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The Metal Tablet from Boğazköy-Hattuša: First Archaeometric Impressions*

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Unearthed by chance in 1986 during restoration work on the interior facade of the Hittite city wall at the Yerkapı area in Hattuša (modern Boğazköy, Turkey), the treaty between the Hittite Great King Tuthaliya IV and Kurunta, King of Tarhuntašša, certainly counts among the most significant discoveries of the Hittite period in the past few decades.[1] This legal document of the thirteenth century B.C. represents the only metal tablet preserved from the entire Hittite world, and, thanks to its pristine state of preservation and the considerable length of its inscription, it is of utmost importance for reconstructing the genealogy and political history of the later Hittite empire.[2] The tablet (also known as the Bronze Tablet) was found in a pit underneath the street pavement, about 35 m west of the Sphinx Gate, most probably deliberately placed there after the removal of its attached clay bullae which thereby rendered it legally invalid.[3] Its dimensions are 35 × 24 cm, with a maximum thickness of 0.8 to 1.0 cm and weighing 5 kg. The maximum length of the attached chains is 31 cm each.[4] The tablet is inscribed in two columns of cuneiform on both sides, separated by two parallel vertical incisions, but with the lines of text partially disregarding the column borders. It is on permanent display in the Late Bronze Age/Hittite section of the Museum of Anatolian Civilizations in Ankara.

Although a scientific analysis of this unique document's metallurgical composition was anticipated by

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[1]H. Otten, *Die Bronzetafel aus Boğazköy: Ein Staatsvertrag Tuthalijas IV.* Studien zu den Boğazköy-Texten, Beih. 1 (Wiesbaden, 1988) and *Die 1986 in Boğazköy gefundene Bronzetafel: Zwei Vorträge*. Innsbrucker Beiträge zur Sprachwissenschaft, Vorträge und kleinere Schriften 42 (Innsbruck, 1989); P. Neve, *Hattuša: Stadt der Tempel und Götter; Neue Ausgrabungen in der Hauptstadt der Hethiter* (Mainz, 1992), 19–23.

[2]The philological-linguistic dimension of the tablet and its implications for later Hittite imperial history are already extensively discussed in Otten, *Die Bronzetafel aus Boğazköy.*

[3]Neve, *Hattuša: Stadt der Tempel und Götter*, 19.

[4]Otten, *Bronzetafel aus Boğazköy*, 1 where the data concur with the museum inventory registry with one exception: the maximum thickness of the tablet is recorded as 0.8 cm in the original entry without qualification.

