-Kušuḫ as new ruler. Thereafter the court of Karkemiš played a key role in the administration of the Syrian kingdoms controlled by Ḫatti, dealing on a regular basis with their political, judicial, economic and religious affairs. Its military power was also essential to contain the expansion of other states such as Egypt and Assyria (de Martino 2014).

The first soundings in the area of Jerablus/Karkemiš were conducted by P. Henderson, the British consul in Aleppo, between 1878 and 1881. Another mission funded by the British Museum worked there at the beginning of the twentieth century, with the participation of D. G. Hogarth, T. E. Lawrence and C. L. Woolley. In 2011, a joint Turco-Italian expedition under the direction of N. Marchetti restarted archaeological investigations at the site (Marchetti 2014). However, the archives of the Late Bronze Age level have not been recovered and thus our information about this kingdom comes mainly from other sites such as Ḫattuša, Ugarit or Emar (Mora 2008).

As noted by Goren et al. (2004: 56), the geological maps of Gaziantep and Karkemiš show that the Upper Euphrates sediments in this area are very homogeneous (see Figure 4). Other geological formations in the vicinity of the site may also affect the composition of ceramic fabrics, e.g., the Gaziantep Formation of the Upper Eocene (silty, clayey or chert-including limestone, or chalk with glauconite) or the ophiolitic exposures of the Koçali Complex (serpentinized ultrabasics, silicified shale and radiolarites). Although there are no published petrographic references to the locally produced pottery, Goren et al. (2004: 56-57) have examined one letter sent from Karkemiš to Ugarit (AO 19.955).



References			
Q	Quaternary (undifferentiated)	ep	Lower Eocene
Qy	Holocene	krü	Upper Cretaceous
Qe	Pleistocene	ω	Basic intrusives
olm	Oligo-Miocene	ρ	Peridotite, Pyroxenite, Harzburgite
e	Eocene (undifferentiated)	σ	Serpentine
eü	Upper Eocene	α	Andesite, Spilite, Porphyrite
el	Middle Eocene	β	Basalt, Dolerite

§ **Figure 4.** Geological map of Karkemiš and its surroundings (modified after Tolun and Erentöz 1962).

Taking this document as a point of departure, we decided to analyze two diplomatic texts and one letter from Emar related to the court of Karkemiš in order to compare their petrofabrics.

2.1.2.1.1. Letter from a king of Karkemiš to Ammištamru II of Ugarit (AO 19.955)

AO 19.955 is a letter sent from a king of Karkemiš to Ammištamru II of Ugarit (c. 1250-1210) regarding the release of some prisoners (Vidal 2010: 724-725). According to Goren et al. (2004: 57), the petrographic features of this tablet resemble those of the Babylonian and Mittannian documents from Tell el-Amarna, and indicate that the Euphrates clay-silt was used without any intentional addition of sand inclusions.

2.1.2.1.2. Letter from a king of Karkemiš to Alziyamuwa (BLMJ 1143)

BLMJ 1143 is a letter from an unnamed king of Karkemiš[14] to a certain Alziyamuwa (Singer 2000). It belongs to a group of cuneiform tablets that were purchased in the antiquities market but can be linked by prosopography, seal impressions and textual typology with those unearthed at Meskene Qadime/Emar (Westenholz 2000: xi). The content of BLMJ 1143 is very similar to that of SMEA-45 1, another letter sent to Alziyamuwa—probably a Hittite official active in the Middle Euphrates region[15]—by the ruler of Ḫatti. Both documents are essentially concerned with the property and tax obligations of a diviner from Emar called Zū-Baʿla, who lived roughly between the end of the fourteenth and the first half of the thirteenth century BC.[16]

SMEA-45 1 informs us that Zū-Baʿla complained to the king for two reasons: on the one hand, part of his landed property had been confiscated by Alziyamuwa and given to a man named Palluwa; on the other hand, he had been subjected to *šaḫḫan*

[14] Considering the information provided by the document Emar VI 201, this ruler was most likely Šaḫurunuwa, the son of Piyassili/Šarri-Kušuḫ (Skaist 2005).

[15] Apart from SMEA-45 1 and BLMJ 1143, there is no reference to Alziyamuwa in our sources; however, it seems logical to assume that he was a Hittite functionary under the jurisdiction of the sovereign of Karkemiš.

[16] For an overview of the documents related to Zū-Baʿla and his family, see Cohen 2009: 147-180 (with previous literature).

luzzi, i.e., a duty or set of duties that were part of the Hittite system of taxation. In response to this complaint, the sovereign of Ḫatti sent a letter to Alziyamuwa (SMEA-45 1) ordering him to restore the confiscated estate and confirming that Zū-Baʿla should not perform *šaḫḫan luzzi*. Both directives were subsequently reproduced by the ruler of Karkemiš in BLMJ 1143.

2.1.2.1.3. Edict of Muršili II of Ḫatti recognizing the status of Piyassili/Šarri-Kušuḫ of Karkemiš (VAT 7420) / Treaty between Šuppiluliuma I of Ḫatti and Piyassili/Šarri-Kušuḫ of Karkemiš (VAT 13008)

VAT 13008 and VAT 7420 are two diplomatic documents related to Piyassili/Šarri-Kušuḫ. The first of them is an agreement concluded with his father, Šuppiluliuma I; it contains a description of the western borders of the kingdom Karkemiš, but the text is not well preserved (Singer 2001: 635; Devecchi 2015: 238). VAT 7420, on the other hand, is a document issued by an unnamed king of Ḫatti who should probably be identified with Muršili II (Güterbock 1956: 120; Mora 1993; Beckman 1996: 154). The text refers to an agreement made with Piyassili by which the sovereign of Ḫatti recognizes the special status of the ruler of Karkemiš within the hierarchy of the Hittite kingdom. As C. Mora (1993: 70) points out, this edict is the first evidence of a political structure organized in three levels: (1) the king of Ḫatti and the crown prince (*tuḫkanti*), (2) the king of Karkemiš, and (3) other subordinate rulers.

2.1.2.2. Two fragments of the agreement between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni (VAT 7423 and VAT 13024)

The diplomatic agreement between Šuppiluliuma I and Šattiwaza was the by-product of a complex geo-political scenario (Bryce 2005: 184-185; Van De Mieroop 2007b: 30-34). After Šattiwaza was deposed from the throne of Mittanni by his cousin Šuttarna III, he fled to Ḫatti in order to request Šuppiluliuma's support. Since Šuttarna was apparently aligned with the Assyrian kingdom, Šuppiluliuma decided to back Šattiwaza. The Hittite ruler subsequently married one of his daughters to Šattiwaza and organized a joint military campaign commanded by his son Piyassili/Šarri-Kušuḫ of Karkemiš.

Once Šuttarna was defeated, Šuppiluliuma and Šattiwaza concluded an agreement to formalize their alliance (Beckman 1996: 37-50; Altman 2004: 264-323; Devecchi 2015: 242-263). The details of this pact are preserved in two documents, one presented from the perspective of the king of Ḫatti (CTH 51) and the other from the perspective of his Mittannian counterpart (CTH 52). However, their form and content indicate that both texts were actually composed by the Hittite chancellery (Beckman 1996: 37; Altman 2004: 300-302, 319-323).[17] CTH 51 has the typical structure of a Hittite treaty: preamble, historical prologue, provisions, deposition clause, list of divine witnesses, curses and blessings. CTH 52, on the other hand, lacks any formal stipulations and its prologue is composed as a statement made by Šattiwaza about the circumstances of his submission to Šuppiluliuma (Altman 2004: 296-318). Each of them was drafted both in Akkadian and in Hittite.

Regarding the fragments studied in this section, VAT 7423 (CTH 52.I) is a copy of Šattiwaza's declaration and VAT 13024 (CTH 51.I.B) is a copy of Šuppiluliuma's version of the agreement. Both were written in Akkadian, but Beckman (1993: 56) notes that the former displays typical sign forms employed in Hittite texts from the first half of the fourteenth century BC, whereas the latter has a script that resembles the Mittannian letters found at Tell el-Amarna. Therefore, this scholar suggests that: (a) VAT 7423 should be attributed to a Hittite scribe, and (b) VAT 13024 was probably copied by a Hurrian scribe from the court of Šattiwaza, and finally deposited in Ḫattuša for some unknown reason (Beckman 1993: 56).

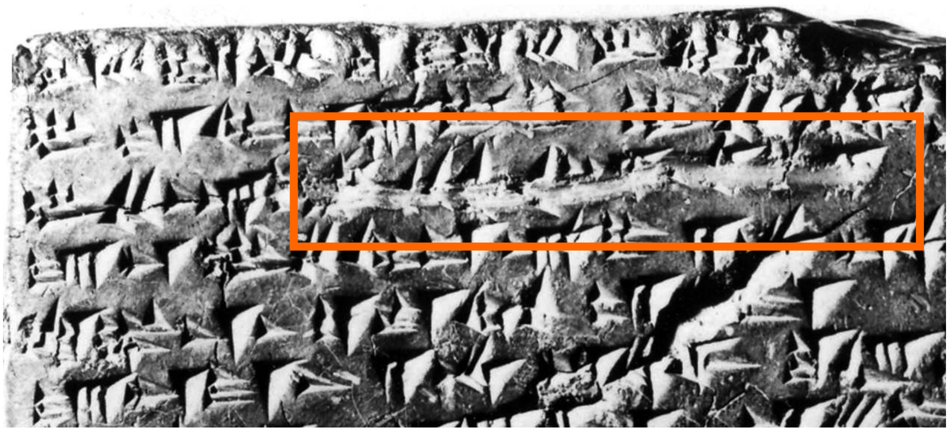
2.1.2.3. A fragment from the "Text A" of the treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru (VAT 7421)

VAT 7421 is a fragment of the treaty between Tudḫaliya IV of Ḫatti (c. 1237-1209), grand-son of Muršili II, and his nephew Šaušgamuwa of Amurru (c. 1230-1210; see Kühne and Otten 1971; Beckman et al. 2011: 50-68; Devecchi 2015: 225-232). Most of the stipulations contained in this agreement are concerned with Šaušgamuwa's

[17] As noted by V. Cordani (2010: 56 n. 27), CTH 52 could also have been drafted by the Mittannian chancellery under the conditions imposed by the Hittites.

responsibilities toward Tudḫaliya, addressing both internal challenges to the latter's office as well as foreign policy issues.[18]

Two copies of the treaty have come down to us. VAT 7421 belongs to the best preserved manuscript, referred to as "Text A." It has been noted by different scholars that this tablet contains numerous erasures, additions written in smaller script and corrections made over erasures (Sommer 1932: 322; Kühne and Otten 1971: 1; Beckman 1996: 99); one well-known example is the inclusion and subsequent erasure of the king of Aḫḫiyawa from the list of rulers whom Tudḫaliya regarded as equals (Figure 5). In view of these features, VAT 7421 is considered to be a draft of the agreement.



§ **Figure 5.** Erasure in VAT 7421. The whole line (IV, 3) reads: LUGAL KUR *Aš-šur* [erasure→]LUGAL KUR *Aḫ-ḫi-ya-u-wa-ya*[←erasure] / the king of Assyria (and) ~~the king of Aḫḫiyawa~~ (MzP BoFN00931).

2.2. Sampling

Since all the studied objects had broken surfaces, the "peeling" method was applied in order to collect the required amount of material without causing any damage to the surface of the tablet (Goren et al. 2004: 12). One or more shallow laminas of

[18] The kingdom of Amurru, located between the Orontes River and the central Levantine coast, was a major source of dispute among the great powers of the Late Bronze Age. Egypt and Ḫatti maintained an intermittent struggle to control this strategic region, but after the battle of Qadeš it finally fell under Hittite dominion. For an overview of the history of Amurru, see Singer 1991.

~5×5 mm were peeled off with a scalpel and subsequently impregnated with epoxy resin to prepare petrologic thin sections, or stored in sealed test tubes for compositional analysis and TGA (Figure 6).

§ **Figure 6.** Sampling of BLMJ 1143 with the "peeling" technique.

2.3. Methods

2.3.1. Thin-section petrography

Ceramic petrography is one of the main physical techniques for the study of archaeological pottery (Stoltman 2001; Peterson 2009; Quinn 2013). As opposed to chemical methods, which measure the concentration of elements in a sample, thin-section petrography can be employed to examine the mineral composition and to define the fabric of a sherd.[19] It must be emphasized, however, that these are complementary rather than competing approaches (Stoltman 2001: 298). Petrography was selected as the primary analytical method for the present study considering not only its inner virtues and limitations, but also the nature of the examined artifacts, the scope of the research problems and the availability of comparative materials.

[19] Mineralogical analysis by XRD is another effective method to identify the main crystalline phases occurring in archaeological ceramics, as well as to quantify them and report their relative concentrations (see Albero 2014: 18-22).

Our methodological and interpretative framework is significantly influenced by the pioneering work of Y. Goren (see, among other contributions, Goren et al. 2002a; 2002b; 2003a; 2003b; 2004; 2006; 2009; Mazar et al. 2010; 2014). As noted by this scholar, the analysis of cuneiform tablets by thin-section petrography is advantageous because it can yield useful results without having to rely on reference databases (Goren et al. 2004: 10). When assessing the provenance of a given ceramic sample by chemical methods, the accuracy of the obtained results depends largely on standard reference groups which are sometimes incomplete or selected without proper archaeological criteria. The information supplied by thin-section petrography, on the other hand, can be directly related to the geological traits of a specific region—usually with a narrower range of possible geographic sources than other quantitative techniques. Besides, certain technological features of the examined artifacts (such as their maximum firing temperature) can also be explored with this method.

One of the main shortcomings of ceramic petrography is its intrusive nature. However, Goren has developed a set of sampling techniques for delicate clay artifacts which are aimed at reducing to a minimum the damage inflicted to the surface of the object (Goren et al. 2004: 11-12). Even though part of the sample is destroyed in this process, it should also be taken into account that the resulting thin section contains valuable information which is preserved and can be employed for future research.

The petrographic features of each sample are presented in individual charts with the following components: (1) Photo of the object; (2) Photo(s) of the thin section; (3) Reference (photo); (4) Find-spot; (5) Sampling method; (6) Reliability; (7) Matrix;[20] (8) Inclusions;[21] (9) Maximum firing temperature; (10) Interpretation. Component (6) follows the criteria established by Goren et al. (2004: 14-15) to estimate the reliability of a sample (i.e., to what extent it may be representative of the whole artifact):

- High: four complete fields through the microscope at X100 magnification (field diameter: 2.25 mm), with a complete range of features.

[20] The clay matrix is the most abundant substance found in a clay fabric. It is made of clay minerals and other materials whose grain-size is less than 2 μm in diameter (Peterson 2009: 13).

[21] The term "inclusion" is employed here to describe all the components larger than clay-size present in a petrofabric, which may be mineral or organic, plastic or non-plastic, intentionally added or not (Rice 2015: 84-85). "Temper" refers to the coarser non-clay particles assumed to have been added by the potter (cf. the discussion about the use of this concept in Rice 2015: 83-85). Several types of non-plastic inclusions can be identified in thin sections (Peterson 2009: 9-13): 1. Mineral inclusions or rock fragments; 2. Organic inclusions (e.g., plant remains, microfossils or bones); 3. Crushed fragments of previously fired ceramics (also known as grog).

- Satisfactory: three complete fields through the microscope at X100 magnification, with a complete range of features in at least two of them.
- Moderate: two complete fields through the microscope at X100 magnification, but apparently not the complete range of features.
- Fair: the sample size is extremely small but supplies some useful petrographic information.

The following transformations were considered in this study to estimate the maximum firing temperature of the examined fragments: 1. combustion of organic material, between ~200-500 ºC (vegetal remains char at ~500 ºC); 2. change in the pleochroism of glauconite from greenish to yellow at ~500 ºC, and subsequently to red at ~600 ºC; 3. decomposition of calcite, between ~700-900 ºC; 4. alteration of hornblende into oxyhornblende at ~800 ºC; 5. isotropism of the matrix due to vitrification, between ~800-1000 ºC (see Goren et al. 2004: 15-16; a schematic summary of these changes can also be found in Figure 11 below).

All the thin sections were analyzed with a Motic BA300Pol polarizing microscope. All the photographs were taken under cross-polarized light.

2.3.2. Thermogravimetric analysis (TGA)

Thermal analysis has been employed in several archaeometric studies to estimate the firing temperature of ancient ceramic materials (e.g., Moropoulou et al. 1995; Krapukaitytė et al. 2008).[22] However, it should be stressed at the outset that this approach is not without constraints. The following technical and methodological factors must be considered:

a. Post-firing chemical processes

When ceramic materials are fired, the most significant mass loss is typically associated with four reactions (Rice 2015: 99-116):

[22] Five cuneiform tablets were analyzed with TGA and DSC by D. Thickett (1998), but only a brief summary of the results is included in his report.

