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Letters have weight: weighted *k*-shells in a Neo-Assyrian co-attestation network

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Abstract Network Analysis is still gaining momentum within Neo-Assyrian (c. 934–612 BCE) scholarship. Studies are exploring different types of networks, as well as what various centrality measures highlight in their datasets. In this contribution, we suggest how weighted *k*-core centrality could be used to identify elite groups within a co-attestation network. The network is built from co-attestations in correspondence dated to the reign of Sargon II (721–705 BCE), and we present a weighting scheme that reflects the strength of communication between those attested in a single document. We then use this weighting scheme to identify the weighted *k*-shells of the network. Our results align with a group whom traditional Assyriological research has identified as part of the elite, and which shows promise for further studies into Neo-Assyrian elites.

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1. Introduction

The wealth of textual material that has been preserved across Mesopotamia from the Neo-Assyrian period (c. 934–612 BCE) has led to intense discussions about those who were in the top strata of Assyrian society. However, there is very little agreement or consensus as to what made an individual a member of an 'elite' group in Assyria.[1] This is also an ongoing discussion in sociology, and many definitions simply do not work for ancient Assyria.[2]

Despite the lack of an overarching definition of who constituted the 'elite' in Assyria, scholars have identified groups who are generally agreed to have been part of this social stratum. The groups they have discussed reflect the nature of

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1 For the difficulties on defining 'elite' in the Neo-Assyrian material, see Richardson 2016: 43–48.

2 Different definitions of elite and the problems involved in monolithic definitions of the elite are discussed in: Lunding, Ellersgaard, and Larsen 2020; O'Neill 2020; and Pakulski 2018. Studying the elite is so elusive that it forms a sub-field of sociology. Elite studies have largely focused on economic and financial forms of power, as these are the primary influences in the modern world. Yet recent advances that focus on inequalities and other social factors have also gained momentum. An overview of the trajectory of elite studies can be found in Heilbron et al. 2018. Methods used to identify elites in modern societies are difficult to use for ancient Near Eastern societies. The three most-used methods in modern sociology are: positional; decisional; and reputational. The positional approach involves identifying those in formal leadership positions in institutions and organizations. It requires a near-complete dataset of a society, which simply does not exist for the Neo-Assyrian period, whose documents only partially survive and skew heavily towards elite institutions like palaces, temples, and scribes. The decisional approach involves identifying those who are active in important policy decisions. In modern democracies this is important, but in monarchies like those during the Neo-Assyrian period, the decision-makers are often limited to the king or the gods. Finally, the reputational approach sees researchers asking experts in the field who the most important people are (Hoffmann-Lange 2018). This is impossible for any ancient culture, as those who are best placed to answer this question all died centuries ago.

the material, which was mostly written by and for some sort of 'elite' group, and so it is only natural that Assyriologists have focused on understanding who these groups are. Below we outline four groups who have been highlighted as 'elite' through traditional scholarship. We will compare our results against these groups in order to assess whether the method of weighted *k*-core identifies individuals who fit any of these 'elite' groups.

The first group is the royal family. Naturally, the Assyrian kings dominate in the textual sources. Letters were sent to and from the king, and long texts describing their great deeds were set up throughout the empire and within their palaces. The kings and their respective families, including their children, siblings, and wives, have been subject to much discussion.[3]

The members of the Assyrian administration, including provincial governors and Assyrian officials, form a second group. Microhistories of specific individuals, as well as analyses based on titles or functions, dominate this type of scholarship, with a particular interest in precisely how the Assyrian empire was run.[4] Two themes can be discerned in this group: the first is identifying the exact differences in governing the Assyrian heartland as opposed to the provinces, and the second is disputing what is commonly referred to as the "rise of the magnates" between 823 and 745 BCE.[5]

Those who can be described as the 'educated elite' have also been the focus of research, and the training of scribes and their positions within society has been subject to intense discussion. The scholars at court had the king's ear, and particular focus has been made regarding their role during the reign of Esarhaddon

3 Examples of research into the lives of Assyrian kings include Siddall 2013, Elayi 2017 and 2018. For examples of studies into members of the royal family, see Melville 1999, Svärd 2015, Novotny & Singletary 2009, Zamazalová 2011, and May 2017.

4 A cursory overview in a footnote will not do justice to the quantity of scholarship regarding this particular trend, but studies that were particularly interesting to us were Radner 2014, Blocher 2001, Dubovský 2006, Fuchs 2008, Grayson 1993, Parpola 2007, and Parker 2009. A critical study for Neo-Assyrian elites is Raija Mattila's *The King's Magnates. A Study of the Highest Officials of the Neo-Assyrian Empire* (Mattila 2000). Mattila defined and outlined the roles of seven offices she identified that were the most important for the administration of the Neo-Assyrian empire (*masennu* 'treasurer', *nāgir ekalli* 'palace herald', *rab šāqê* 'chief cupbearer', *rab ša-rēši* 'chief eunuch', *sartinnu* 'chief judge', *sukkallu* 'grand vizier', and *turtānu* 'commander-in-chief'). For an example of a study incorporating archaeological evidence, see Barjamovic 2011. Pongratz-Leisten argued for three groups who constituted the 'elite': the educated intellectuals who formed the image of the king; the magnates and royal eunuchs; and the temple clergy. She goes on to stress the importance of those who could reinforce the connection between the king and the gods (Pongratz-Leisten 2013).