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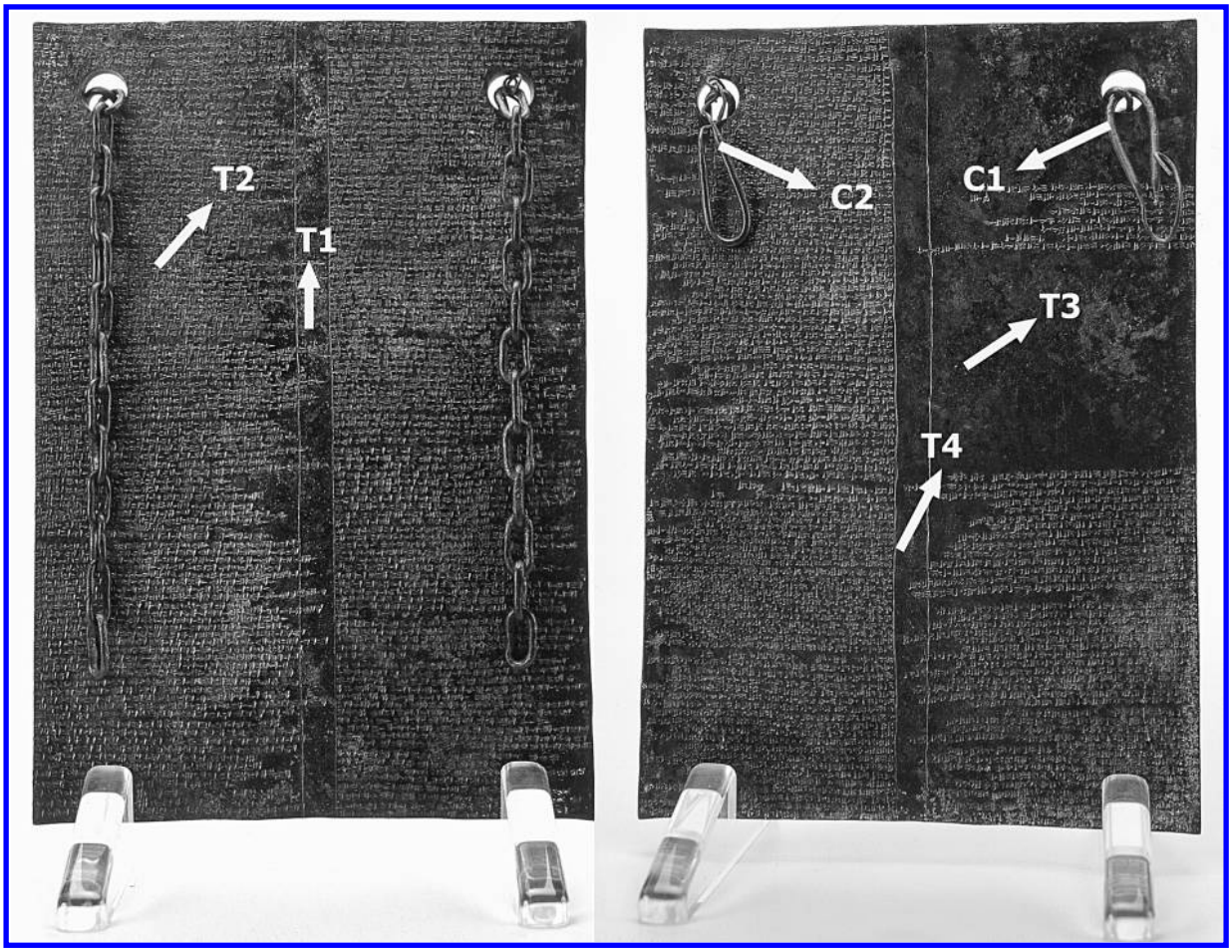

Figure 1—Front and back of the metal tablet from Hattuša, with the XRF measurement areas indicated.

Heinrich Otten in his monographic study, it has remained unrealized.[5] This is indeed unfortunate since our knowledge of Hittite metal production, consumption, and alloying techniques is largely based on textual evidence, not on the results of metallographic analysis. A large discrepancy still exists between the considerable number of philological studies dedicated to the Hittite vocabulary for metals, their values, their function in both secular and ritual context for workshops and alloying practices,[6] and the small number of spectrographic analyses actually carried out on Hittite metal artifacts.[7] That said, establishing a profitable correlation of philological and archaeometric data so as to plot the results of metallographic analyses against the evidence from written records hardly seems possible at the current time, as desirable as it may be. More to the point, extraordinary and prestigious

[5]Otten, *Bronzetafel aus Boğazköy*, 1, n. 2.

[6]A. Kempinski and S. Košak, "Hittite Metal 'Inventories' and Their Ecomonic Implications," *Tel Aviv* 4 (1977): 87–93; J. Siegelová, "Anwendung von Kupfer und Bronze in Anatolien anhand der hethitischen Texte," in *Handwerk und Technologie im alten Orient: Ein Beitrag zur Geschichte der Technik im Altertum*, ed. R.-B. Wartke, Internationale Tagung Berlin, 12.–15. März 1991 (Mainz, 1994), 119–24; E. Floreano, "The Role of Silver in the Domestic Economic System of the Hittite Empire," *Altorientalische Forschungen* 28 (2001): 209–35; J. Siegelová, "Metals in Hittite Records," in *Ancient Mining and Metallurgy in Turkey and the Eastern Mediterranean*, ed. Ü. Yalçın, H. Özbal, and A. G. Paşamehmetoğlu (Ankara, 2008), 43–56.