(1) Loss of mechanically combined water: ~100-200 ºC.
(2) Combustion of organic material: ~200-500 ºC.
(3) Dehydroxylation of clay minerals such as kaolinite or montmorillonite: ~400-650 °C.
(4) Decomposition of carbonates: ~700-900 ºC.

Previous applications of thermal analysis to examine ancient pottery fragments and estimate their maximum firing temperature rely on the basic assumption that, upon experimental reheating, those changes that are considered to be irreproducible will take place only when the upper limit of the original heating is surpassed (Drebushchak et al. 2005: 622). The decomposition of hydroxyls ($2OH^{-} \rightarrow O^{2-} + H_2O$) and the decomposition of carbonates ($CaCO_3 \rightarrow CaO + CO_2$) are frequently regarded as irreversible reactions that indicate a maximum firing temperature below ~400-650 ºC and ~700-900 ºC, respectively (see, e.g., Palanivel and Rajesh 2011; Meyvel et al. 2012).

However, as pointed out by Drebushchak et al. (2005), the role of post-firing processes occurring during hundreds or even thousands of years of storage under ambient conditions is significant in this respect. Three aspects deserve special attention:

- After ceramics are fired, mass gain takes place due to a set of slow reactions produced in the newly formed meta-clay by adsorption of water from the environment and recovery of some structural hydroxyl groups (Shoval and Paz 2013). Wilson et al. (2012) describe the mass of a typical archaeological pottery sample (m_r) as the sum of five components ($m_r = m_{cer} + m_{nrc} + m_{w0} + m_{w1} + m_a$): ceramic mass m_{cer} (mass of the total inorganic mineral assemblage which remains intact after reheating the sample to 500 ºC) + non-refractory component mass m_{nrc} (any substances other than water that contribute to the mass loss on reheating to 500 ºC: organic materials such as food residues, microbiological contaminants, absorbed humic acids, etc., as well as minerals unstable at low temperatures) + type 0 water mass m_{w0} (physisorbed water, i.e., capillary water trapped in the pores of the sample and weakly bound adsorbed water which is removed by heating the sample at 105 ºC) + type 1 water mass m_{w1} (chemisorbed molecular water which is typically removed at 200-300 ºC) + type 2 water mass m_a (the mass of water gained during rehydroxylation after the original firing; see below). Thus, mass loss in the range of ~100-500 ºC can be explained by the elimination of m_{w0} + m_{w1} (water) as well as m_{nrc} (e.g., humic material) resulting from post-depositional processes.

- Dehydroxylation is not fully irreversible, since it has been demonstrated that ceramics gain mass and expand continuously after firing as a result of rehydroxylation, i.e., chemical recombination with environmental moisture (Wilson et al. 2003; Hamilton and Hall 2012). Wilson et al. (2003) described the rate of moisture expansion in fired clay ceramics and the associated mass gain by a $(\text{time})^{1/4}$ power law (cf. also Savage et al. 2008; Hall et al. 2011), but this model has been contested by Le Goff and Gallet (2014; cf. also Gallet and Le Goff 2015), who suggest a $(\text{time})^{1/N}$ power law with a variability in the values of the exponent $1/N$ between ~1/2 and ~1/4. Although rehydroxylation is a very slow process, Wilson et al. note that on a time scale of thousands of years "mass gain is typically 1-2% of the sample mass" (2009: 7). This estimate seems to be confirmed in a recent study by S. Shoval and Y. Paz (2013), who examined the mass loss percentages due to dehydroxylation of a group of pottery sherds dating from the Late Neolithic to the Roman period.

- Secondary calcite can occur in archaeological ceramics, either as a completely allochthonous component (precipitated from calcium carbonate saturated solutions percolating through the soil) or as a partly allochthonous component (Ca present in the pottery fragment + external C and O) (Maggetti 1982: 129; Buxeda and Cau 1995; Cau et al. 2002; Fabbri et al. 2014). Thus, the detection of mass loss in the range of ~700-900 ºC may be due to the decomposition of secondary carbonates (Tschegg et al. 2009).

b. Firing conditions

The changes that take place in ceramic materials during firing are kinetic processes that depend on three primary variables: time, temperature and atmosphere (Rice 2015: 99-100; cf. Drebushchak et al. 2011: 460). Thus, it is problematic to derive a single parameter (temperature) from the analysis of an artifact subjected to transformations that are functions of three parameters. D. Albero (2014: 87-88) points out that simplistic interpretations concerning pottery firing often prevail, with an overestimation of the maximum firing temperature; moreover, it has been argued that the correlation between firing temperature and technological procedures is not always direct (Gosselain 1992; Livingstone 2001).

c. Sampling constraints

Estimates about the maximum firing temperature of archaeological pottery are also limited by the degree of representation of the examined sample, since heat is not distributed in a uniform manner across the ceramic body (Maggetti et al. 2011) and mass loss values can vary among different parts of the same vessel (Drebushchak et al. 2007). Considering the morphology of cuneiform tablets, we may assume a priori a more uniform distribution of heat in comparison with ceramic pots, but it should be noted that the technological procedures employed to fire these artifacts are unknown to us. In addition, the samples examined in the present study (one fragment per tablet with a maximum mass of ~25 mg) may not be representative of the total composition of each object.

Taking into account these factors, we will deliberately avoid estimating maximum firing temperatures only on the basis of TGA mass loss values. The results will be interpreted along with the available petrographic data, in order to test mass loss trends against observable mineralogical transformations (cf. Rice 2015: 387, and see Figure 11 below). All the samples were analyzed with a TA Instruments Q500 Thermogravimetric Analyzer.

2.4. Previous research: portable X-ray fluorescence (pXRF) and instrumental neutron activation analysis (INAA)

Many of the documents examined here were also analyzed with portable X-ray fluorescence (pXRF) and instrumental neutron activation analysis (INAA) by Goren et al. (2011). X-ray fluorescence offers significant advantages for future research on cuneiform tablets, given its non-invasive nature and relatively simple operating procedures. However, as emphasized by A. Hunt and R. Speakman (2015: 638), it cannot replace fully quantitative analysis by other techniques such as INAA or ICP-MS.

In the study by Goren et al. (2011), three measurements were performed at different flat points of each object, and the obtained values were averaged and processed using the standard Bonn statistical method to consider the possible varying inhomogeneity of the clay (Beier and Mommsen 1994). Elements affected by post-depositional processes or firing were disregarded, as well as those with values below or near the LOD level of two standard deviations (Goren et al. 2011: 689). The average concentrations of the 14 most significant elements (Al, Si, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Rb, Sr, Zr and Nb) were compiled and subsequently tested by different statistical procedures such as discriminant analysis and principal component analysis (PCA) in order to establish the grouping of the samples.

The complete INAA results of the samples pertinent to our thesis have not been published yet, but the category to which they were assigned can be found in the article by Goren et al. (2011). Clay tablets have also been examined in previous studies with these techniques (Artzy et al. 1976; Dobel et al. 1977; Blackman 2003; Goren et al. 2006; Sterba et al. 2011; Uchida et al. 2011; Grave and Kealhofer 2014) and with other methods such as ICP-OES/ICP-MS (Balossi et al. 2004; Goren et al. 2004), XRD (Thickett 1998), SEM (Cartwright and Taylor 2011; Tuji et al. 2014) and Magnetic susceptibility (Sterba et al. 2011; Uchida et al. 2011).

2.4.1. Egyptian letters

Table 2 shows the composition of each of the seven Egyptian fragments studied here, which were analyzed by Goren et al. (2011) along with four tablets made of Esna marl (EA 14, 162, 340, 357) and another two made of Nile silt (EA 163, 339). Four patterns (labeled EgypA, EgypB, EgypC and EgypD) were detected within the whole set of Egyptian samples, in accordance with petrographic subdivisions (Goren et al. 2011: 689; see Table 3). EgypA and EgypD correspond to the Esna marl and Nile silt tablets respectively, whereas the seven letters produced with marly clay are classified as either EgypB (VAT 6169+7669, 7677, 13067) or EgypC (VAT 6156, 6161, 6168, 6172). The last two clusters differ after correction mainly in Mn and K, and since no variation is observed by petrography or INAA, Goren et al. point out that the subdivision “might be needless and obtained only due to a given too small experimental uncertainty for Mn and K” (2011: 689-691).

§ *Table 2*. Elemental composition of seven Egyptian fragments as determined by pXRF (after Goren et al. 2011: 690-691). The values are expressed in ppm (mg/kg) and represent an average of three measurements at different positions; only 14 significant elements are shown.

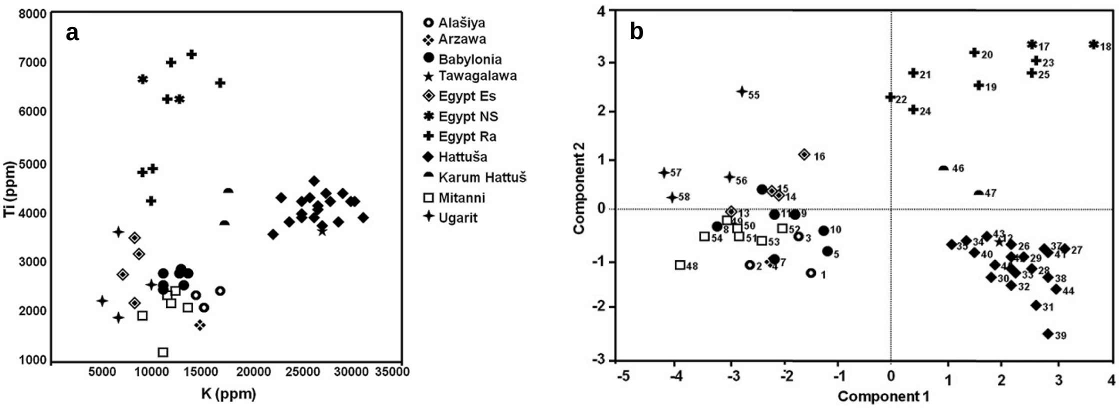
VAT	Al	Si	K	Ca	Ti	V	Cr
6156	50.436	218.267	11.390	90.540	6246	346	210
6161	35.872	221.316	8831	86.121	4795	363	166
6168	36.146	180.451	9640	85.175	4266	291	151
6169+7669	56.116	279.687	13.871	33.522	7181	317	196
6172	46.628	212.408	9969	68.120	4905	294	177
7677	53.561	295.497	16.851	35.165	6580	410	207
13067	39.221	288.451	11.912	35.826	6973	360	182

VAT	Mn	Fe	Ni	Rb	Sr	Zr	Nb
6156	1060	59.012	64	13	280	225	25
6161	888	49.519	75	8	323	219	23
6168	949	54.153	82	9	262	190	22
6169+7669	1497	59.706	92	10	283	212	23
6172	736	52.279	91	9	262	175	21
7677	1613	58.244	84	11	335	194	24
13067	1422	45.698*	45	9	299	174	21

* Rectified value (in Goren et al. 2011: 690 the comma was placed in the wrong position).

§ *Table 3*. Elemental concentration patterns of Egyptian tablets as determined by pXRF (after Goren et al. 2011: 692). Averages *M* in μg/g (ppm) and spreads σ in percent of *M*.

	EgypA (2 samples, factor 1.00)		EgypB (3 samples, factor 1.00)		EgypC (4 samples, factor 1.00)		EgypD (2 samples, factor 1.00)		EgypBC (7 samples, factor 1.00)	
	M	σ (%)	*M*	σ (%)	*M*	σ (%)	*M*	σ (%)	*M*	σ (%)
Al%	4.62	14	4.87	13	4.16	15	6.19	8.1	4.47	14
Ca%	14.9	14	3.29	5.9	8.30	19	1.92	12	5.31	53
Cr	138	18	192	14	180	18	218	11	185	16
Fe%	3.82	4.8	5.51	8.1	5.24	4.4	6.64	16	5.39	5.5
K%	0.85	10	1.34	6.3	0.97	8.4	1.07	26	1.15	16
Mn	733	6.7	1519	6.0	924	7.6	1140	5.2	1136	24
Nb	16.8	13	22.7	6.7	22.8	7.4	25.5	12	22.6	7.1
Ni	–		69.5	31	73.7	26	71.4	27	72.0	28
Rb	10.2	10	10.2	11	9.74	16	18.6	6.6	9.92	11
Si	16.6	6.5	27.6	1.1	20.8	5.7	22.3	12	24.3	16
Sr	322	58	301	8.3	276	9.2	116	26	286	8.0
Ti%	0.34	4.9	0.70	10	0.51	11	0.64	4.7	0.59	16
V	207	12	357	13	324	9.3	330	18	336	9.9
Zr	152	4.2	187	3.1	197	7.5	269	36	193	9.3



§ **Figure 7.** (a) K-Ti plot of the reference tablets studied with pXRF by Goren et al. (2011), in ppm (mg/kg); (b) Principal component analysis (PCA) of the results from the same set of tablets using 14 elements (after Goren et al. 2011: 693-694). Egypt Es (◈) = Esna marl tablets; Egypt NS (✱) = Nile silt tablets; Egypt Ra (✚) = Marl D tablets.

According to Goren et al. (2011: 689), X-Y plots of K and Ti proved to be particularly significant to observe provenance clusters before applying more advanced statistical methods. For the Egyptian assemblage, tablets made of Nile sediments (both Nile silt and Marl D categories) presented a distinctive pattern with low K and high Ti contents (Figure 7a). In the PCA plot of the reference group analyzed by Goren et al., the Marl D samples also cluster coherently (Figure 7b). Even tough the full INAA data remain unpublished, five of the Egyptian fragments from the times of Ramses II were examined and assigned to the same category (i.e., "Egyptian marl": VAT 6156, 6168, 6169+7669, 6172, 13067; see Goren et al. 2011: 686).

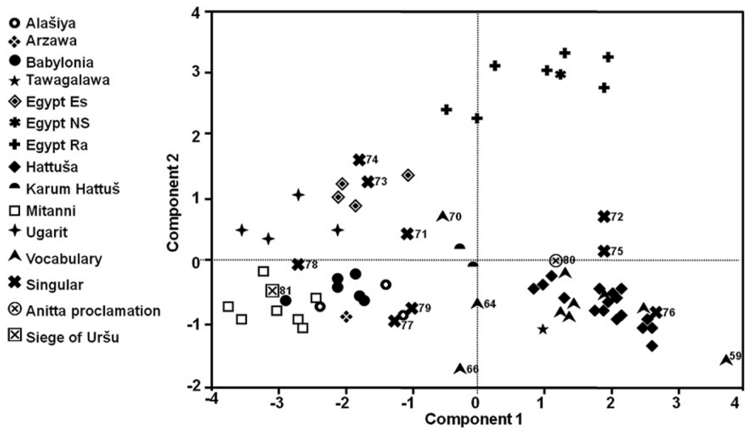
2.4.2. Documents related to Karkemiš

The elemental concentrations of VAT 7420 and VAT 13008 were analyzed by pXRF in the previously mentioned study conducted by Goren et al. (2011). Table 4 shows these results along with the values for VAT 7679, another document which may have also been produced in the Upper Euphrates region (though probably not in Karkemiš; see Goren et al. 2011: 694).

§ *Table 4*. Elemental composition, as determined by pXRF, of three tablets which may be related to the Upper Euphrates region (after Goren et al. 2011: 690-691). The values are expressed in ppm (mg/kg) and represent an average of three measurements at different positions; only 14 significant elements are shown.

VAT	Al	Si	K	Ca	Ti	V	Cr
7420	31.775	150.276	9631	18.3181	2680	285	312
7679	28.856	182.296	10.329	52.204	2866	451	714
13008	31.275	27.7770	14.642	27.505	4553	231	406

VAT	Mn	Fe	Ni	Rb	Sr	Zr	Nb
7420	1043	38.805	152	14	366	87	12
7679	804	45.026	339	10	231	59	8
13008	948	56.319	314	14	270	100	11



§ **Figure 8.** Principal component analysis (PCA) of the reference tablets studied with pXRF by Goren et al. (2011), using seven significant elements (Al, Si, K, Ti, Rb, Zr and Nb; after Goren et al. 2011: 694). Relevant references: (✖ 71) = VAT 13008; (✖ 77) = VAT 7421; (✖ 78) = VAT 7420; (⊠ 81) = VAT 7679.