5 Siddall 2013; Blocher 2001; Zaia 2018.

(680–669 BCE).[6] Priests were also a vital part of Assyrian society, and occupied esteemed positions.[7]

Finally, attention has been turning to those who ran the palace itself. Even though they were not involved in the running of the empire, the cooks, tailors, weavers, musicians, and even suppliers of the king's palace can be considered a part of the 'elite'.[8]

These previous studies have been undertaken through painstaking close readings of Neo-Assyrian texts in Akkadian (their original language). However, now that many of the existing cuneiform texts are in some sort of digital form, Assyriologists are in a position to apply digital techniques to datasets.[9] One method that has proven popular is Network Analysis (NA). Based on mathematical graph theory, NA is an approach that models relationships between entities. The entities are represented as nodes, and their connections as ties. The resulting graphs can be used to identify trends and patterns in large datasets and, when applied to people, can identify important individuals within a specific network. It is for the latter reason that Social Network Analysis (SNA) in particular has been important in exploring elites in modern societies.[10]

Assyriologists have applied these principles to understand individual archives,[11] the social position of deities,[12] and even the finer semantics and usages of specific Akkadian words.[13] There have so far been limited applications of SNA to Neo-Assyrian material, and to our knowledge only one focused on researching elite groups. Christopher Jones' PhD dissertation used SNA to try to identify 'soft power' in the higher echelons of the Neo-Assyrian empire.[14] SNA has also successfully been used in the analysis of modern elites with datasets similar in struc-

6 For example, Parpola 1993; Luukko 2007; Radner 2009; overviews can also be found in Heeßel 2017 and Fincke 2017.
7 The daily lives of four priests were examined in Zaia 2019, which provides a window into their concerns.
8 Groß 2020; Svärd 2015.
9 Digitization projects include the Cuneiform Digital Library Initiative (CDLI), the Open Richly Annotated Cuneiform Corpus (Oracc), and the Database of Neo-Sumerian Texts (BDTNS, after the Spanish acronym). Others have taken the approach of providing digital text editions, such as Achemenet. Digital text editions are texts that are provided online, but without the back-end data. Other important digital projects include Prosobab and the Geomapping Landscapes of Writing (GLoW).
10 An overview of how SNA has been used in the analysis of modern elites can be found in: Knoke 1993; Larsen and Ellersgaard 2017; Keller 2018; and Kong et al. 2019.
11 For example: Wagner et al. 2013; Waerzeggers 2014; King and Pirngruber 2022; Kulikov et al. 2021.
12 Alstola et al. 2019.
13 Svärd et al. 2018; 2020; Bennett 2023.
14 Jones 2021.

ture to those available to us for the Neo-Assyrian period. In particular, we were inspired by the work of Anton Larsen and Christoph Ellersgaard, who have used a version of *k*-core to investigate who the power elite of modern Danish society were.[15] We wish to note that they made many assumptions about the characteristics of a person belonging to the elite when using unweighted *k*-core.

Our contribution asks two questions based on this background knowledge: 1) who is highlighted when *k*-core and weighted *k*-core centrality measures are applied to a Neo-Assyrian co-attestation network? And 2) do those individuals correspond to any of the social groups outlined previously who are considered 'elite' by traditional Assyriology?

Thus far, more traditional centrality measurements, such as (weighted) degree, betweenness, and eigenvector centralities have been relied upon for Assyriological research.[16] With this study, we build upon this methodology by suggesting that weighted *k*-core centrality could be used to identify elite groups within a co-attestation network through the method of *k*-shell decomposition. In this exploratory study, we strive to avoid imposing too many assumptions on the data. We only use the inverse of the crowd size as the weight, and show that this assumption alone brings a good approximation of an elite using weighted *k*-core.

2. Choosing a Neo-Assyrian dataset based on the historical background

In this section, we outline the data we used for this study. Even though we were inspired by the approach of Anton Larsen and Christoph Ellersgaard, we cannot replicate their careful curation of the data. The sheer amount of data freely available to them about the intricacies of many Danish organizations is simply not replicable with preserved ancient documents from the Neo-Assyrian period.[17] In this section, we outline the historical background for our data, the specifics of the Prosopography of the Neo-Assyrian Empire (henceforth PNA) – which was the basis for our data – and the decision to focus on the dataset from the reign of Sargon II (721–705 BCE).