[7]The metallographic analyses carried out so far on second-millennium Hittite objects are limited to a handful of data obtained in the first half of the twentieth century and compiled by H.-G. Bachmann in his 1984 publication "Düsenrohre und Gebläsetöpfe: Keramikfunde aus Metallverarbeitungswerkstätten," in *Boğazköy VI: Funde aus den Grabungen bis 1979*, ed. K. Bittel et al. (Berlin, 1984), 107–15.

objects such as the Kurunta treaty are likely to have received special and perhaps unexpected technological treatment. Therefore, a basic archaeometrical analysis targeting the object's elemental composition promises to enhance our knowledge of the archaeological dimension of Hittite metalwork.

Thanks to collaboration between the Museum of Anatolian Civilizations at Ankara and the Sarayköy Nuclear Research and Training Centre, this important task has been accomplished with the help of a portable, energy-dispersive x-ray fluorescence device (P-XRF), which allowed nondestructive surface scanning with a 300 µm Peltier-cooled PIN detector in order to reveal the object's outer chemical composition. For calibration, the AISI standard was used. Four different areas of the tablet's metallic surface (T1–T4) with no or only minimal patina traces were selected for x-ray penetration. In addition, two sections of the attached chains (C1–C2) were scanned with the same device (see fig. 1). The results obtained from the nondestructive element analysis are given in table 1.

Table 1—Element analysis chart showing alloys in weight percentage.

	Copper	Iron	Lead	Cobalt	Nickel	Zinc	Tin
T1	63.34	.33	.11				36.22
T2	62.58	1.12					36.29
T3	68.36						31.64
T4	61.18	.99					37.83
C1	89.82	2.12		.90	7.17		
C2	89.89	2.69		.93	6.49		

The Tablet

What immediately attracts attention are the extremely high values of tin (Sn), ranging from 31.64 (T3) to 37.83 (T4) percent. High tin content is not unknown in the ancient Near East. It is already attested in Early Bronze Age contexts where the analysis of crucible fragments from Tell al-Judaidah used for processing bronze, dated to around 3000–2900 B.C., yielded up to 37 percent tin.[8]

However, the addition of tin in such high amounts has no positive effect on the smelting process or the physical qualities of the finished object, since amounts of up to 5 percent are considered more than sufficient to create bronze with technical specifications ideal for casting and durability.[9] The reason for this enormous percentage of tin must be to manipulate the appearance of the metal as it gives the object a light silverish color and sheen. This can be achieved by adding large amounts of alloying agents like tin, or even by coating the artifact with a thin layer of tin, a technique that should also be considered a possibility for the Bronze Tablet. Altering the color of a metal object by adding higher amounts of tin or arsenic is well attested in New World metallurgy[10] and is likewise suspected in the case of metal artifacts associated with some later Early Bronze Age or Hattian communities in Central Anatolia.[11] Of particular interest in this context is the recent identification of the Hittite word for tin (*arzili-*), a discovery of utmost importance for philological studies focusing on the manifold aspects of Hittite metalwork.[12] By re-reading certain Hittite texts with the new interpretation, it seems that tin was in fact used to coat objects of sacrificial value, including statues and water basins.[13] The purpose of this coating procedure was not only to protect or seal the object but also to enhance the ritual significance of such

[8]A. Adriaens et al., "Tin Bronze Metallurgy in Transformation: Analytical Investigation of Crucible Fragments from Tell al-Judaidah, Amuq (Turkey) Dating to circa 3000–2900 BC," in *Archaeometry 98. Proceedings of the 31st Symposium Budapest, April 26–May 3 1998*, ed. E. Jerem and K. T. Biro, BAR International Series 1043 (II) (Oxford, 2002), 273–77; these data coincide with not yet published results from LBA Alalakh (Tell Atchana) crucible residues, which likewise revealed very high tin values (information kindly provided by the anonymous referees).