Despite some similar concentration patterns, the number of samples and the experimental constraints mentioned before make it difficult to establish a "Karkemiš/Upper Euphrates cluster." It should be noted that VAT 7420 and VAT 7679 fall close to the Mittannian and Babylonian groups in the PCA plot of all the tablets examined by Goren et al. (in accordance with the petrographic similarities between these groups; see Figure 8).

2.4.3. VAT 7423

The chemical composition of VAT 7423 was analyzed by pXRF and INAA. The results of both studies place it within the Ḫattuša category (Goren et al. 2011: 686-687; see also Figure 7b, under sample reference [◆ 40]).

2.4.4. VAT 7421

VAT 7421 was analyzed with pXRF and INAA by Goren et al. (2011). Its INAA class is described as "singular" or "Cyprus I," and the pXRF values are also considered to be "singular" (Goren et al. 2011: 686-687; see Table 5). However, in the PCA plot of all the studied tablets this sample falls on the fringe of the Alašiya cluster, which is formed by three documents made with Pachna marl (VAT 153 [EA 38], 1654 [EA 33], 6184; see Figure 8, under sample reference [✖ 77]).

§ *Table 5*. Elemental composition, as determined by pXRF, of one Hittite treaty and three tablets from Cyprus (after Goren et al. 2011: 690-691). The values are expressed in ppm (mg/kg) and represent an average of three measurements at different positions; only 14 significant elements are shown.

VAT	**Al**	**Si**	**K**	**Ca**	**Ti**	**V**	**Cr**
7421	54.663	211.846	17.952	87.060	2833	280	307
153	50.012	208.763	16.612	121.189	2461	186	125
1654	30.571	137.784	14.900	133.004	2139	175	104
6184	42.077	185.981	14.333	154.817	2390	223	140

VAT	**Mn**	**Fe**	**Ni**	**Rb**	**Sr**	**Zr**	**Nb**
7421	1830	49.197	272	20	206	89	12
153	676	31.926	62	28	292	95	14
1654	634	33.078	66	27	338	93	13
6184	1531	33.820	54	26	365	105	16

3. Results

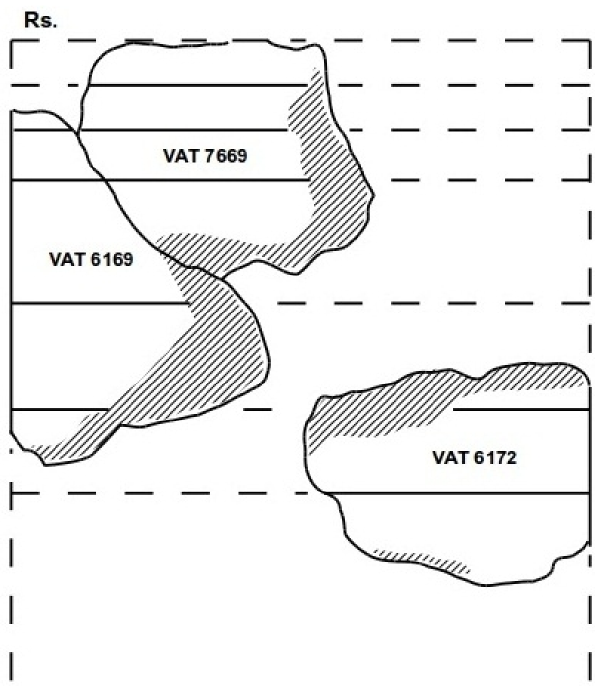
3.1. Egyptian letters

3.1.1. Petrographic data

All the fragments examined here have a similar petrofabric, which may be identified as belonging to the "Marl D" group from the Vienna system, or perhaps as a mixture of Nile silt and marly clays. The section color of the Marl D category ranges from red (2.5YR 4/8) to grayish-brown (2.5Y 5/2) and pale olive (5Y 5/3), and very frequently it is also dark brown (Nordström and Bourriau 1993: 181-182). Its most distinctive feature is the presence of irregular limestone particles scattered throughout the matrix; according to Hope et al. (2002: 108), in addition to quartz and limestone, Marl D also contains varying quantities of plagioclase, K-feldspar, amphibole, pyroxene and biotite.

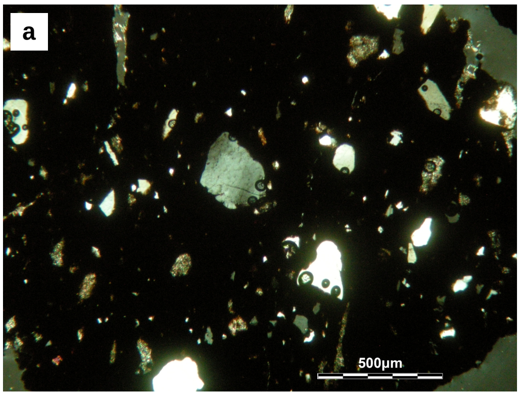
Among the analyzed fragments, VAT 6169+7669 and VAT 6172 deserve special attention. Edel (1994b: 95-100) has suggested that they belong to the same tablet, even though they do not join directly (see Figure 9). In his discussion about the philological rationale for such an indirect join, this scholar notes that early on H. Otten had expressed some reservations about it and had even pointed out a clear difference in the color of the clay (Edel 1994b: 97-98).

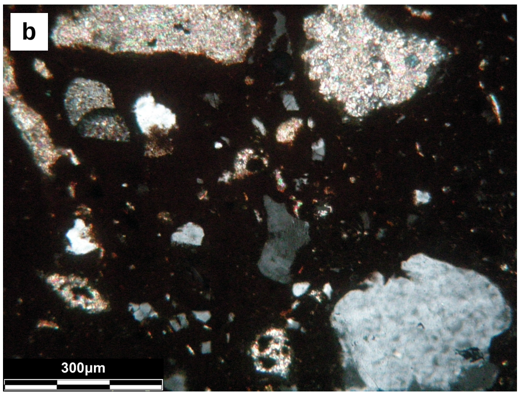
In fact, a number of divergent traits between the thin-sections suggest that these fragments actually did not belong to the same tablet: (1) the matrix of VAT 6169+7669 exhibits microlamination and is more isotropic than that of VAT 6172; (2) VAT 6169+7669 contains some foraminifers; (3) they are also different in terms of type and sorting of accessory minerals; (4) VAT 6169+7669 was probably fired at a higher temperature (over 800 ºC, judging from the alteration of hornblende into oxyhornblende, the decalcination of calcite and the high isotropism of the matrix; cf. the TGA results in section 3.1.2). VAT 6169+7669 and VAT 6172 also present different pXRF elemental concentration patterns (the former belongs to the EgypB group, whereas the latter falls into the EgypC group), but this discrepancy could be explained by a small experimental uncertainty for some elements (see section 2.4.1).



§ Figure 9. Reconstruction of VAT 6169+7669(+)6172 (after Silvin Košak, *Joinskizzen zu den hethitischen Texten* at the Hethitologie Portal Mainz, sub "VAT 6169").

VAT 6156





Reference (photo)

MzP BoFN01223c/1224c.

Find-spot

Büyükkale, Building A (Boğazköy/Ḫattuša).

Sampling method

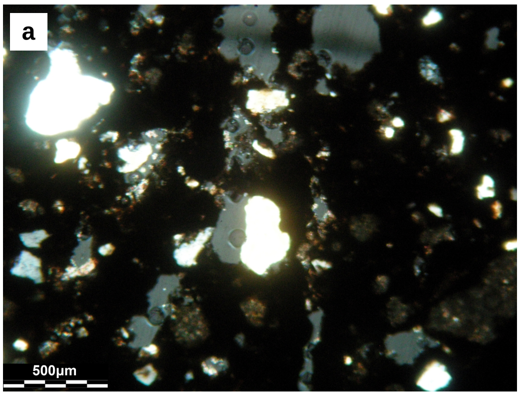
Peeling.

Reliability

High.

Matrix
Dark reddish-brown in PPL, nearly isotropic. Ferruginous and silty (~5%) clay. The silt contains quartz and other accessory heavy minerals such as amphibole and biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; angular to sub-rounded quartz grains (up to ~300 μm) and calcareous rock fragments (up to ~300 μm), as well as biotite. No remains of vegetal material were traced.
Maximum firing temperature
Probably ~800-900 ºC (decalcination of calcite; high isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the "Marl D" group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 6161



Reference (photo)

MzP BoFN01244a.

Find-spot

Büyükkale, Building E (Boğazköy/Ḫattuša).

Sampling method

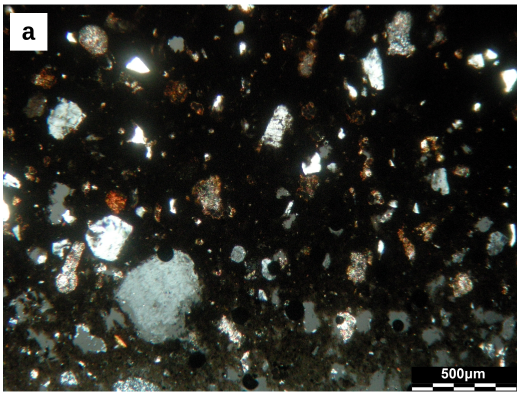
Peeling.

Reliability

High.

Matrix
Dark reddish-brown in PPL, nearly isotropic. Ferruginous and silty (~5%) clay. The silt contains quartz and other accessory heavy minerals such as amphibole and biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; sub-angular to sub-rounded quartz grains (up to ~300 µm) and calcareous rock fragments (up to ~300 µm). No remains of vegetal material were traced.
Maximum firing temperature
Probably ~800-900 ºC (decalcination of calcite; high isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the "Marl D" group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 6168



Reference (photo)

MzP BoFN01225a/1226b.

Find-spot

Büyükkale, Building E (Boğazköy/Ḫattuša).

Sampling method

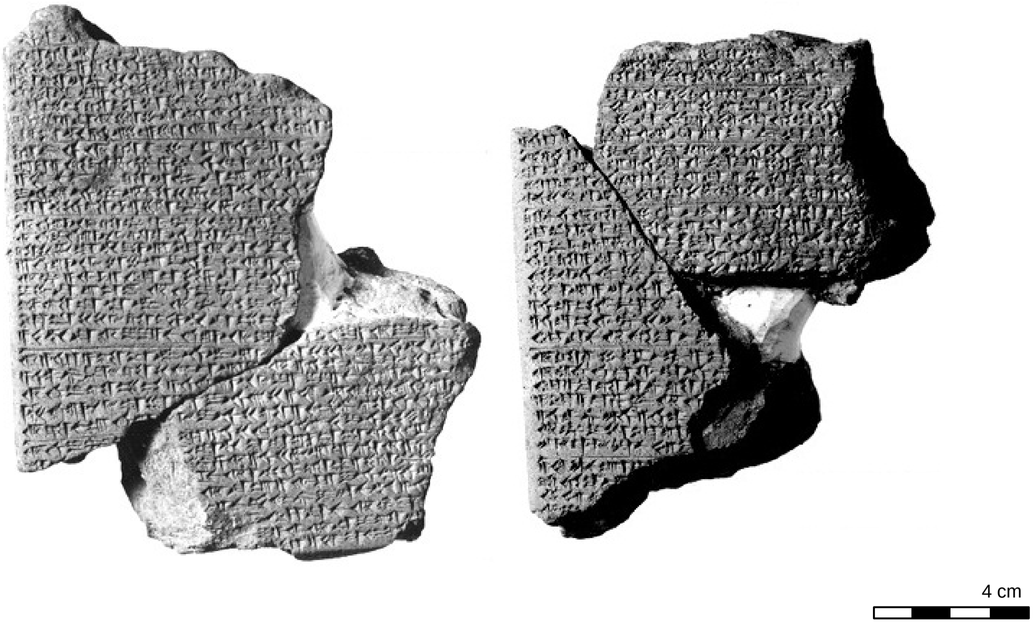
Peeling.

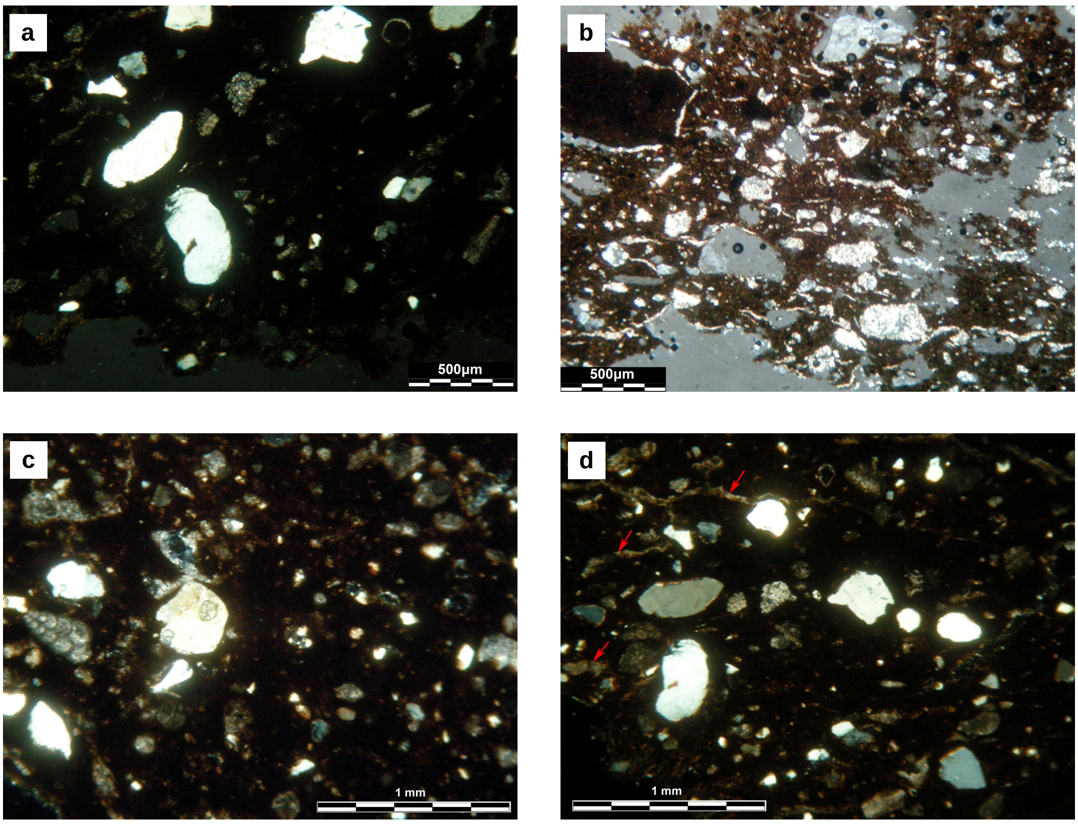
Reliability

High.

Matrix
Dark reddish-brown in PPL, highly isotropic. Ferruginous and silty (~5%) clay, almost devoid of foraminifers. The silt contains quartz and other accessory heavy minerals such as biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; angular to sub-rounded quartz grains (up to ~400 µm) and calcareous rock fragments (up to ~200 µm), as well as biotite and opaques. No remains of vegetal material were traced.
Maximum firing temperature
Probably over 800 ºC (alteration of hornblende into oxyhornblende; decalcination of calcite; high isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the "Marl D" group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 6169+7669



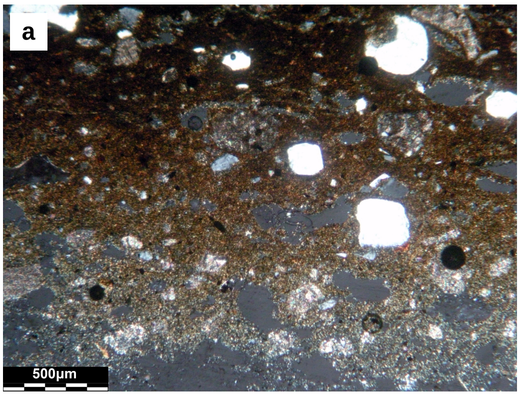


Reference (photo)

MzP BoFN01253/1254.

Find-spot
Büyükkale, Building E (Boğazköy/Ḫattuša).
Sampling method
Peeling.
Reliability
High.
Matrix
Dark reddish-brown in PPL, highly isotropic and microlaminated. Ferruginous and silty (~5%) clay. The silt contains quartz and other accessory heavy minerals such as plagioclase and biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; sub-angular to sub-rounded quartz grains (up to ~500 µm) and calcareous rock fragments (up to ~300 µm), as well as biotite, opaques and oxyhornblende. No remains of vegetal material were traced. Some foraminifers can be observed (photo [c]). Secondary crystallization of calcite can be observed in the voids (birefringent material concentrated along cracks and pores, photo [d]).
Maximum firing temperature
Probably over 800 ºC (alteration of hornblende into oxyhornblende; decalcination of calcite; high isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the “Marl D” group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 6172



Reference (photo)

MzP BoFN01274b.