15 Anton Larsen and Christoph Ellersgaard define a multitude of tie strengths which they use for pruning or emphasizing connections between persons in the network, but they do not use the weights to define the *k*-cores and *k*-shells of the network directly (Larsen and Ellersgaard 2017; 2018).

16 A more in-depth discussion of the previous usages of SNA in Assyriological research can be found in Goddeeris 2022: 370–382.

17 Larsen and Ellersgaard 2017: 57–58.

The Neo-Assyrian period is characterized by an administration from northern Iraq that controlled a vast geographical region – at its height, the rulers of Assyria governed a region from Egypt to the Zagros Mountains. A vast amount of documentation has survived from this period, spanning many different genres.[18] Thousands of preserved documents provide insight into the internal machinations of the Neo-Assyrian empire. Almost all of these texts were found in 'elite' contexts, such as royal archives in the Neo-Assyrian palaces. The preserved texts were thus largely written by and for the 'elite' of the Assyrian empire.[19] Even though this introduces some bias into our method, the large number of documents means that the Neo-Assyrian period is a good candidate for digital methods such as SNA.

A key contribution to the field of Assyriology is the PNA. This 4-volume series of edited books gives short biographies of all the individuals listed in Neo-Assyrian documents.[20] The first three volumes are organized according to named individuals, while the last volume is organized according to professions. Included in these short biographies are the publication or museum numbers of the texts where the individuals were mentioned. Heidi Jauhiainen and Tero Alstola have built a co-attestation network based on the contents of the first three PNA volumes, which they have graciously allowed us access to.[21]

The PNA network is based on the names of individuals who are mentioned together in the same ancient document. Each name in the PNA volumes I–III is represented as a node, and their attestation in the same document is represented as a tie.[22] The network therefore does not preserve any further details regarding the social interactions between those in the same document – only that they were mentioned together.

It should also be noted that Jauhiainen and Alstola's PNA network does not include data from royal inscriptions. Royal inscriptions are complicated documents that are already very difficult to analyze for Assyriologists, and continue to cause

18 A short overview can be found in Frahm 2017a: 2–5 and Lanfranchi, Mattila, and Rollinger 2019.

19 Frahm 2017b: 162–165.

20 The texts that formed the basis of this research were both published and unpublished cuneiform texts dated to the Neo-Assyrian period according to scholarship in 2011, when volume three part two was published.

21 Now published as Jauhiainen and Alstola 2022.

22 Individuals with the same name in the PNA are disambiguated, and this is preserved in Jauhiainen and Alstola's PNA network. Different individuals with the same name are assigned a number according to their PNA entry. For example, the entry for Kunâia in volume 2/I (p. 638) lists seven different individuals who have this name. In the PNA network, they are given as Kunâia_1, Kunâia_2, Kunâia_3, and so on. This is also the format the names appear in our research, for the sake of consistency.

problems for digital approaches to them.[23] Texts in this genre were commissioned by the Assyrian king to describe in detail the great deeds he had carried out during his reign. They can therefore be very long and mention the names of many different individuals. As Jauhiainen and Alstola point out, this can create a false impression of interactions in Neo-Assyrian texts. Therefore, royal inscriptions were excluded from the original PNA network by Jauhiainen and Alstola.[24]

In contrast, correspondence can be treated as discrete moments in time when people gathered together in an act of communication. We conceptualize these moments as 'events', which were recorded in a single document. In other words, we conceptualize each written document in the co-attestation network as an 'event' where individuals had an opportunity to communicate. However, as anyone who has attended a concert or crowded store can attest, more people at an event decreases the possibility of communicating effectively with everyone there. By weighting the co-attestation network according to this basic assumption, we can reflect the quality and frequency of communication between individuals. The visualization of the co-attestations across these documents as a network therefore offers a unique insight into the administration of the Neo-Assyrian empire, and means this PNA data has potential for further research into the ever-growing field of Neo-Assyrian administration and bureaucracy.

However, the Neo-Assyrian period spans more than three hundred years. Administrative and bureaucratic changes over such a time period are practically inevitable. In addition, the number of preserved texts, the topics they discuss, and their geographical span do not align. For example, the texts relating to Assyrian king Esarhaddon are famous for the large number of letters to scholars.[25] In comparison, there are virtually no texts preserved from the reign of Shalmeneser V (727–722 BCE).[26] In order to assess what *k*-core highlights in an ancient co-attestation network, we limited it to the data in Jauhiainen and Alstola's PNA network from the reign of Sargon II (721–705 BCE). In addition, we focused solely on the

23 Excellent introductions to the problems of interpreting texts in this genre can be found in Fales 1999 and Frahm 2019. One of the issues with digital approaches to these texts are their formulaic nature, with many sections repeating phrases and motifs. See Sahala & Lindén 2020 for a more in-depth discussion on how this can complicate digital approaches.