[9]E. Pernicka, "Gewinnung und Verbreitung der Metalle in prähistorischer Zeit," *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz* 37 (1990): 47–56. The traces of iron, ranging from 0.33 to 1.12 percent, are either contaminations of the copper ore or are related to the chemical matrix of the surrounding soil where the tablet was buried.

[10]D. Hosler, "Sound, Colour and Meaning in the Metallurgy of Ancient West Mexico," *World Archaeology* 27 (1995): 100–115; H. Lechtman, "Arsenic Bronze: Dirty Copper or Chosen Alloy? A View from the Americas," *Journal of Field Archaeology* 23 (1996): 506.

[11]T. Zimmermann, "Anatolia as a Bridge from North to South? Recent Research in the Hatti Heartland," *Anatolian Studies* 57 (2007): 70–71; T. Zimmermann and T. Yıldırım, "Three Best to Have in Plenty—Rethinking Central Anatolian Early Bronze Age Alloying Traditions," in *Ancient Mining in Turkey and the Eastern Mediterranean*, ed. Ü. Yalçın, H. Özbal, and A. G. Paşamehmetoğlu (Ankara, 2008), 87–97.

[12]O. Soysal, "Das hethitische Wort für 'Zinn'," *Historische Sprachforschung* 119 (2006): 109–16.

[13]Ibid., 111–12.

items using rare and valuable substances like tin, still counted as one of the most sought-after raw materials of the second millennium B.C.[14] It is therefore highly probable that the treaty between Tudhaliya IV and Kurunta was considered not only to be a document of great political significance but one of profound ritual importance as well, and consequently it was coated or alloyed with precious tin. Another famous and prestigious legal document, the original Hittite version of the Kadesh peace treaty between Ramses II and Hattušili III, was written on a silver tablet, unfortunately no longer extant.[15] So the enrichment of copper with large amounts of tin may have been an attempt to impart a light, whitish sheen reminiscent of silver.

The Chains

Two additional XRF-scans (C1–C2) were carried out on the chains to reveal their metallurgic composition. The results are somewhat puzzling. First, an entirely different alloy than the one used to cast the tablet was applied, with no measurable amount of tin added to the smelted copper (Cu).[16] The presence of nickel (Ni) in amounts of up to 7.17 percent is equally surprising, but it may be the result of natural contamination of the copper ore, since nickel added in such quantities has neither a positive effect on the casting process nor does it alter the object's color, for which much higher amounts of nickel (up to 40 percent) would be necessary.[17] Since nickel as an independent alloy is believed to be unknown to metalsmiths before the Middle Ages,[18] an accidental Cu-Ni alloy, as suggested here, is likely to be associated with mineral deposits in so-called ophiolithic rocks extant in considerable quantities in the Taurus region, northeastern Anatolia, Cyprus, and Oman.[19] However, natural alloys of this type generally also contain a certain amount of arsenic (As) contamination, forming Cu-As-Ni,[20] which is entirely absent from our element chart. Another explanation for the higher amounts of nickel might be the presence of iron (Fe) in values up to 2.69 percent, another raw material worked on a large scale in the Hittite Empire.[21] In this case there are three possibilities: so-called poor solid copper with a certain percentage of iron contamination was processed;[22] the iron is present as a result of the smelting procedure itself;[23] or copper ore was smelted in a contaminated crucible containing the remains of a previous iron smelting process. In all cases some nickel would exist as a by-product. However, the actual amount of up to 7.17 percent nickel might attest to the use of meteoric iron, since extraterrestrial iron is known to contain nickel in values ranging from 5 to 60 percent with an average of about 8 percent.[24] Such a result would be a significant contribution both to Hittite philology and archaeology, since some philologists have associated the term black iron (AN.BAR) from the heavens (GE_6) mentioned in Hittite records with meteoric iron[25] but could not confirm this with

[14]O. Belli, "The Problem of Tin Deposits in Anatolia and Its Need for Tin, according to the Written Sources," in *Anatolian Iron Ages: The Proceedings of the Second Anatolian Iron Ages Colloquium Held at İzmir, 4–8 May 1987*, ed. A. Çilingiroğlu and D. French, (Oxford, 1991), 2.