Find-spot

Unknown (Boğazköy/Ḫattuša).

Sampling method

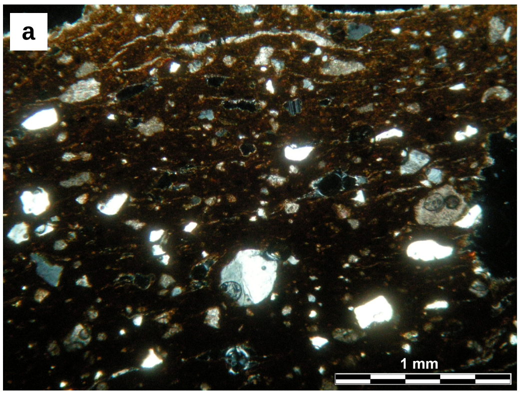
Peeling.

Reliability

High.

Matrix
Dark reddish-brown in PPL, partly isotropic. Ferruginous and silty (~5%) clay. The silt contains quartz and other accessory heavy minerals such as amphibole and biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; angular to sub-rounded quartz grains (up to ~300 µm) and calcareous rock fragments (up to ~300 µm), as well as biotite and opaques. No remains of vegetal material were traced.
Maximum firing temperature
Probably around ~700-800 ºC (decalcination of calcite; partial isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the "Marl D" group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 7677



Reference (photo)

MzP BoFN01404a/1405a.

Find-spot

Unknown (Boğazköy/Ḫattuša).

Sampling method

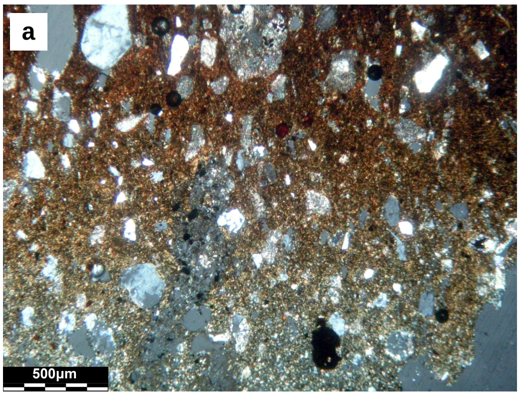
Peeling.

Reliability

Satisfactory.

Matrix
Dark reddish-brown in PPL, highly isotropic and microlaminated. Ferruginous and silty (~5%) clay. The silt contains quartz and other accessory heavy minerals such as amphibole and biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; angular to sub-rounded quartz grains (up to ~200 µm) and calcareous rock fragments (up to ~200 µm), as well as biotite, plagioclase and opaques. No remains of vegetal material were traced. Secondary crystallization of calcite can be observed in the voids (birefringent material concentrated along cracks and pores).
Maximum firing temperature
Probably around 800 ºC (decalcination of calcite; partial isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the “Marl D” group from the Vienna system, or as a mixture of Nile silt and marly clays.

VAT 13067



Reference (photo)

MzP BoFN01658b/1659b/1660b.

Find-spot

Temple I (Boğazköy/Ḫattuša).

Sampling method

Peeling.

Reliability

High.

Matrix
Dark reddish-brown in PPL, partly isotropic. Ferruginous and silty (~5%) clay, almost devoid of foraminifers. The silt contains quartz and other accessory heavy minerals such as biotite.
Inclusions
Poorly sorted fine sand particles that maintain a gradual continuum with the silt in terms of grain size; angular to sub-rounded quartz grains (up to ~300 µm) and calcareous rock fragments (up to ~300 µm), as well as biotite and opaques. No remains of vegetal material were traced.
Maximum firing temperature
Probably around ~700-800 ºC (decalcination of calcite; partial isotropism of the matrix).
Interpretation
This petrofabric can be described as an Egyptian marly clay mixed with calcareous and quartz sand. It may be identified as belonging to the "Marl D" group from the Vienna system, or as a mixture of Nile silt and marly clays.

3.1.2. TGA data

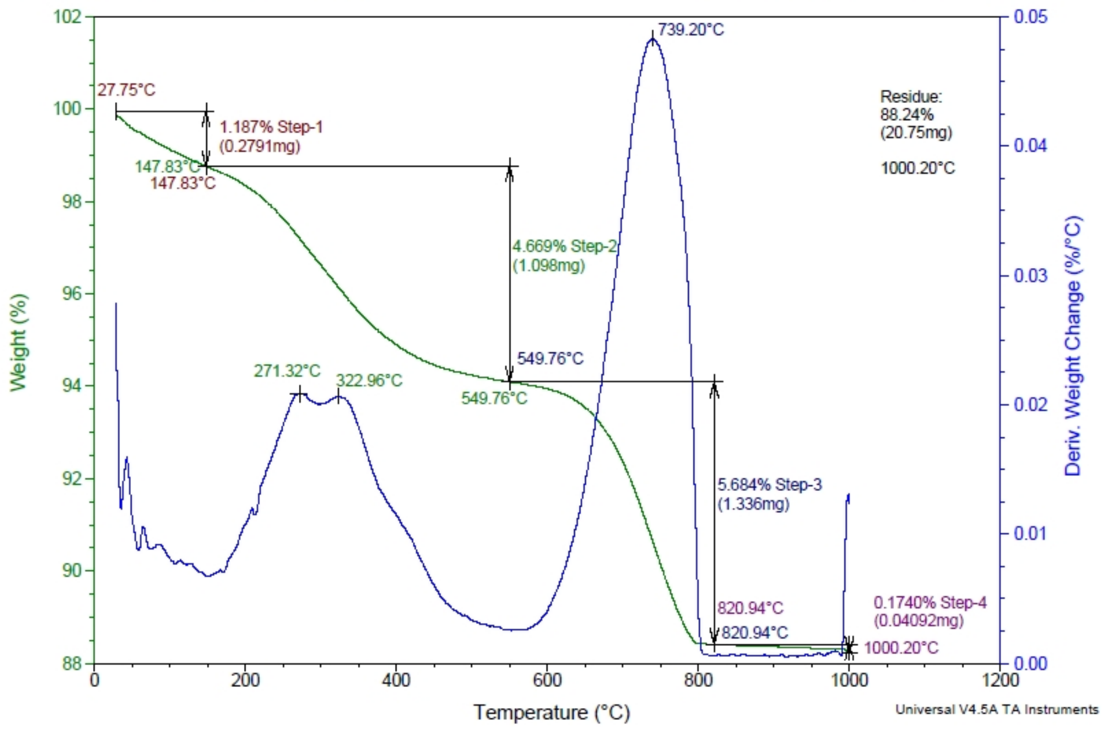
Four fragments from the times of Ramses II (VAT 6161, 6168, 6172, 13067) and one letter from Tell el-Amarna (EA 190) were analyzed using TGA, in order to compare the data with the available petrographic information and estimate their maximum firing temperature. The mass of the samples was ~10-25 mg. Measurements were carried out from room temperature to 1000 °C, at a heating rate of 10 °C min^{-1}, in static air. Figure 10 (a-e) shows the thermogravimetric curves of the fragments, and Table 6 contains a summary with relevant data about the loss of mass.

According to J. Marzahn (pers. comm. to Y. Goren), head-curator of the cuneiform collection at the Vorderasiatisches Museum, there is no record that the tablets stored there were fired for conservation purposes. It is possible that such a procedure was carried out and not registered, especially in the first half of the twentieth century; however, the still unpublished archaeomagnetic analysis conducted by Yitzhak Vassal, Erez Ben Yosef, Ron Shaar and Yuval Goren on several documents from this collection reveals that many of them were fired above ~600-700 ºC in the second millennium BC.

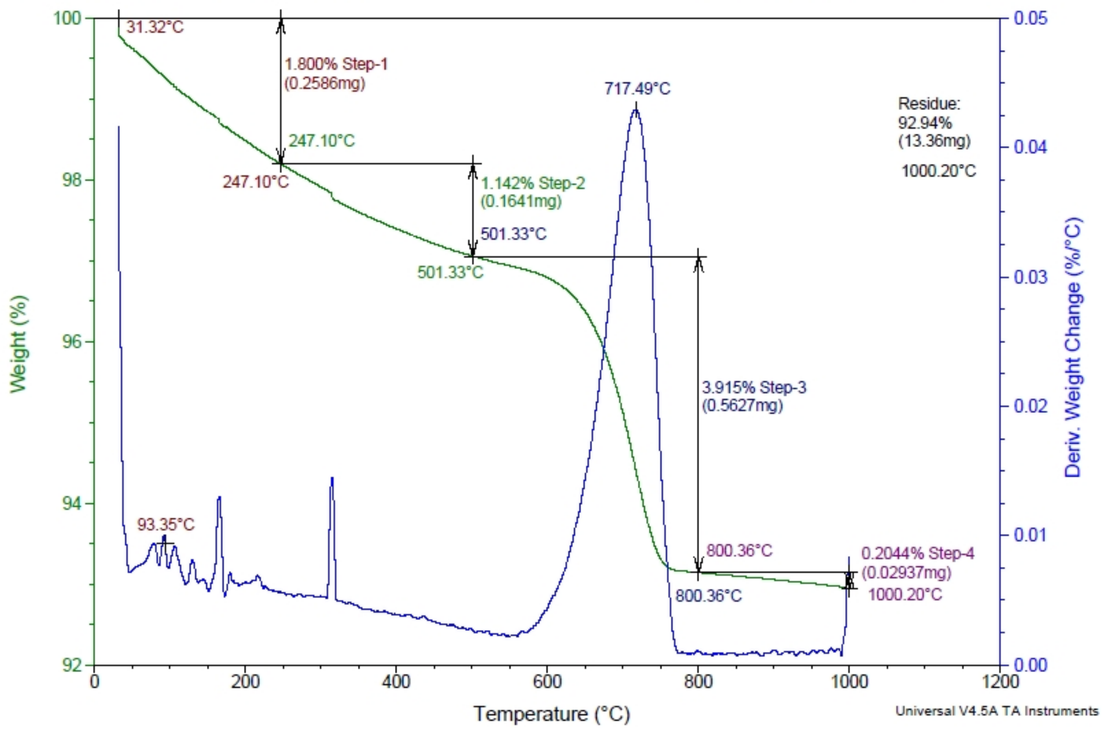
The mineralogical changes observed in the thirteenth-century fragments suggest that their average maximum firing temperature was higher than that of the locally produced Amarna tablets examined by Goren et al. (2004). This difference seems to be confirmed by the TGA results. Figures 11a and 11b show, in a comparative manner, the transformations detected by thin-section petrography and the reactions produced upon experimental reheating in one sample from each group (VAT 6161 and EA 190, respectively).

As pointed out in section 2.3.2, post-firing processes have to be carefully considered in order to assess the correlation between mass loss and maximum firing temperature of archaeological ceramics. Since the thin sections of the fragments from Ḫattuša exhibit signs of firing at ~700-900 ºC, mass loss below and at this range should be connected with the following processes: (a) elimination of moisture water and non-refractory components (~100-500 ºC), (b) dehydroxylation of clay minerals (~400-650 °C) and (c) decomposition of secondary calcite (~700-900 ºC).

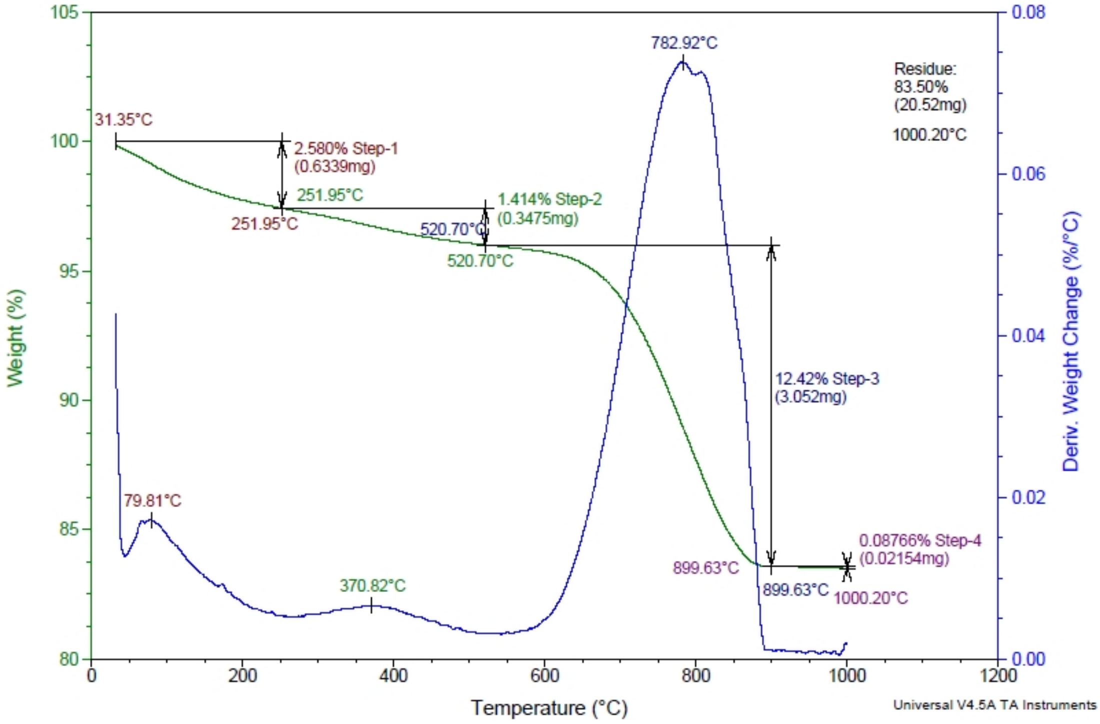
For the thirteenth-century documents, mass loss in the range of ~400-650 °C is consistent with the elimination of chemically combined rehydroxylated water acquired during the lifetime of each sample after firing (VAT 6161: ~1.5%; VAT 6168: ~1%; VAT 6172: ~1.2%; VAT 13067: ~2.5%; cf. Shoval and Paz 2013: 116). However, the values of EA 190 are higher in this range (~4.5%), and also between ~700-900 ºC. This differing pattern can probably be attributed to a set of reactions occurring above the original maximum firing temperature, i.e., the dehydroxylation of clay minerals and the decomposition of carbonates. It should also be noted that the loss of mass of the Ḫattuša fragments at ~700-900 ºC seems to be produced by the decomposition of secondary calcite; in fact, a considerable amount of this mineral was observed by thin-section petrography in VAT 6169+7669 (see photo [d] of the petrographic chart) and VAT 7677. Further support to our results comes from the unpublished archaeomagnetic study mentioned before, which shows that one thirteenth-century Egyptian letter was fired above the Curie temperature of its iron-rich ferromagnetic minerals (magnetite: ~580 ºC; hematite: ~680 ºC) during the Late Bronze Age.



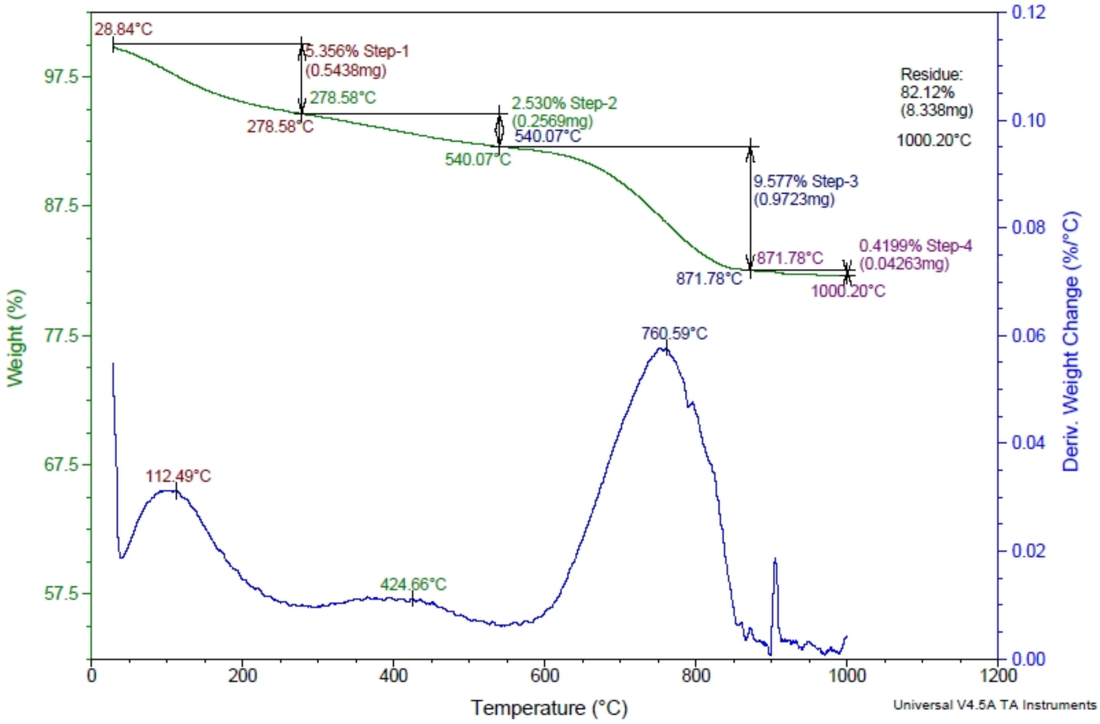
§ Figure 10. (a) TGA/DTG curves of VAT 6161.