24 Jauhiainen and Alstola 2022: 4.

25 201 of the letters published in State Archives of Assyria (SAA) volume ten are written from Assyrian and Babylonian scholars from the reign of Esarhaddon (Parpola 1993: XXIX).

26 As Frahm points out in his overview of Neo-Assyrian history, the evidence for Shalmeneser V's reign comes from later periods and fragmentary Assyrian sources (Frahm 2017b: 180).

correspondence documentation from this period, which were mostly excavated from royal archives in the palaces of Kalḫu and Nineveh.[27]

We chose to investigate the correspondence from the reign of Sargon II because we believe this would be the best test for understanding what weighted *k*-core highlights in a co-attestation network. Sargon II's reign is best characterized as one of increased military activities, armed struggles for control over Babylonia, and significant building projects, including a brand new capital.[28] All of these activities took place over a huge geographical span, including battles in Urarṭu (a large kingdom to the north of Assyria), and receiving diplomatic gifts from Egyptian and Arabian rulers.[29] In order to keep up with developments across the huge geographical span of the empire, Sargon II relied upon informants and spies who sent letters to Nineveh.[30] A large amount of this correspondence has survived to the present day. The correspondence is therefore largely sent to and from the Assyrian king, so an expected result from our study is that Sargon II will be central in our networks. However, these documents contain information about the entire empire, and are not restricted to discussions of the inner workings of the palace. Even though this correspondence will be centered on the Assyrian king, we believe the geographical scope of this dataset provides a good snapshot into the administrative and bureaucratic workings of the Assyrian empire. We therefore decided to limit our dataset to this group of documents.

Three volumes of the eminent series State Archives of Assyria (henceforth SAA) are devoted solely to the correspondence of Sargon II, and these formed our initial dataset, from which we carried out preliminary tests and analyses (of 609 texts, with 547 unique names and 1,727 attestations in the texts).[31] However, these text editions were published from 1987 to 2001. Since then, much work has been done to revise the contents of these documents, and there are other texts within the PNA data that are now dated to the reign of Sargon II.[32] We therefore consulted the list of texts dated to the reign of Sargon II collected by Jones in his doctoral thesis,[33] and used this to guide our collection of texts. We collected all

27 676 texts were excavated in Nineveh, and 31 in Kalḫu (Jones 2021: Appendix A).
28 A brief overview can be found in Frahm 2017b: 180–183, and Josette Elayi wrote a biography of the king in Elayi 2017.
29 These are mostly known from Sargon II's royal inscriptions (RINAP 2/1, 1 120b–125a; RINAP 2/1, 7 27) and a 'letter' addressed to the god Ashur describing a campaign against Urarṭu (Mayer 1983; Foster 2007: 91).
30 Dubovský 2006.
31 SAA 1, 5, and 15. See also footnote 34.
32 Bradley Parker's contribution to Simo Parpola's Festschrift titled *Of God(s), Trees, Kings, and Scholars,* is a key example of why the original PNA data must be investigated in parallel with more recent scholarship. Parker explains that in 2009, Karen Radner had already published two updates to her original PNA entry for Ašīpâ_3 (Parker 2009: 181).
33 Jones 2021: Appendix A.

the data from PNA that was initially dated to the reign of Sargon II, added texts listed in Jones' thesis and, in ambiguous cases, we erred on the side of the PNA data. Our final dataset was 727 texts, which mention 734 unique names, and 2,126 attestations of those names.[34]

3. Weighted *k*-core centrality

K-core centrality is a measurement designed to identify groups of nodes that have an internal support (or degree) of at least *k*.[35] In a nutshell, *k*-core centrality aims at finding one (or more) particularly well-connected group(s) within a network and uses a method of *k*-shell decomposition in the process.

To find the maximum *k*-core of a network, the *k*-core metric repeatedly calculates the nodes' degree centrality and cuts the nodes that do not have a degree of at least *k,* increases *k,* and repeats the procedure until no nodes are left in the graph. For each *k,* the graph is broken down to reveal the most cohesive group within the network with a degree of at least *k* (Fig. 1).[36] For each increase of *k,* we refer to the nodes that were cut as belonging to the relevant *k*-shell.[37]

When we talk about the *k*-core centrality of a node, we thus refer to these *k*-shells, but because *k* is increased at a steady interval, there may be gaps in the sequence of *k*-shell numbers if no nodes are cut at a certain stage. For intuitive reasons and ease of comparison, the *k*-shell numbers we refer to in this paper are

34 For a list of the texts, see Appendix C. With the additional 118 texts, Network 1 (N1) grew from 547 individuals connected by 1,537 ties to 734 persons linked by 2,269 ties. Still, the network analytical and qualitative results (presented in sections 4, 5, and 6) are very similar to those of our original dataset. The process allowed us a unique opportunity to test the stability of the network results with regards to the number of sources, as well as the structure of the networks and the importance of Sargon II (see section 4.2). More on the stability of weighted *k*-core and the impact of Sargon II on centrality measures can be found in Appendix D. For the robustness of centrality measures in the old dataset, see esp. footnote 12 of Appendix D.