[15]T. Bryce, *The Kingdom of the Hittites* (Oxford 1999), 306–307.

[16]The traces of cobalt (Co, 0.90 and 0.93 percent) must be imagined to be unintentional, natural contaminations of copper (see. also Pernicka, "Gewinnung und Verbreitung," 47–48).

[17]Pernicka, "Gewinnung und Verbreitung," 55; see also other metal artifacts, including one figurine from Tell Judaidah, which also yielded substantial nickel contamination, in R. Braidwood and L. Braidwood, *Excavations in the Plain of Antioch I: The Earlier Assemblages, Phases A–J*, OIP 61 (Chicago, 1960), 315–17.

[18]Pernicka, "Gewinnung und Verbreitung," 55.

[19]A. Hauptmann and A. Palmieri, "Metal Production in the Eastern Mediterranean at the Transition of the 4th/3rd Millennium: Case Studies from Arslantepe," in *Anatolian Metal I*, ed. Ü. Yalçın, Der Anschnitt Beiheft 13 (Bochum, 2000), 79–80, fig. 7.

[20]Pernicka, "Gewinnung und Verbreitung," 55; Hauptmann and Palmieri, "Metal Production in the Eastern Mediterranean," 79.

[21]J. Siegelová, "Gewinnung und Verbreitung von Eisen im Hethitischen Reich im 2. Jahrtausend v.u.Z.," *Annals of the Náprstek Museum* 12 (1984): 71–168; Ü. Yalçın, "Zum Eisen der Hethiter," in *Das Schiff von Uluburun: Welthandel vor 3000 Jahren*, ed. Ü. Yalçın, C. Pulak, and R. Slotta (Bochum, 2005), 493–502.

[22]G. Rapp Jr., "On the Origins of Copper and Bronze Alloying," in *The Beginning of the Use of Metals and Alloys*, ed. R. Maddin (Cambridge, Mass., 1988), 21–27.

[23]R. Maddin, T. Stech Wheeler, and J. D. Muhly, "Distinguished Artifacts Made of Native Copper," *Journal of Archaeological Science* 7 (1980): 211–25.

[24]Pernicka, "Gewinnung und Verbreitung," 62. However, Pernicka notes here that the presence of nickel, especially in values of about 5 percent, might not be enough to securely identify meteoric iron; further studies of the metallic structure would be necessary in that case.

[25]But see K. Reiter, *Die Metalle im Alten Orient unter besonderer Berücksichtigung altbabylonischer Quellen*, Alter Orient und Altes Testament 249 (Münster, 1997), 395–96, who rejects the equation

archaeological evidence.[26] Core samplings of the chain would be necessary to further evaluate this hypothesis, but such an inevitably destructive approach is not likely to be approved for one of the most prestigious objects in the Ankara museum collection. One cannot exclude a rather more exotic alloying procedure, but a much greater number of new metal analyses focusing on Late Bronze Age/Hittite metal objects would be necessary to prove such an assumption.

Conclusion

The first archaeometric, nondestructive analysis of the Bronze Tablet from Hattuša has revealed a noteworthy set of data that will certainly encourage more discussion. Our conclusions regarding the technical aspects and purpose of the alloys applied to the tablet are by necessity only preliminary while so few Hittite metal objects have been analyzed. It would, therefore, be highly desirable to carry out serial spectral analyses on a larger group of items from the Hittite era to highlight this particular period of metal production and consumption, whose roots, techniques, and traditions still remain largely obscure to the archaeological world.

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of "iron from heaven" with meteoric iron, since heaven itself can not be made of iron ([AN.B]AR-*aš nepis*).

[26]Siegelová, "Metals in Hittite Records," 54; Yalçın, "Zum Eisen der Hethiter," 499.