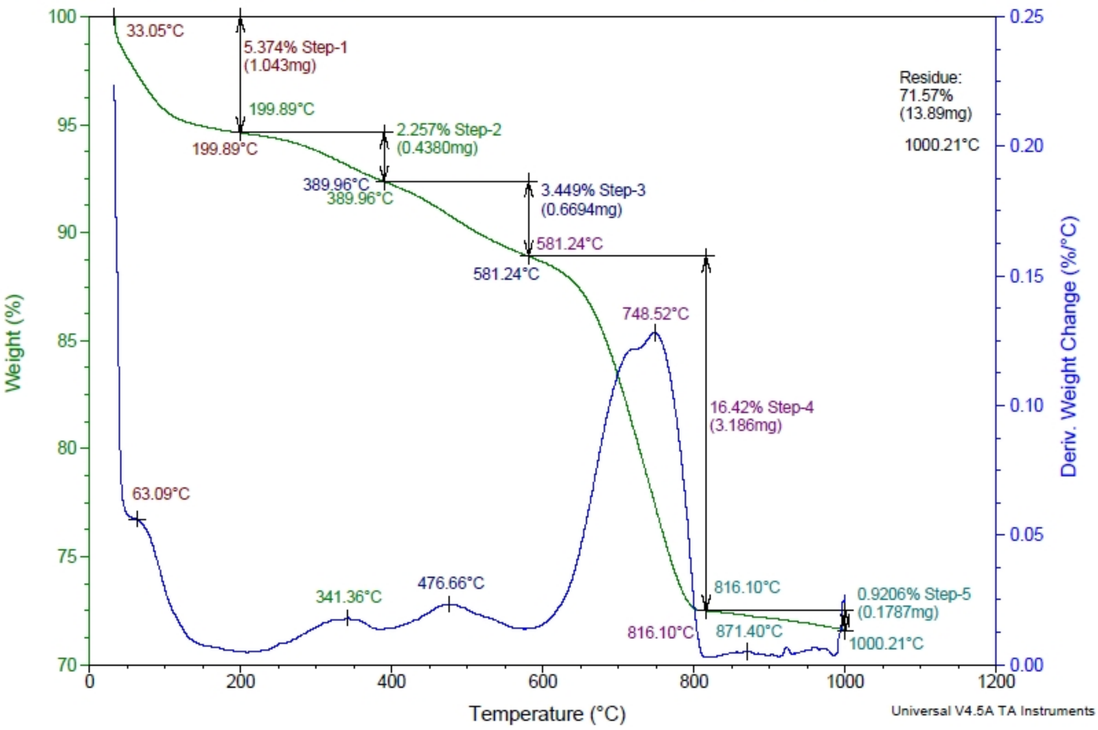
§ Figure 10. (b) TGA/DTG curves of VAT 6168.



§ **Figure 10.** (c) TGA/DTG curves of VAT 6172.



§ **Figure 10.** (d) TGA/DTG curves of VAT 13067.



§ **Figure 10.** (e) TGA/DTG curves of EA 190.

§ *Table 6*. Main thermogravimetric data of the Egyptian tablets. Heating rate: 10 °C min^{-1}. pdt = procedural decomposition temperature (°C): initial/final temp. of the step.

Sample	First step		Second step		Third step	
	loss/%	pdt	loss/%	pdt	loss/%	pdt
VAT 6161	1.18	27	4.66	147	5.68	549
		147		549		820
VAT 6168	1.80	31	1.14	247	3.91	501
		247		501		800
VAT 6172	2.58	31	1.41	251	12.42	520
		251		520		899
VAT 13067	5.35	28	2.53	278	9.57	540
		278		540		871
EA 190	5.37	33	2.25	199	3.44	389
		199		389		581

Sample	Fourth step		Fifth step		Residue /% at 1000 °C
	loss/%	pdt	loss/%	pdt	
VAT 6161	0.17	820	-	-	88.24
		1000		-	
VAT 6168	0.20	800	-	-	92.94
		1000		-	
VAT 6172	0.08	899	-	-	83.50
		1000		-	
VAT 13067	0.41	871	-	-	82.12
		1000		-	
EA 190	16.42	581	0.92	816	71.57
		816		1000	

Changes/ Estimated max. f. t.	100 °C	200 °C	300 °C	400 °C	500 °C	600 °C
Thin-section petrography: Mineralogical transformations		Combustion of organic material				Glauconite turns red
				Pleochroism of biotite increases		
				Glauconite turns yellow		
TGA: Reactions above original m. f. t.		Combustion of organic material				
	Loss of moisture water (m_{w0} + m_{w1})			Dehydroxylation of clay minerals		
		Decomp. of evaporites				
TGA: Reactions below original m. f. t.	Elimination of non-refractory components (humic material, microbiological contaminants, etc.)					
	Loss of moisture water (m_{w0} + m_{w1})			Dehydroxylation of clay minerals		
		Decomp. of evaporites				

Changes/ Estimated max. f. t.	700 °C	800 °C	900 °C	1000 °C	1100 °C	1200 °C
Thin-section petrography: Mineralogical transformations	Anomalous birefringence of calcite	Decomp. of calcite	Calcite reaction rims in the matrix	Isotropism of the matrix	Creation of gehlenite	
		hornblende > oxyhornbl.				
		Partial isotrop. of the matrix	Partial isotrop. of the matrix			
TGA: Reactions above original m. f. t.	Decomposition of calcite			Destruction of crystalline phases		
TGA: Reactions below original m. f. t.	Decomposition of secondary calcite					

§ **Figure 11.** (a) Transformations detected by thin-section petrography in VAT 6161, along with the reactions produced upon experimental reheating above and below the original maximum firing temperature.

Changes/ Estimated max. f. t.	100 °C	200 °C	300 °C	400 °C	500 °C	600 °C
Thin-section petrography: Mineralogical transformations		Combustion of organic material				Glauconite turns red
				Pleochroism of biotite increases		
				Glauconite turns yellow		
TGA: Reactions above original m. f. t.		Combustion of organic material				
	Loss of moisture water (m_{w0} + m_{w1})			Dehydroxylation of clay minerals		
		Decomp. of evaporites				
TGA: Reactions below original m. f. t.	Elimination of non-refractory components (humic material, microbiological contaminants, etc.)					
	Loss of moisture water (m_{w0} + m_{w1})			Dehydroxylation of clay minerals		
		Decomp. of evaporites				

Changes/ Estimated max. f. t.	700 °C	800 °C	900 °C	1000 °C	1100 °C	1200 °C
Thin-section petrography: Mineralogical transformations	Anomalous birefringence of calcite	Decomp. of calcite	Calcite reaction rims in the matrix	Isotropism of the matrix	Creation of gehlenite	
		hornblende > oxyhornbl.				
		Partial isotrop. of the matrix	Partial isotrop. of the matrix			
TGA: Reactions above original m. f. t.	Decomposition of calcite			Destruction of crystalline phases		
TGA: Reactions below original m. f. t.	Decomposition of secondary calcite					

§ Figure 11. (b) Transformations detected by thin-section petrography in EA 190, along with the reactions produced upon experimental reheating above and below the original maximum firing temperature.

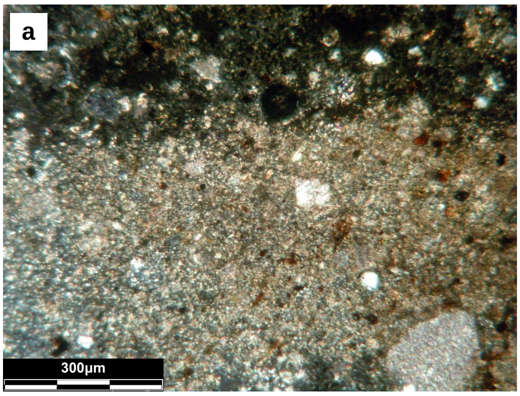
3.2. Hittite diplomatic texts and letters

3.2.1. Petrographic data

Seven documents are presented in this section: four tablets with a similar petrofabric related to Karkemiš (one of which was previously studied by Goren et al. 2004 and is included here for the sake of comparison [AO 19.955]), two versions of the agreement between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni, and a fragment from the "Text A" of the treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru.

AO 19.955 (after Goren et al. 2004: 57)

Scale not available



Reference (photo)

Photo by Yuval Goren.

Find-spot

Ras Shamra/Ugarit.

Sampling method

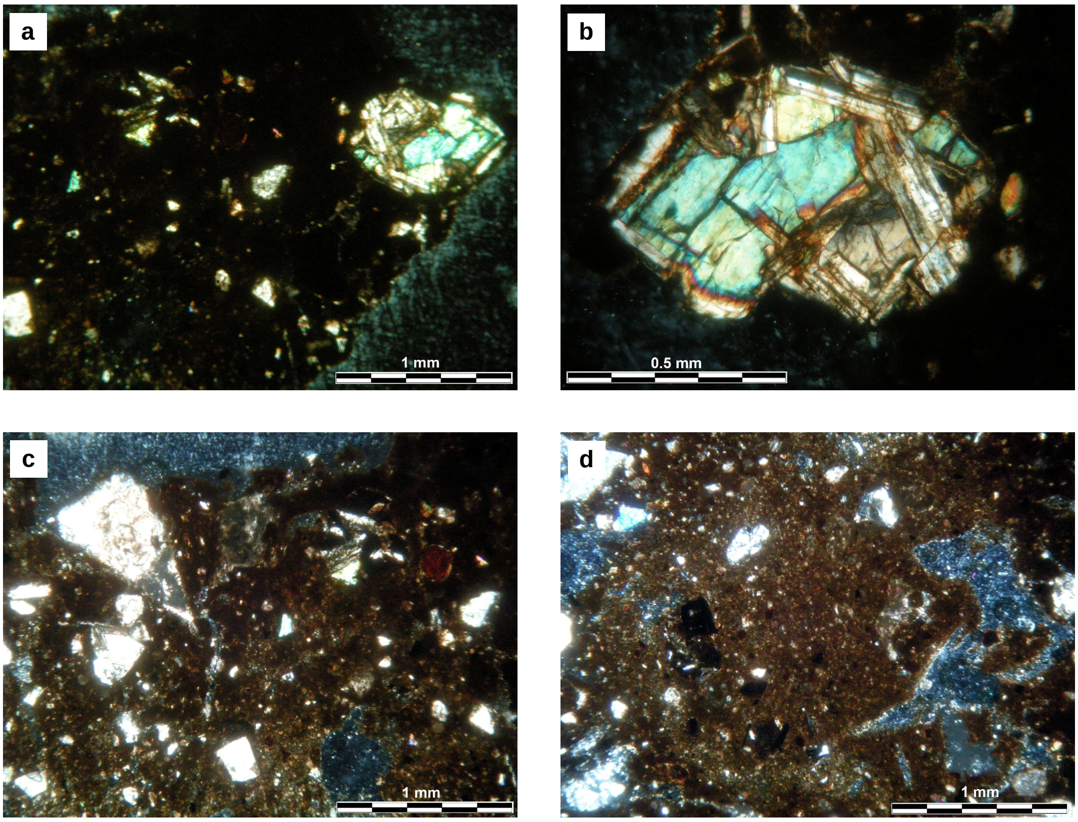
Peeling.

Reliability

Satisfactory.

Matrix
Ochre to orange-tan in PPL, birefringent with speckled b-fabric. The silt (5%) is rich in mineral types including muscovite, quartz, calcite, serpentine, hornblende, opaques, rutile, zircon and feldspar.
Inclusions
Very few accidental grains of micritic limestone.
Firing temperature
Below 800 ºC (no changes in the hornblende), but probably above 700 ºC (decalcination of calcite).
Interpretation
This fabric is similar to that of the Mesopotamian tablets from the Amarna archive. Upper Euphrates clay-silt was employed without any intentional addition of sand inclusions.

BLMJ 1143

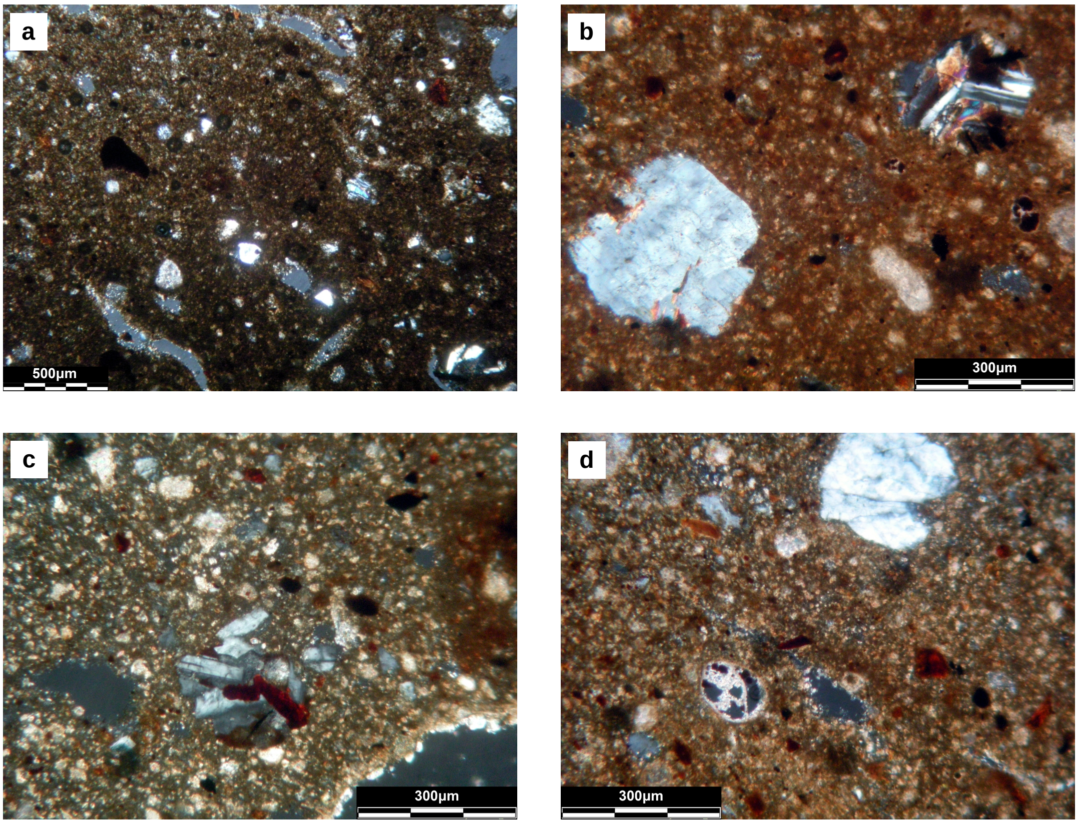


Reference (photo)

Westenholz 2000: 192.

Find-spot
Unknown (but most probably Meskene Qadime/Emar).
Sampling method
Peeling.
Reliability
High.
Matrix
Carbonatic, ochre to orange-tan in PPL and birefringent with speckled b-fabric. The silt is rich in mineral types including muscovite, quartz, calcite, serpentine and opaques.
Inclusions
Poorly sorted sand made up of sub-angular to sub-rounded grains of basalt (up to ~900 µm), dolerite, limestone and quartz. The most conspicuous non-plastic components of this tablet are clear calcite crystals (visible to the naked eye) which split along their cleavage planes, indicating that they were deliberately crushed and added to the paste.
Maximum firing temperature
Undetermined, since it was fired in modern times for conservation purposes (BLMJ 1143 conservation file from the Bible Lands Museum; see also Westenholz 2000: 78).
Interpretation
This tablet was made with marl mixed with sand that contains an assembly of minerals coming from the edge of an ophiolitic area. Besides, crushed calcite was intentionally added to the paste. From the available petrographic and textual information it can be concluded that BLMJ 1143 was produced in Karkemiš.