35 A full mathematical explanation is given in Seidman 1983. See also Wasserman and Faust 1994: 266–67; Brughmans and Peeples 2023: 128–129.

36 Doreian and Woodard 1994. While all nodes in this group represent the given *k*-core, structurally they may form one or more components.

37 For those readers who are not familiar with network analysis, we have found that the analogy of an onion can help to cement the concept. If the network is like an onion, and the innermost part of the onion is the most cohesive group in the network (i.e. the maximum *k*-core), each *k*-shell represents an onion layer that can be peeled away to reveal the core. In this comparison, the *k*-core centrality measure removes the 'onion layers' of the network from the outermost (or most peripheral) to the innermost (or most central) layer. Layers are removed until removing another *k*-shell leaves no nodes in the graph – which is how we come to the *k*-core. In the process, the nodes that are removed in the same 'onion layer' are assigned the same *k*-shell number.

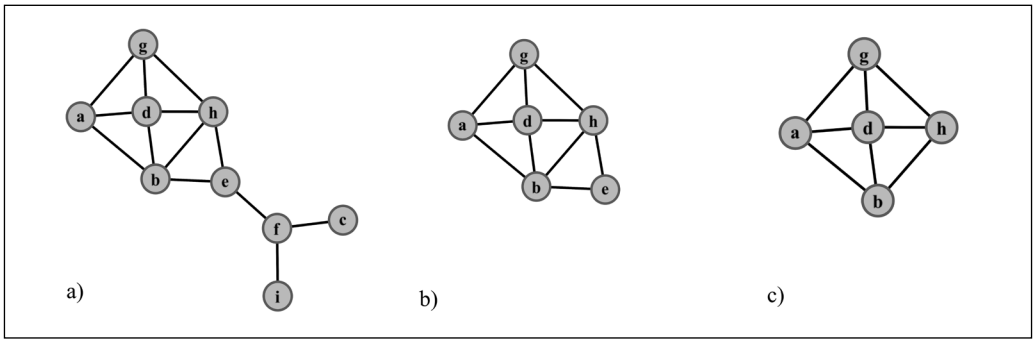

Fig. 1 Example of the breakdown of the sample network a). In b), *k* is set to two, so nodes *c* and *i* were excluded. Without these nodes, the degree of *f* dropped from three to one, so it is also excluded from the 2-core. Next, in c) we increase *k* to three, thus removing node *e* as well. If we increase *k* to four, all remaining nodes are cut, so the maximum *k*-core of this sample network is the 3-core, which includes nodes *a, b, d, g,* and *h.* Graph by E. Bennett.

the running *k*-shell indexes, which we assign to the *k*-shells as they are identified by the *k*-core procedure.

However, the *k*-core metric is unweighted, so in a co-attestation network, this metric is heavily influenced by the number of persons mentioned in a document. In Neo-Assyrian texts, this is particularly significant for documents that include witness lists or other lists of individuals. These lists form well-connected groups in the graphs, which result in these individuals being considered relatively central by the *k*-core metric.[38] It follows that the unweighted version of *k*-core centrality is problematic for the identification of elites in an unmodified network, as it provides no insight into the kinds of communication found in the texts.[39]

Larsen and Ellersgaard also found this to be the case for their research. To accommodate the problem, they used unweighted *k*-shells with cut-off thresholds on the weighted ties to identify the 'power elite' within Danish society based on a dataset of co-affiliations.[40] To identify which ties to sever, they used elaborate

38 For a concrete example, see section 5.1.
39 Further details about the suitability of this measurement are in section 5.
40 Larsen and Ellersgaard 2017. These were membership lists of formal organizations (such as foundations, corporations, or Parliament), and formal events (such as galas and formal dinners). If we think of each membership list as a document, then this can also be viewed as a co-attestation network. As our data is based on the co-attestations of individuals in documents that were not written by the average person in the Neo-Assyrian period, we suggest these datasets are more similar than they first appear. Neither were written by or for the lower echelons of society, and the networks reflect that individuals were attested together in the same document.

assumptions about the quality of the relations based on event size, event frequency, friends of friends, etc.[41] When a method uses multiple assumptions and only tests these on one dataset, there is always a danger that the pre-understanding of the data is projected onto the model, such that the method visualizes what the researchers expected to find at the outset. In our case, we wanted to minimize the risk of imposing our pre-determined notions of what an 'elite' group would look like in our networks. This was particularly the case with co-attestation networks that did not include qualitative data regarding the relationships of individuals within the original texts. We therefore made the conscious choice to make only one generally applicable assumption concerning event size, thus simplifying the weighting scheme proposed by Larsen and Ellersgaard, and minimizing the risk of imposing our own assumptions onto the data.

In our networks, a bond is formed between two persons if they are present at the same event (i.e. mentioned in the same ancient text). Our general assumption is that the fewer people there were at an event, the stronger their bonding was likely to be during the event. In other words, a complete letter with two people will likely reflect a direct, clear communication between those involved. In comparison, a document with six people is less likely to reflect an equally clear and direct communication between two people.[42]

To reflect this, we define the weight of a directed tie between two persons arising from one event (or ancient text) as the inverse of the number of directed ties between all n persons associated with the event. Additionally, a person cannot be tied to him- or herself. This means that the sum of all ties arising from an event is 1. In a directed network, ties can run from person b to person a, as well as from a to b, so that two ties link the pair if the relationship is reciprocated. In our case the network is undirected, so the number of possible ties is only half as many as in the directed network, since we are only interested in whether person a and b are linked or not. The formula for our weighting system in a directed network is

$$\frac{1}{n(n-1)}$$

and, in an undirected network,

$$\frac{2}{n(n-1)}.$$

41 Larsen and Ellersgaard 2017: 58–60.

42 For example, SAA 1 5 is a letter sent directly from the king to Ašipâ_3, and all information is communicated clearly to Ašipâ_3. In comparison, in SAA 15 25 Nabû-bēlu-ka"in_1 reports a message from a third party to the king. The communication between Nabû-bēlu-ka"in_1 and the king is therefore weaker than in SAA 1 5, as there are more people involved in the event.

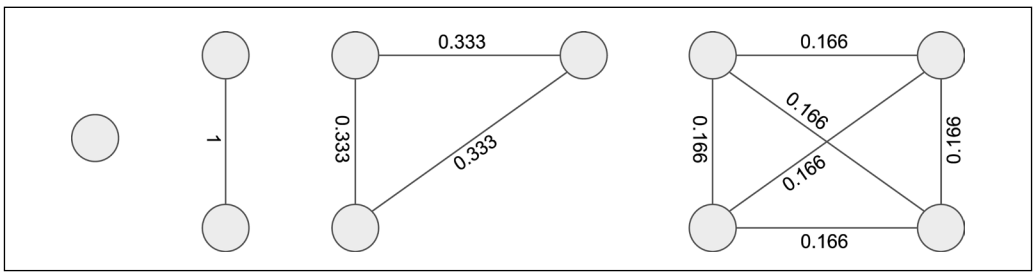

Fig. 2 Schematic representation of the applied weighting scheme within a document. Graph by L. Tambs.

According to this weighting scheme, texts mentioning zero or one person will amount to no ties (since we do not represent self-loops). Texts mentioning two named individuals will generate one relational tie with a strength of '1'. Three persons will be linked by three ties with weights of '0.333'. With four people, we get six ties with weights of '0.166', and so on (Fig. 2).

If the same two persons appear together in several documents, the strength of their tie is accumulated over all their joint events. The relatively simple weighting system is only contingent on the co-attestation data, and thus allows for a data-driven assumption that the size of an event is inversely proportional to the tie strength between nodes.[43] It follows that the larger the accumulated tie strength between two nodes, the more documents the two individuals are present in, and documents with many individuals contribute only fractionally to the tie strength between individuals.

The weighted *k*-core centrality measure applied in this study uses the weighted tie strength between nodes according to our schema. The maximum weighted *k*-core will have a weighted degree of at least *k*. In a social network, this tool will identify strongly connected groups, and weighted *k*-core centrality with our weighting schema is less skewed by the number of individuals attested in a single text than the unweighted *k*-core centrality measure. As we will demonstrate, it therefore performs significantly better on the explored, unmodified co-attestation networks.

We used the R package igraph[44] to generate a list of unweighted *k*-shells, and adapted an algorithm published by Jonathan Cohen[45] to calculate the weighted

43 The strength of a tie could be an arbitrarily complex function of the context, so an interesting research topic on its own is to find the simplest scheme that yields the most plausible result.
44 Csardi & Nepusz 2006.
45 Cohen 2008.

k-shells.[46] Since the unweighted *k*-shells were derived by iteratively calculating the *k*-core centrality before increasing *k* by 1, they were calculated directly based on the increments of *k,* whereas our weighted *k*-shells are calculated using the following granularity formula

$k \times 0.1$,

defining the boundary of each weighted *k*-shell.[47]

The use of our weighting system to calculate weighted *k*-core centrality allows for a more nuanced approach to our PNA data whilst also imposing as few assumptions as possible upon the data. To test whether the weighting system and granularity for weighted *k*-core was capable of highlighting individuals who conform to current understandings of Neo-Assyrian elites, we proceeded to test the methodology on our Sargon II dataset.