VAT 7420

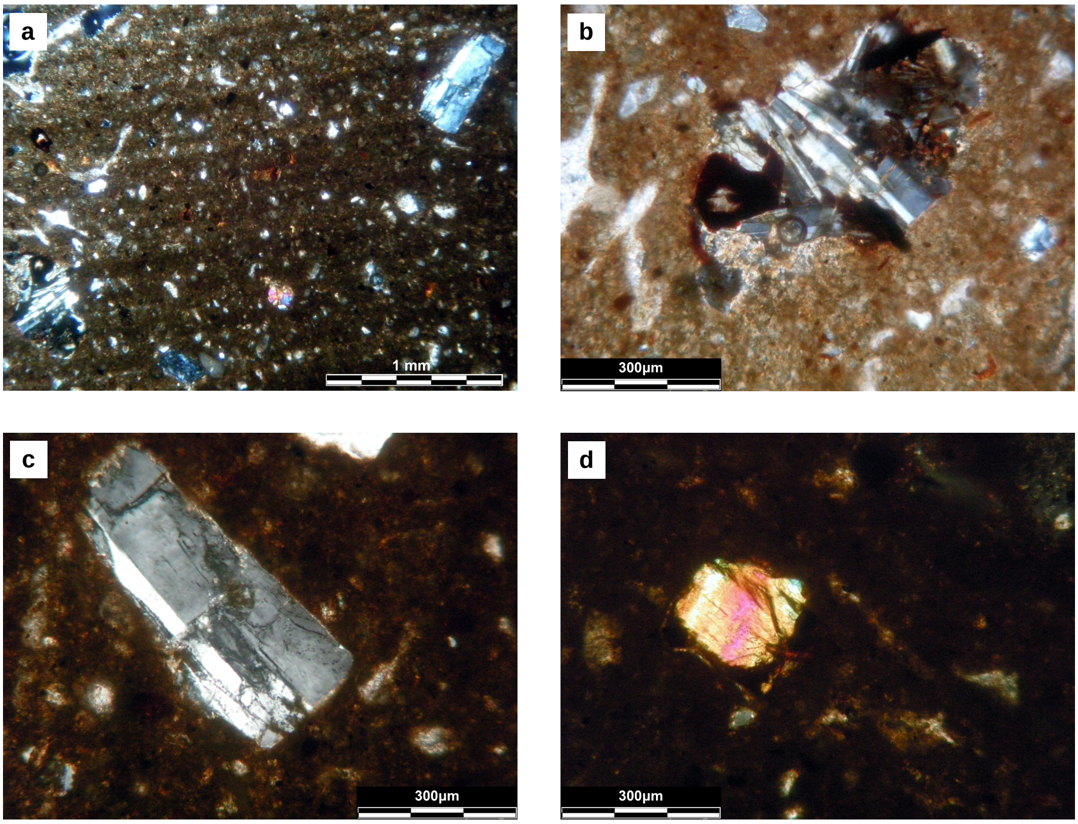


Reference (photo)

MzP BoFN01277/1278.

Find-spot
Unknown (Boğazköy/Ḫattuša).
Sampling method
Peeling.
Reliability
High.
Matrix
Carbonatic, ochre to orange-tan in PPL and birefringent with speckled b-fabric. The silt is rich in mineral types including muscovite, quartz, calcite, serpentine, opaques and feldspar.
Inclusions
Moderately sorted sand made up of rounded to sub-rounded grains of basalt (up to ~200 μm), dolerite, limestone, quartz and serpentinized minerals. Some foraminifers can also be observed.
Firing temperature
Undetermined.
Interpretation
This tablet was made with marl mixed with sand that contains an assembly of minerals coming from the edge of an ophiolitic area. The shape and sorting of the inclusions suggest that they are derived from river sand, which was collected and perhaps sieved in order to employ it as temper. Considering these features and the cumulative evidence from the remaining tablets examined here, we may conclude that it was produced in Karkemiš.

VAT 13008

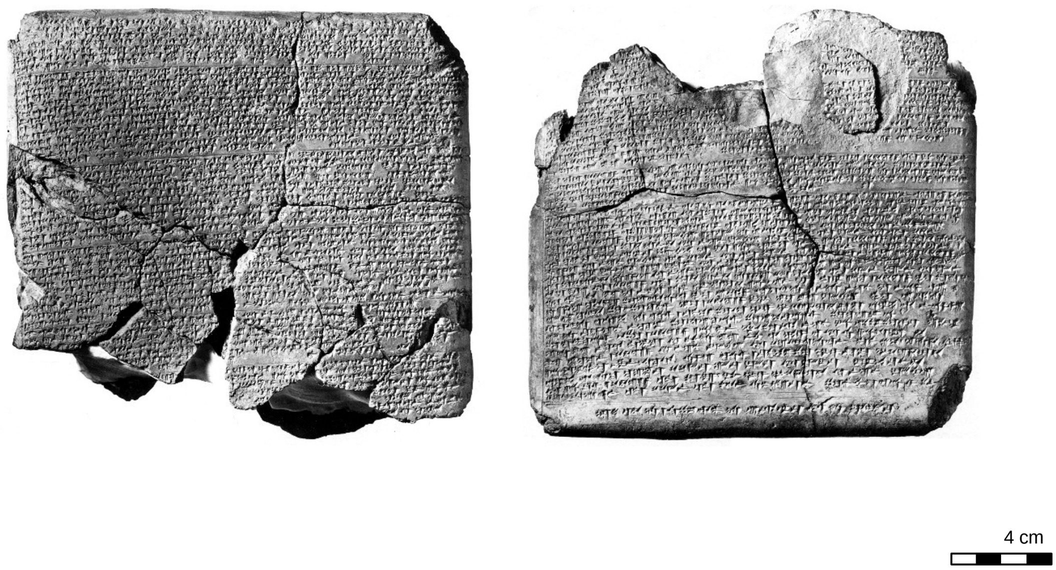


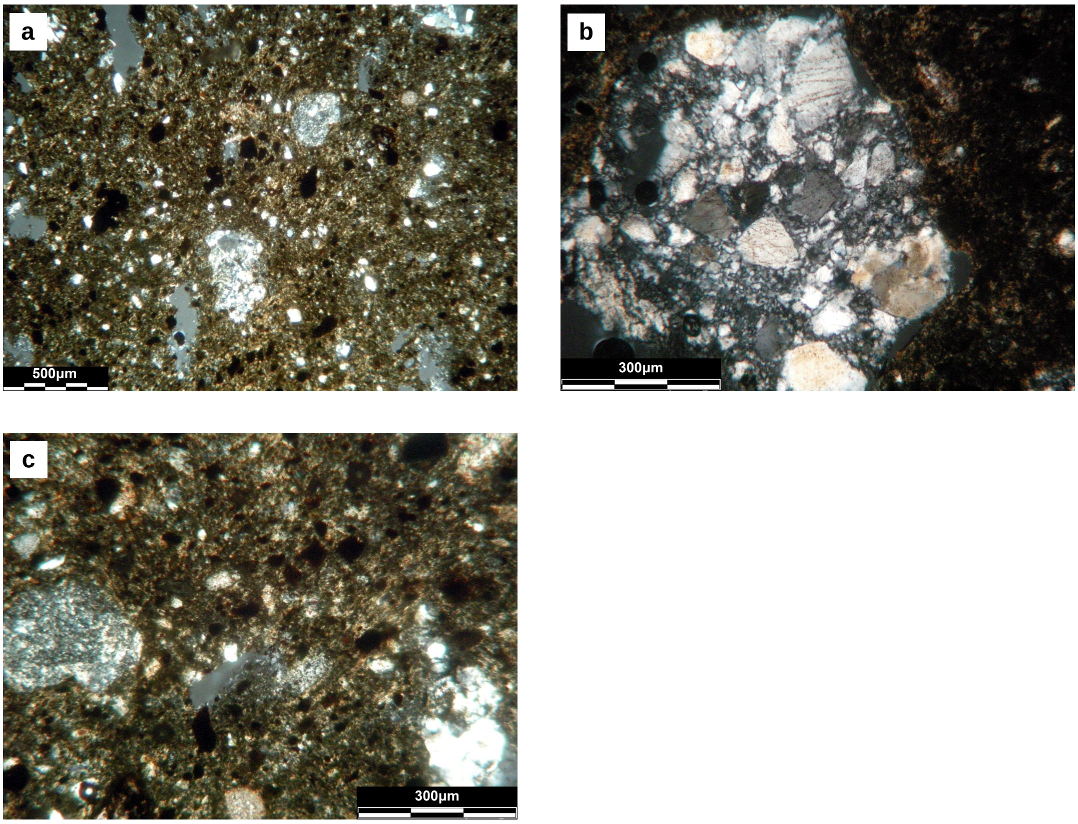
Reference (photo)

MzP BoFN00386a/387a.

Find-spot
Unknown (Boğazköy/Ḫattuša).
Sampling method
Peeling.
Reliability
High.
Matrix
Clayey, carbonatic, ochre to orange-tan in PPL and birefringent with speckled b-fabric. The silt is rich in mineral types including muscovite, quartz, calcite, serpentine and opaques.
Inclusions
Poorly sorted sand made up of angular to sub-rounded grains of basalt (up to ~600 μm), dolerite, plagioclase, olivine, limestone, quartz and serpentinized minerals.
Firing temperature
Undetermined.
Interpretation
This tablet was made with marl mixed with sand that contains an assembly of minerals coming from the edge of an ophiolitic area. Considering these features and the cumulative evidence from the remaining tablets examined here, we may conclude that it was produced in Karkemiš.

VAT 7423



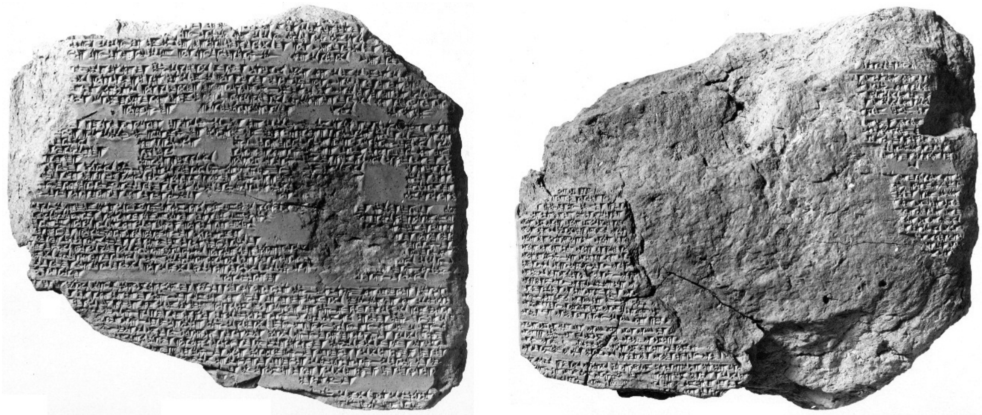


Reference (photo)

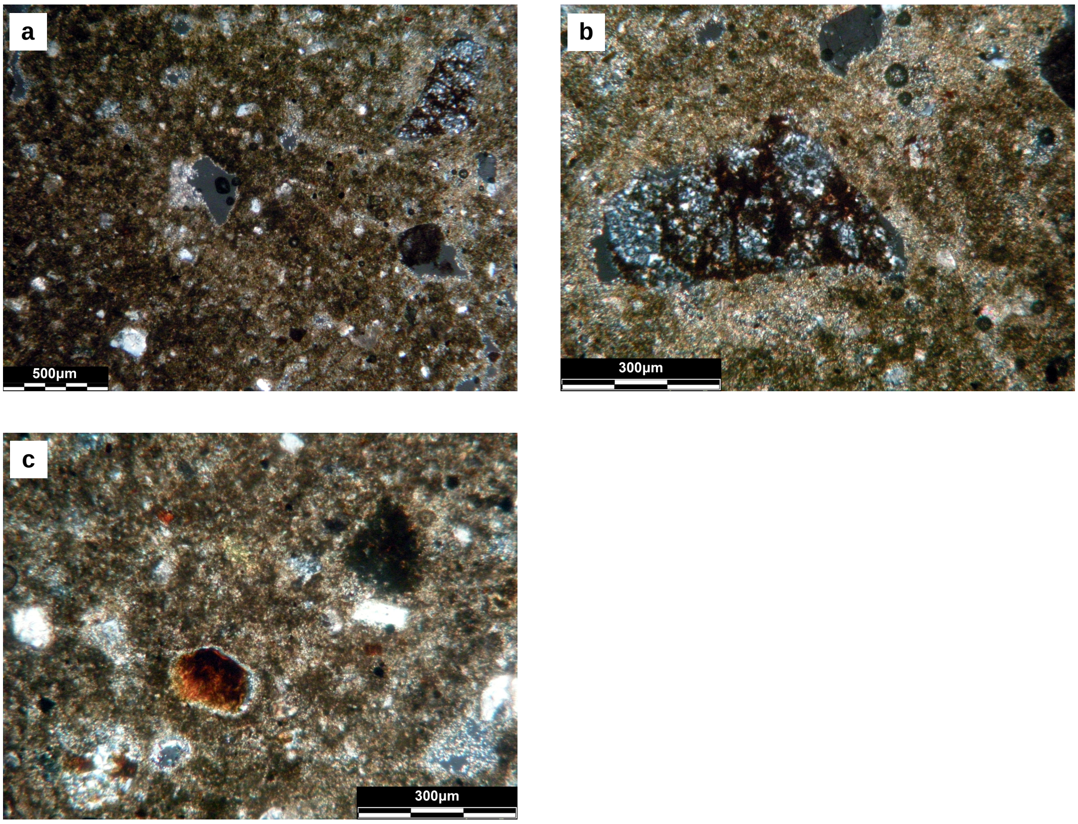
MzP BoFN01474/1475.

Find-spot
Temple I (?) (Boğazköy/Ḫattuša).
Sampling method
Peeling.
Reliability
High.
Matrix
Clayey, birefringent with striated b-fabric. The silt contains opaque minerals, biotite, quartz, calcite and plagioclase.
Inclusions
Sparsely spread sand-sized minerals including sub-rounded grains of quartz (up to ~400 μm), as well as limestone, quartzite, biotite, phyllite and iron oxides. No remains of vegetal material were traced.
Firing temperature
Undetermined.
Interpretation
Considering its petrographic traits and the comparative material previously analyzed by Goren et al. (2004: 31-32), this tablet can be readily assigned to Ḫattuša (environment dominated by low to medium grade metamorphic rocks).

VAT 13024



Scale not available

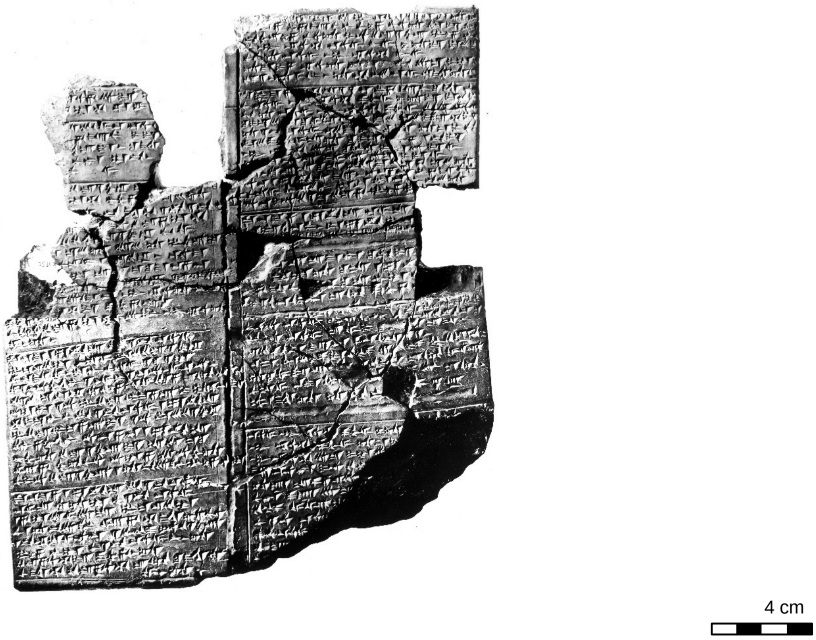


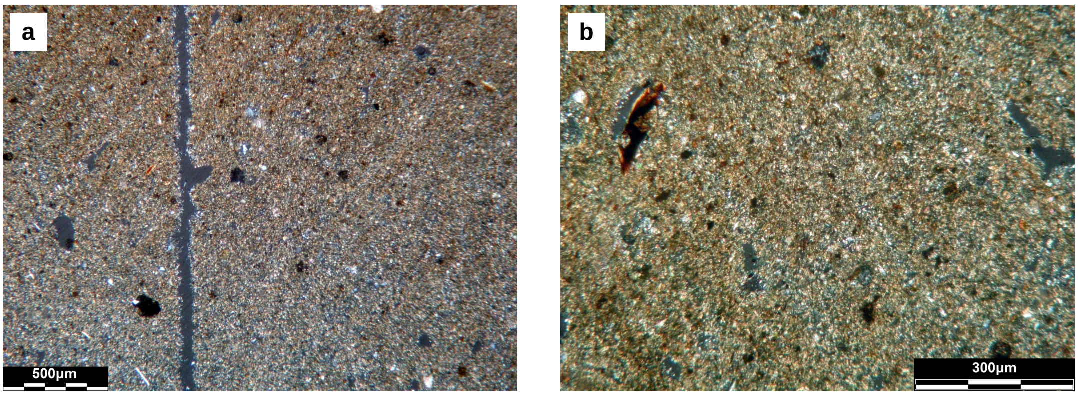
Reference (photo)

MzP BoFN01717/1718.