4. The networks

We began with a 2-mode network that consisted of persons (node type 1) attested in texts (node type 2) based on Jauhiainen and Alstola's PNA network data. After establishing the tie strengths according to our weighting scheme, this dataset was collapsed into a 1-mode network where only the individuals are represented as nodes. In it, two individuals are linked if they appear together in at least one of the studied letters from the reign of Sargon II, but the weight of their tie represents the sum of their tie strength, based on all the documents where they are attested together.[48]

After running the unweighted and weighted *k*-core measures, the results were imported into Gephi[49] where the layout was set with the force-driven layout algorithm 'ForceAtlas2'.[50] The resulting model's structural characteristics and high level of degree and betweenness centralization led us to create two ad-

46 Our code calculates and prints three values for each node: its weighted shell number, the weighted support shared by the nodes in this shell, and a weighted running shell index. For the sake of convenience, we predominantly refer to the *k*-shell indexes, occasionally supplemented by information on the support. In the case of unweighted *k*-shells, the support equals the number of neighboring nodes when outer shells have been removed. For weighted *k*-shells, the support is the sum of the strength of the ties to the neighboring nodes when outer shells have been removed.

47 One avenue for future research is to experiment with this granularity.

48 The weighted and unweighted *k*-shells discussed below were calculated on the basis of such 1-mode networks.

49 Bastian et al. 2009.

50 Jacomy et al. 2014, with an 'edge weight influence' of 1.

ditional versions of the dataset, which helped us better understand the network data and evaluate the extent to which weighted *k*-core and other centrality measures are affected by the key figure, namely the king.[51] Network 1 (henceforth N1) includes everyone attested in the studied documents, Network 2 (N2) excludes king Sargon II and his ties, and Network 3 (N3) excludes the maximum weighted *k*-core identified in N1, consisting of Sargon II and Ṭab-ṣil-Ešarra as well as their ties.[52]

Through network analysis and a comparison of these datasets, we evaluated the level of dominance held by the king (and the maximum weighted *k*-core) in the original network,[53] and tested the robustness of six centrality metrics (*k*-core, weighted *k*-core, degree, weighted degree, eigenvector, betweenness) across N1 and N2.[54] Both approaches helped us better understand our datasets and aided us in assessing the relevance of weighted *k*-core centrality for finding 'elite' persons in our network data.

4.1 The dominance of Sargon II

The network analysis revealed that N1 consists of 734 individuals linked by 2,269 ties. The whole network is made up of nine connected components, but the largest contains 97.41% (715) of the nodes and 99.38% (2,255) of the ties. Since the vast majority of the modeled persons (including the king) are linked to at least one other person in the giant component, they are all (indirectly) connected by a continuous path of such ties.

Fig. 3 shows how the high degree and betweenness centralization of N1 is due to the prominent position of Sargon II – the largest node. He clearly holds an extremely dominant position in the dataset and serves as the main gatekeeper or broker. This is to be expected, given that we are looking at a co-attestation network of his letters and lack information on further connections that might have existed between the people and groups he corresponded with. Still, the vastly

51 On the significance of a graph's shape for measures of centrality and centralization, see e.g. McCulloh et al. 2013: 73–77; Wasserman and Faust 1994: 170–171. Following the established terminology, the giant component of our N1 resembles a star-shaped graph, whereas N2 comes closer to a circle (or ring) graph. For a digestible overview of network topologies, and the difficulty of pinning a model down to one type, see McCulloh et al. 2013: 78–86. As a case in point, our co-attestation networks are scale-free, with power law distributions characterized by few nodes being involved in many ties, yet show small world, core-periphery and/or cellular tendencies.

52 The characteristics of the three network models are summarized in Appendix B. For the networks and datasets, see the Zenodo repository (the URL of which can be found in Appendix A).

53 In each case, the relevant nodes and ties were removed before remaining tie strengths were recalculated and the ForceAtlas2 layout algorithm re-ran.