Find-spot
Unknown (Boğazköy/Ḫattuša).
Sampling method
Peeling.
Reliability
High.
Matrix
Carbonatic, ochre to bright tan in PPL and optically active. The silt contains quartz and mica.
Inclusions
Sand-sized minerals and rock fragments including grains of radiolarite (up to ~550 µm) stained with dark reddish-brown limonite around the *radiolaria* spheres, as well as limestone, quartz, serpentine and hornblende. No remains of vegetal material were traced.
Firing temperature
Undetermined.
Interpretation
This petrofabric presents a combination of marl, weathered ophiolitic components and radiolarian chert which can be assigned to the city of Ugarit. Other similar tablets have been described by Goren et al. (2004: 88-91) and by M. Kaufman (2008).

VAT 7421





Reference (photo)

MzP BoFN00929/930.

Find-spot

Temple I (?) (Boğazköy/Ḫattuša).

Sampling method

Peeling.

Reliability

High.

Matrix
Higly carbonatic, pale ochre in PPL and birefringent. Mica flakes are abundant within the matrix, as well as small bodies of orange clay. The fine silt contains quartz and calcite.
Inclusions
Almost devoid of non-plastic components, with very few grains of mica and plagioclase which are probably detrital in the clay matrix and not intentionally mixed.
Firing temperature
Undetermined.
Interpretation
This tablet was made with a very fine, micaceous and marly clay. It is not possible to determine its provenance, since the thin section contains mostly matrix. However, considering the INAA and pXRF data, it might be possible to describe this material as marl from the Pachna Formation in Cyprus. Other similar tablets have been described by Goren et al. (2004: 50-51).

4.
Discussion

4.1. Egyptian letters

4.1.1. Clays and pottery production in Egypt

Since cuneiform tablets were a relatively new technological device in Egypt at the time of Ramses II, the analysis of their physical properties has to rely necessarily on previous studies about pottery production. In this research field, the most commonly used raw materials have been traditionally described as “marl” clay and “Nile silt” clay (Nordström and Bourriau 1993: 157; Bourriau et al. 2000: 121).[23] Each of them has distinctive geological/compositional traits:[24]

- Marl clays

- Geological origin: shales and limestones deposited in the Upper Cretaceous/Miocene (100-38 million years ago) which can be found along the Nile valley from Esna to Cairo, and in the oases to the west of the river.[25]
- Composition: high content of calcium carbonate, with finely disseminated inclusions of iron oxides. Organic material is generally absent, but foraminifers may be detected in thin sections.
- Dry color: shades of grey.
- Firing color: pale red/pink or pale grey in an oxidizing atmosphere; they may become red above 800 ºC, and greenish-grey between 1000 and 1100 ºC.
- Melting temperature: above 1100 ºC.

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[23] As noted by Bourriau et al. (2000: 121), even though the concept of a “silt clay” is contradictory in terms of particle size, the expression is now well-established and widely employed. Other clay formations were also exploited in the past, e.g., kaolin clays found at Aswan (from the early Roman period onward).

[24] See the detailed description in Nordström and Bourriau 1993: 160-161; Bourriau et al. 2000: 121-122.

[25] Secondary deposits of washed-down and mixed sediments containing calceo-ferruginous marl can also be found along the floodplain, e.g., in Wadi Qena (Nordström and Bourriau 1993: 161).

- Nile silt clays

- Geological origin: alluvial clays deposited on the floodplain of the Nile in Egypt and Sudan between the Upper Pleistocene (starting c. 128.000 BP) and the present.
- Composition: high content of silica, with finely disseminated iron hydroxides. Considerable amounts of mica and organic matter.
- Dry color: grey to almost black.
- Firing color: dark red to dark reddish-brown or brown in an oxidizing atmosphere between 1000 and 1100 ºC.
- Melting temperature: between 1100 and 1200 ºC.

On the basis of this broad division, ceramic specialists have created a visual classification scheme for Egyptian pottery fabrics known as the "Vienna system" (Nordström and Bourriau 1993: 168-182). It consists of two main categories (Nile and marl fabrics), each of them sub-divided into five groups (A-E) according to several criteria such as relative quantity/size of inclusions, porosity, hardness, wall-thickness or firing.

4.1.2. Previously studied tablets produced in Egypt

4.1.2.1. Egyptian tablets from Tell el-Amarna

The cuneiform archive discovered at Tell el-Amarna, the ancient city of Akhetaten founded by Amenhotep IV as his new capital in Middle Egypt, consists of c. 380 clay tablets.[26] Most of them are part of the diplomatic correspondence between the Egyptian royal court and other Near Eastern states (Moran 1992; Rainey 2015), both major regional powers and minor kingdoms (in particular, the Egyptian subordinate or "vassal" rulers from Syria-Palestine). The remaining c. 30 non-epistolary documents include literary compositions, syllabaries, scribal exercises, lexical texts and lists (Izre'el 1997). Goren et al. (2004) have analyzed a substantial part of the Amarna

[26] Originally published in Knudtzon 1915; Rainey 1978. On the circumstances of their discovery, see Mynářová 2007: 13-39.

corpus from a petrographic/chemical point of view, including seven of the 11 letters written by the king of Egypt. These documents, along with two additional fragmentary letters, 15 scholarly texts and a blank tablet, have typically Egyptian fabrics and therefore represent the closest studied parallel to the correspondence from the times of Ramses II (see Table 7).

Five of the examined letters (EA 1, 14, 162, 190, 367) were made with clay from the so-called Esna shales, i.e., shales belonging to the upper Paleocene to lower Eocene Esna Formation which outcrops in several localities in Upper Egypt (Said 1990).[27] This type of clay might have been used too for EA 370 (Goren et al. 2004: 28). On the other hand, one letter written by the Egyptian king (EA 163) and one fragmentary letter (EA 382, perhaps sent from one official to another according to Moran 1992: 369) were made of Nile silt. EA 339, a fragment attributed to a Canaanite scribe on the basis of its script (Goren et al. 2004: 29), was most likely produced with the same raw material. From the group of scholarly texts of Egyptian provenance, 14 tablets were made with Esna marl (EA 340, 341, 343, 345, 346, 347, 348, 349, 350, 352+353, 354, 355, 357, 358) and one with Nile silt (EA 368). A blank tablet kept at the Ashmolean Museum (Ash. 1893 1-41: 429) was also manufactured with marl of the Esna Formation. The estimates derived from thin-section petrography indicate that most of the locally made Amarna documents were fired at ~500 ºC or below (see Table 7). This range is consistent with the TGA results of EA 190, presented in section 3.1.2.

Based on the fact that EA 163 and EA 368 were both made with Nile silt, Goren et al. (2004: 27) suggest that the former could have been a school text (i.e., a scribal epistolary exercise) rather than an actual letter sent by the king. However, it should be noted that: (a) most of the scholarly tablets were actually produced with Esna marl, and (b) there is evidence of other letters (EA 382 and probably EA 339) made with Nile silt, even though apparently they were not sent by the Egyptian ruler. In any case, the available data is insufficient to arrive at a firm conclusion.

Goren et al. (2004: 30) point out that most of the "formal Egyptian documents" of the Amarna archive (i.e., diplomatic letters produced in the royal scriptorium) were written on Esna marl. Whereas Nile silt was widely employed for ceramic production in ancient Egypt, there is only one isolated pottery assemblage made with Esna shales and it dates to the second half of the fourth millennium BC (Naqada IIIa "Canaanizing"

[27] The identification of Esna marl is based both on the petrographic/micropaleontological evidence and on the distinctive chemical composition obtained by means of ICP-AES and ICP-MS (Goren et al. 2004: 29).

vessels found in tomb U-j at Abydos; see Porat and Goren 2002). According to Goren et al. (2004: 30), the selection of this particular material by the Amarna scribes could have had functional and aesthetic reasons, since the Nile silt and marl clays normally used for pottery manufacture have certain properties which may produce visually unappealing tablets with blurred signs, "unsuitable for the high standard of the royal court" (e.g., silty textures and high contents of ferrous minerals and organic matter that fire to a dark reddish-brown or even black color in a reducing atmosphere). Considering the fact that most of the letters sent by other regional powers as well as by minor Canaanite rulers were made with low quality materials regularly employed in their area of origin for pottery manufacture, they also suggest that "in Egypt a remote source of clay was used for the production of cuneiform tablets due to the lack of brightly coloured fine textured clay near the capitals of Amarna, Thebes and Memphis" (Goren et al. 2004: 30). This general picture could be revisited and confirmed in the future with more petrographic data from the remaining Egyptian letters found at Tell el-Amarna (EA 5, 31, 99, 369) and elsewhere (e.g., KL 69.277 and KL 69.279, two tablets from an unnamed king of Egypt to a Canaanite ruler discovered in Kāmid el-Lōz; see Edzard et al. 1970).[28]

§ *Table 7*. Egyptian tablets from Tell el-Amarna analyzed by Goren et al. (2004), with estimated maximum firing temperature based on thin-section petrography.

Tablet	**Type of document**	**Type of clay**	**Estimated max. f. t.**
EA 1	Letter	Esna marl	Below 500 ºC
EA 14	Letter	Esna marl	Over 500 ºC, below 700 ºC
EA 162	Letter	Esna marl	Below 500 ºC
EA 163	Letter	Nile silt	Below 500 ºC
EA 190	Letter	Esna marl	Below 500 ºC
EA 367	Letter	Esna marl	~500 ºC
EA 370	Letter	Esna marl (?)	~500 ºC
EA 382	Letter	Nile silt	Undetermined
EA 339	Letter	Nile silt	Undetermined
EA 340	Scholarly text	Esna marl	Unfired
EA 341	Scholarly text	Esna marl	Below 500 ºC
EA 343	Scholarly text	Esna marl	Below 500 ºC
EA 345	Scholarly text	Esna marl	Undetermined

[28] The fact that the Egyptian letters addressed to foreign rulers were found in Amarna and not abroad should be taken into account for a general interpretation about their nature. Moran (1992: xvii-xviii) suggests that perhaps some of them were not sent due to oversight, or were copies filed because of their importance (or even drafts of hypothetical Akkadian translations based on Egyptian originals). However, Goren et al. (2004: 24) consider that some tablets could have been "copies of letters kept as models for future correspondence (e.g., EA 14, 31, 99, 367, 369-370)," while the rest should be regarded as broken, damaged or disqualified texts.

EA 346	Scholarly text	Esna marl	~500 ºC
EA 347	Scholarly text	Esna marl	~500 ºC or below
EA 348	Scholarly text	Esna marl	Below 500 ºC
EA 349	Scholarly text	Esna marl	~700 ºC (?)
EA 350	Scholarly text	Esna marl	~500-600 ºC
EA 352+353	Scholarly text	Esna marl	~500 ºC
EA 354	Scholarly text	Esna marl	~500 ºC
EA 355	Scholarly text	Esna marl	~500 ºC
EA 357	Scholarly text	Esna marl	Below 500 ºC
EA 358	Scholarly text	Esna marl	Below 500 ºC
EA 368	Scholarly text	Nile silt	Undetermined
Ash. 1893 1-41: 429	Blank tablet	Esna marl	Undetermined

4.1.2.2. Jerusalem 2

Two very small fragments of cuneiform tablets were recently discovered in the Ophel excavations at Jerusalem (Mazar et al. 2010; 2014). Both have been dated to the Late Bronze Age, even tough they were found in a later Iron Age IIA context.[29] One of them, referred to as Jerusalem 2, is a tiny flake (9.5×9×5 mm) which contains parts of five cuneiform signs. This object offers some interesting data for our study in terms of mineralogical and chemical composition (Mazar et al. 2014: 131-134); however, it should be kept in mind that the reliability of the published results is considerably affected by sampling constraints: on the one hand, the size of the sample collected for thin-section petrography was insufficient to characterize the coarser non-plastic inclusions; on the other hand, only two pXRF measurements could be performed (instead of three or four, as was the case in previous studies of clay tablets; see Goren et al. 2011).

According to Y. Goren, the clay of this tablet is not local and "may be more in keeping with the typical Egyptian Nile sediments" (Mazar et al. 2014: 133). His suggestion is supported by the fact that the elemental composition of Jerusalem 2, as determined by pXRF, presents a high correlation with the Egyptian letters from the times of Ramses II examined here (see section 2.4.1).

[29] References to Jerusalem during the Late Bronze Age are rather scant in the epigraphic record, but we know that in the fourteenth century BC it was ruled by a certain Abdi-Ḫeba, who sent at least six letters to the king of Egypt (EA 285-290).

4.1.3. Summary: manufacture of clay tablets in Egypt

The fourteenth-century tablets found at Tell el-Amarna constitute the first recorded attempt to develop a local cuneiform tradition in Egypt. A fragment of a letter and a fragment of a seal impression dating to the Middle Bronze Age were discovered in Tell el-Dabʿa/Avaris, the capital of the Hyksos, but they are probably of foreign origin (Bietak et al. 2009; van Koppen and Lehmann 2012-2013). Considering the limited number of locally produced tablets available to us, it is difficult to assess the channels of transmission by which cuneiform writing was imported to Egypt. However, external influences from the Hittite and Babylonian milieus have been acknowledged on the basis of paleographic affinities and the content of the scribal curriculum (Beckman 1983; Wilhelm 1984; Artzi 1992; Izre'el 1997: 9-13; Mynářová 2015); moreover, three scholarly texts have a Mesopotamian fabric (EA 342, 344, 356; see Goren et al. 2004: 77-78, 82-83).[30] As for the raw materials, a few of the Egyptian tablets found at Amarna were produced with Nile silt, which was normally employed for ceramic manufacture, but most of them were made with Esna marl. This type of clay was not available in the immediate vicinity of Tell el-Amarna and Thebes and therefore had to be obtained from a rather distant location. The choice of Esna marl, quite atypical in the Egyptian tradition of pottery production, might be related to the fact that its texture is finer and its color brighter than Nile silt clays, resulting in better crafted and more readable tablets.[31] Most of them were probably fired at around 500 ºC or below (and perhaps even not fired at all in some cases), whereas the maximum firing temperature of the Mesopotamian and Syro-Anatolian documents studied by Goren et al. (2004: 319) is generally in the range of 700-800 ºC.

The Amarna tablets written in Egypt represent the only direct precedent to the cuneiform corpus from the times of Ramses II. In her comparative study of these two groups of texts, J. Mynářová notes that there are significant structural differences between them (especially regarding the standardized opening passages) and considers that it is possible to speak about "two distinct systems or traditions developed and used in the area of the ancient Near East including Egypt over the period of the 14th and 13th centuries B.C.E., i.e. the 'Amarna' and the 'Ramesside' tradition respectively" (2009:

[30] According to Goren et al. (2004: 84), the ductus of EA 368 indicates that this tablet may have been written by a scribe from Assyria or Mittanni.

[31] Perhaps this was also an attempt to emulate the fine fabric characteristic of some Babylonian and Mittannian tablets (Goren et al. 2004: 319).

117). The results of our analysis confirm a clear difference between both sets of tablets in terms of raw materials and maximum firing temperature. All the thirteenth-century fragments from Ḫattuša analyzed in this study have a similar fabric, made with marly clay, which may be identified as belonging to the so-called Marl D category of the Vienna system (or as a mixture of Nile silt and marly clays). Their maximum firing temperature, as determined by both petrography and TGA, is probably in the range of 700-900 ºC.

Marl D is the most common fabric for New Kingdom amphorae in Egypt (Aston 2004: 184); according to P. McGovern (1997: 76), local calcareous marls are well-suited for this kind of vessels because of their strength and non-permeability, in contrast to Nile alluvial clays. The same properties could have been taken into consideration by the scribes who produced cuneiform tablets, which also had to be transported across long distances. Based on the examination of ceramic vessels from Malkata by NAA, McGovern (1997) postulated a Theban origin for this type of clay. However, some of his methodological assumptions have been criticized by other scholars (Aston 2004: 186; Bourriau 2004: 86-88), in particular concerning the suitability of his control group. D. Aston considers that the distribution patterns of Marl D pottery actually favor a northern provenance: "With the exception of amphorae, which are found throughout Egypt, the greatest number of shapes, and the largest percentage of Marl D in relation to other Marl clays is to be found in the Eastern Delta and the Memphite/Fayoum region, which strongly implies, as has previously been argued by ceramicists, that the origin of this clay is to be sought in the north" (2004: 186). Similarly, J. Bourriau (2004: 88) suggests that a source in the Memphite region (close to the Delta and Fayoum vineyards) seems most likely. Another NAA study of sherds from different sites across Egypt by Bourriau et al. (2006) shows, as already pointed out by McGovern (1997: 79), that Marl D has a distinctive chemical fingerprint in relation to other New Kingdom marly clays; the results of this analysis also support the idea of a single source region.

It would be logical to assume that the Egyptian letters found at Ḫattuša were sent from Qantir/Pi-Ramses, the seat of Ramses II's court, especially considering the fact that a cuneiform fragment belonging to the Egyptian-Hittite correspondence was recently discovered there (Pusch and Jakob 2003). However, other possible places of origin (such as Memphis) should not be disregarded a priori. Even if Marl D clay was extracted in the vicinity of Memphis or Fayoum, transporting the raw materials along the Pelusiac branch of the Nile down to Pi-Ramses would have been an effective logistic solution. If that were the case, the practice of collecting clay from a relatively remote location would be similar to the supply procedure suggested by Goren et al. (2004: 30) for the Amarna tablets made with Esna marl. Such a mechanism could be considered impractical from a cost-effectiveness perspective, since probably other types of clay were more readily available. However, it should be kept in mind that in Egypt cuneiform tablets were relatively atypical and exclusive technological devices, mostly employed for diplomatic communication (at least within the corpus available to us, which of course is biased by ancient storage practices, post-depositional processes and archaeological chance). In a political system were prestige was constantly under negotiation (Liverani 2001), it is logical to expect high quality standards for the physical support of the messages sent by the king and his entourage. Moreover, as noted by M. Feldman, tablets could have an intrinsic value similar to that of luxury items: “The insistence by the ancient correspondents that tablets be read, listened to, exchanged, and stored affirms the importance of these artifacts as material presence in a way akin to the luxury goods (…) We should therefore take seriously the central importance of the letters’ materiality and presence in Late Bronze Age diplomatic interactions” (2006: 145). These objects were a physical proof of the political, legal and symbolic relationships established among Near Eastern rulers, both past and present.

The maximum firing temperature of the Egyptian letters discovered in Ḫattuša is similar to that of the Babylonian, Hittite, Mittannian and Ugaritic tablets studied by Goren et al. (2004), perhaps as the result of an intentional process of emulation.[32] This range also matches the estimates suggested by Hope (1977: 67), on the basis of refiring experiments, for the Malkata Marl D amphorae (800-850 ºC) and may point to an analogous treatment of the same type of clay. The fragment known as Jerusalem 2 might have been made with a similar material, according to its petrographic traits and its elemental composition as determined by pXRF, but the available evidence is not conclusive. Further research on other Egyptian documents found at Amarna, Ḫattuša and elsewhere (e.g., Kāmid el-Lōz or Ugarit) that remain unexamined could enhance our understanding of the local tradition(s) of tablet manufacture.

[32] According to Goren et al., the act of firing was carried out “to ensure that the tablets would last for long and to prevent any possibility of forgery of details in the text” (2004: 319).

4.2. Hittite diplomatic texts and letters

4.2.1. Four documents related to Karkemiš

The tablets examined in this section were made of a similar type of clay. BLMJ 1143, VAT 7420 and VAT 13008 contain sand of basalt, dolerite, quartz and other minerals. BLMJ 1143 shows also intentionally added calcite, which is visible to the naked eye. Goren et al. (2004: 314) have described another tablet from Palestine that contains the same tempering material. Although calcite was employed in the production of cooking pots to increase the thermal shock resistance of the clay body and to reduce its porosity, these properties are irrelevant for cuneiform tablets. Thus, Goren et al. suggest as a possible explanation that perhaps the scribe "took some ready-mixed clay with inclusions from the lump of the local potter who had prepared it for the production of cooking vessels" (2004: 314).

Considering that: (a) these documents share common petrographic traits which can be related to the geological environment of Karkemiš and its surroundings, and (b) AO 19.955 and BLMJ 1143 were sent by an unnamed ruler of this kingdom, whereas VAT 7420 and VAT 13008 are connected with Piyassili/Šarri-Kušuḫ, then we can conclude that all of them were produced in Karkemiš. The chemical composition of VAT 7420 and VAT 13008 show some similar patterns, which can also be linked to VAT 7679, another tablet probably made in the Upper Euphrates region. These values could be taken as the basis of a pXRF "Karkemiš/Upper Euphrates cluster" in future studies.

Whereas AO 19.955 and BLMJ 1143 were sent to Ugarit and Emar, respectively, VAT 7420 and VAT 13008 were transported to Ḫattuša for some unknown reason. In the case of VAT 13008, there is a reference at the end of the document suggesting that the original text was engraved upon a golden tablet (Singer 2001: 635); therefore, the present fragment should be regarded as a copy or a draft. Further scientific research on other tablets from Karkemiš may improve our understanding of the local petrofabrics.

4.2.2. Two fragments of the agreement between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni (VAT 7423 and VAT 13024)

VAT 7423 has a typical Ḫattuša fabric, and it is also similar to other clay documents from this city in terms of chemical composition. The tablet contains Šattiwaza's sworn statement, which was probably drafted by the chancellery of Ḫatti, and its paleographic features reveal that the text was copied by a Hittite scribe. Thus, the fact that it was produced in Ḫattuša comes as no surprise.

VAT 13024, on the other hand, is a copy of Šuppiluliuma's version of the agreement made with clay from Ugarit. It should probably be attributed to a Mittanian scribe, but it remains unclear why it was copied in northern Syria. One possibility is that the diplomatic conference between Šuppiluliuma and Šattiwaza took place at Ugarit. This city may have been regarded as a half-way meeting point between Ḫattuša and Waššukkanni,[33] the capital of Mittanni, at least within a hypothetical itinerary via the pass of the Cilician Gates (Figure 12).[34]

Another possible explanation to understand the presence of a Mittanian "diplomatic mission" in Ugarit is the fact that this city was under the sphere of influence of the king of Karkemiš, whose alliance with Šattiwaza was explicitly reinforced in the agreement between the latter and Šuppiluliuma (as a matter of fact, there is special section of the treaty entirely devoted to the mutual relations between Šattiwaza and Piyassili/Šarri-Kušuḫ; see KBo 1.1 rev. 22-34). However, these are highly speculative suggestions; further scientific research on the remaining fragments of the agreement may shed more light on the circumstances of its composition.

[33] Identified by some scholars with Tell Feḫeriye (see Goren et al. 2004: 38-39, 43-44; Wilhelm 2013).
[34] For the Hittites, this was one of the main crossings from the Anatolian plateau into the Amuq plain and Syria (Jasink 1991; Seeher 2011: 384; Weeden 2014: 34).

§ **Figure 12.** Hypothetical itinerary to Ugarit from Ḫattuša (via the pass of the Cilician Gates) and Waššukkanni.

4.2.3. A fragment from the "Text A" of the treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru (VAT 7421)

It is not possible to assess the provenance of VAT 7421 only on the basis of the petrographic features from the examined thin section, since this sample consists mainly of a fine, micaceous and marly clay. However, considering the pXRF and INAA data, it might be possible to identify it as marl from the Miocene Pachna Formation of Cyprus. This material was employed to make three of the Alašiya letters found at Tell el-Amarna (EA 33, 34, 38; Goren et al. 2004: 48-75), as well as one fragment of a docket (VAT 6184; Goren et al. 2011: 686-687).

Such a possibility is not unreasonable from a historical and geographic point of view. The most significant piece of evidence in this respect comes from KBo 12.38, which contains a copy of an inscription that commemorates the conquest of Alašiya by Tudḫaliya IV: "[(The king of Alašiya)] with his wives, his children, [and his …] I seized; all the goods, [with silver, g]old, and all the captured people I [re]moved and [brought] them home to Ḫattuša. The country of Alašiya, however, I [enslaved] and made tributary on the spot" (KBo 12.38 I, 3-8, after Güterbock 1967). Another relevant text is KBo 12.39, a treaty between Ḫatti and Alašiya attributed to Tudḫaliya or his son Šuppiluliuma II (see most recently de Martino 2007; Vigo 2008).[35]

Since VAT 7421 is a draft of the agreement, we can infer that it was composed before or during the diplomatic meeting between both kings. Although this conference could have taken place in Cyprus, located less than 200 km away from the coast of Amurru, it is also possible that the Hittite ruler was there for a different purpose, or just in a scale in his journey to meet Šaušgamuwa (see Figure 13).[36]

§ **Figure 13.** Hypothetical itinerary from Ḫatti to Amurru via Alašiya.

[35] For an up-to-date overview of the relations between Ḫatti and Alašiya, see de Martino 2008.
[36] It should be noted that the letters from Amurru of the entire period predating this treaty were examined by Goren et al. (2003a; 2004: 101-125). VAT 7421 does not share any common petrographic traits with the documents from the main centers of this region, including Ṣumur, Tunip and Irqata.

5.
Conclusion

Following a recent trend focused on the materiality of ancient texts, we have studied the provenance and some of the technological features of 13 cuneiform tablets/fragments. Since this set of documents was rather heterogeneous, the research problems were formulated on a case by case basis considering different historical, archaeological and material aspects. A summary of the most significant findings of each case study is presented here, followed by a more general conclusion concerning methodological issues related to the analysis of cuneiform tablets.

a) Egyptian letters

Seven fragments of letters sent from Egypt to Ḫatti in the thirteenth century BC were examined by thin-section petrography and thermogravimetric analysis. The results were compared with other documents manufactured in Egypt, especially those from the Amarna archive. Both groups show notorious differences in terms of raw materials and manufacture technology. Whereas the Amarna tablets were produced either with Esna marl or Nile silt and fired at ~500 ºC or below, the fragments from Ḫattuša have a petrofabric similar to the "Marl D" group from the Vienna system (marly clay mixed with calcareous and quartz sand) and their maximum firing temperature is in the range of ~700-900 ºC (as indicated by different mineralogical transformations identified in the thin sections [e.g., the alteration of hornblende into oxyhornblende, the decalcination of calcite and the high isotropism of the matrix] and by the TGA results, which were interpreted considering several reactions connected with post-depositional processes such as the elimination of moisture water and non-refractory components, the dehydroxylation of clay minerals and the decomposition of secondary calcite).

Thus, the material traits of each category of documents seem to confirm the idea of two different epistolary traditions suggested by Mynářová. This difference may also reflect an internal evolution of the use of cuneiform writing in Egypt. Local scribes had to reproduce and adapt not only the linguistic parameters which had been employed during thousands of years in Mesopotamia, but also the physical support for cuneiform texts. Moreover, it should be taken into account that tablets were the material embodiment of diplomatic communication among kings. Therefore, the extraction and transportation of the clay to the place of manufacture (perhaps Qantir/Pi-Ramses) and the production process should also be understood in the light of the socio-political context of these artifacts, rather than only from a cost-effectiveness point of view.

The fragments VAT 6169+7669 and VAT 6172 were previously assumed to belong to the same tablet, even though they do not join directly. However, several divergent features (presence of foraminifers, type/sorting of accessory minerals, isotropism of the matrix, estimated maximum firing temperature and chemical composition) suggest that this assumption is erroneous.

b) Tablets from Karkemiš

Four documents connected with the court of Karkemiš were examined in order to compare their petrofabrics. Two letters sent from this city to Ugarit and Emar were taken as reference samples, and another two diplomatic documents related to Piyassili/Šarri-Kušuḫ were added to the corpus. All these tablets share common petrographic traits which can be associated with the geological environment of the Upper Euphrates area in general, and of Karkemiš in particular (marl mixed with sand of basalt, dolerite, limestone, quartz and serpentinized minerals). The addition of crushed calcite as temper in BLMJ 1143 represents an interesting trait in terms of manufacture technology, with only one known parallel from Palestine.

As a result of the present study, we have now a reference petrofabric from Karkemiš which can be tested against other documents from this city found in Ugarit and elsewhere. Moreover, the pXRF elemental concentration patterns of VAT 7420 and VAT 13008 may represent the basis of a "Karkemiš cluster" for future research.

c) Diplomatic agreement between Šuppiluliuma I of Ḫatti and Šattiwaza of Mittanni

This case study offers an interesting example of how the combination of archaeological, philological, paleographic and petrographic/chemical data can produce otherwise unexpected correlations. VAT 7423 is a copy of the agreement presented from the point of view of Šattiwaza; however, it has been suggested on the basis of philological and historical criteria that the text was actually composed by the chancellery of Ḫatti. Its paleographic traits suggest that it was copied by a Hittite scribe, and its petrofabric shows the typical features observed in other tablets made in Ḫattuša (identical type of clay, with sand of quartz, limestone, quartzite, biotite and phyllite). The chemical composition of this fragment, as determined by pXRF, is also consistent with the Ḫattuša cluster. On the other hand, VAT 13024 is a copy of Šuppiluliuma's version found in Ḫattuša, produced with clay from Ugarit (marl with weathered ophiolitic components and radiolarian chert) and apparently written down by a scribe from Mittanni, according to its particular ductus.

Thus, we are dealing with a tablet containing the Mittannian perspective of the diplomatic agreement but composed by the Hittite chancellery and copied by a Hittite scribe in Ḫattuša, and another document with the Hittite version copied by a Mittannian scribe in Ugarit. More than one possible explanation can be suggested to recreate the circumstances of the composition of VAT 13024, e.g., a diplomatic conference in northern Syria or a journey for administrative purposes. In any case, it should be emphasized that these complex relations can only be disclosed with an interdisciplinary approach to the examined documents.

d) Treaty between Tudḫaliya IV of Ḫatti and Šaušgamuwa of Amurru

VAT 7421 is one of the two available copies of this agreement, but its petrographic features (fine, micaceous and marly clay) are insufficient to determine its provenance. However the INAA and pXRF data may point to a Cypriote origin. If that were the case, the main raw material of this petrofabric could be identified as Pachna marl, already observed in other tablets sent from Cyprus/Alašiya to Egypt. Moreover, certain textual features of VAT 7421 show that it was a draft, and therefore that it was most probably composed before the agreement was concluded. This hypothetical scenario could be explained in the context of Tudḫaliya's military campaigns in the island, as well as by the geographic proximity to Amurru.

A few conclusive remarks should be made concerning the analytical methods applied in this dissertation. Despite its destructive nature, thin-section petrography is an unavoidable method to study singular clay artifacts produced under unique conditions and with varying raw materials (which are not necessarily the same as those employed by local potters, e.g., the use of Esna marl in Egypt). This method does not require large reference databases and can yield valuable results in a rather independent manner. Nevertheless, it is evident that the combination of physical and chemical methods enhances significantly the range of possible sources of a given object. Once a strong reference group is defined with ceramic petrography and/or other fully quantitative chemical methods (e.g., INAA or ICP-MS), non-destructive techniques such as pXRF can be employed to study new tablets that cannot be sampled.

The estimation of the maximum firing temperature of archaeological ceramics is a rather complex issue, since the changes that take place in these materials during the firing process are also conditioned by the soaking time and the type of atmosphere. Moreover, the use of thermal analysis in general and of TGA in particular is not devoid of constraints. Some of the commonly held assumptions about the correlation between mass loss and firing temperature are not always true, since certain reactions produced after thousands of years of storage under ambient conditions produce considerable transformations in the composition of the clay (e.g., rehydroxylation and formation of secondary calcite). However, other complementary methods such as thin-section petrography can be employed to compare the data and test the validity of the obtained results.

It is not uncommon in the field of archaeometry to encounter merely descriptive and largely irrelevant analyses of ancient materials. In the course of this dissertation we have intended to formulate meaningful research questions based on a holistic approach toward cuneiform tablets. Our results show that the interpretation of data greatly benefits from an integration of the different analytic levels, including text, context and physico-chemical features. Less than 500 clay tablets, out of hundreds of thousands, have been examined with scientific techniques until now. Further interdisciplinary archaeometric research will certainly improve our understanding of these artifacts and, by extension, of the ancient societies that produced them.

6.
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