54 For the robustness tests, see below and Appendix D.

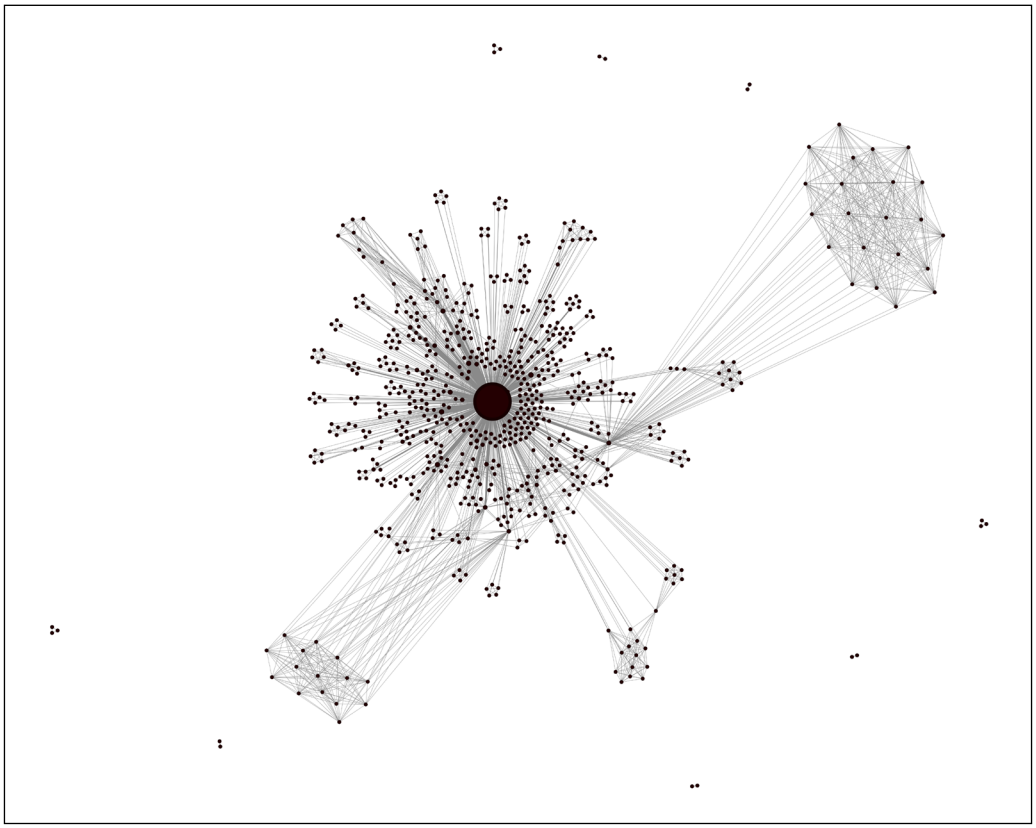

Fig. 3 The 1-mode whole network of people attested in documents from the reign of Sargon II. Node size reflects a person's weighted degree (30–300). Graph by L. Tambs, created in Gephi. (High resolution images of all network visualizations, as well as the graph files, can be found in the accompanying Zenodo repository, for which see Appendix A.)

larger size of his node suggests that he dominates the network to the point where other variations are difficult to grasp.

With the help of formal SNA tools, we analyzed the king's dominance by various measures. For example, the average path length (referring to the number of ties separating two nodes) in the giant component is 2.242, meaning that most persons included within it are linked by relatively few steps. However, the star-like layout of the graph indicates that the average path length is short because a high number of the paths go through the network's absolute center, which is the node representing the king.[55] His dominant network position is confirmed by ap-

55 For this concept, see e.g. Scott 2017: 105–106. In the giant component of N1, Sargon II is the only person with the minimum eccentricity score of '2'. See also footnote 61.

plied centrality measures: with the exception of unweighted *k*-core, Sargon II is the most central node by weighted *k*-core, degree, weighted degree, eigenvector *and* betweenness centrality.[56]

The structural characteristics of the whole network and high centralization of the main component are clearly dependent on Sargon II's node. While this is unsurprising, the degree to which he dominates the graph poses challenges for the network analysis and requires a critical assessment of the measures discussed. Although this (full) dataset remains most representative of historical realities, we therefore also tried hiding the node of the king as part of the network analysis. This helped us to better understand the network data, the reliability of applied metrics, and the significance of the network analytical results.[57]

Once the king and his ties were removed, the network size dropped to 733 individuals linked by 1,650 ties.[58] Although N2 also has a clearly defined giant component (Fig. 4), this whole network is fragmented into 143 connected components, of which the largest contains 56.48% (414) of the nodes and 76.42% (1,261) of the ties. The noticeable drop in the relative size of the giant component confirms that Sargon II's node functions as the glue that keeps much of N1 together.[59] As expected, we thus also observe an increase in the average path length measured in this model's main component (now 4.605).

Fig. 4 illustrates that many of the newly formed components of N2 represent groups of various sizes that have become disconnected from the main component, yet remain internally linked despite the king's removal. At the same time, the presence of 81 isolates (i.e. nodes with no ties, represented as black dots in Figs. 7 and 8) reveals that many people in the giant component of N1 were poorly integrated since they were exclusively linked to Sargon II.[60] Removing the king thus removes their connections altogether.

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56 The twenty highest ranking nodes of each measure are listed in Appendix D and its supporting information, for which see Appendix A.

57 Since the king is the key figure of the studied letters and elite groups, removing him admittedly altered the historical reality portrayed in N2 (and N3). Still, we deem the exercise necessary for the methodological objectives of this paper. For the performance of applied metrics, see esp. section 4.2 and Appendix D.

58 For characteristics and a comparison between the models, see Appendix B.

59 Fragmentation is a common trait of highly centralized networks, as explained by McCulloh et al. 2013: 73.

60 With reference to Fig. 3, they are positioned very close to the center of N1, forming a half-moon around the right side of the king's node. They have no *k*-core or weighted *k*-core centrality in N2, but in N1 they form part of *k*-shell one and weighted *k*-shell one. According to the PNA descriptions, many represent people attested in a single (undated and/or broken) text.

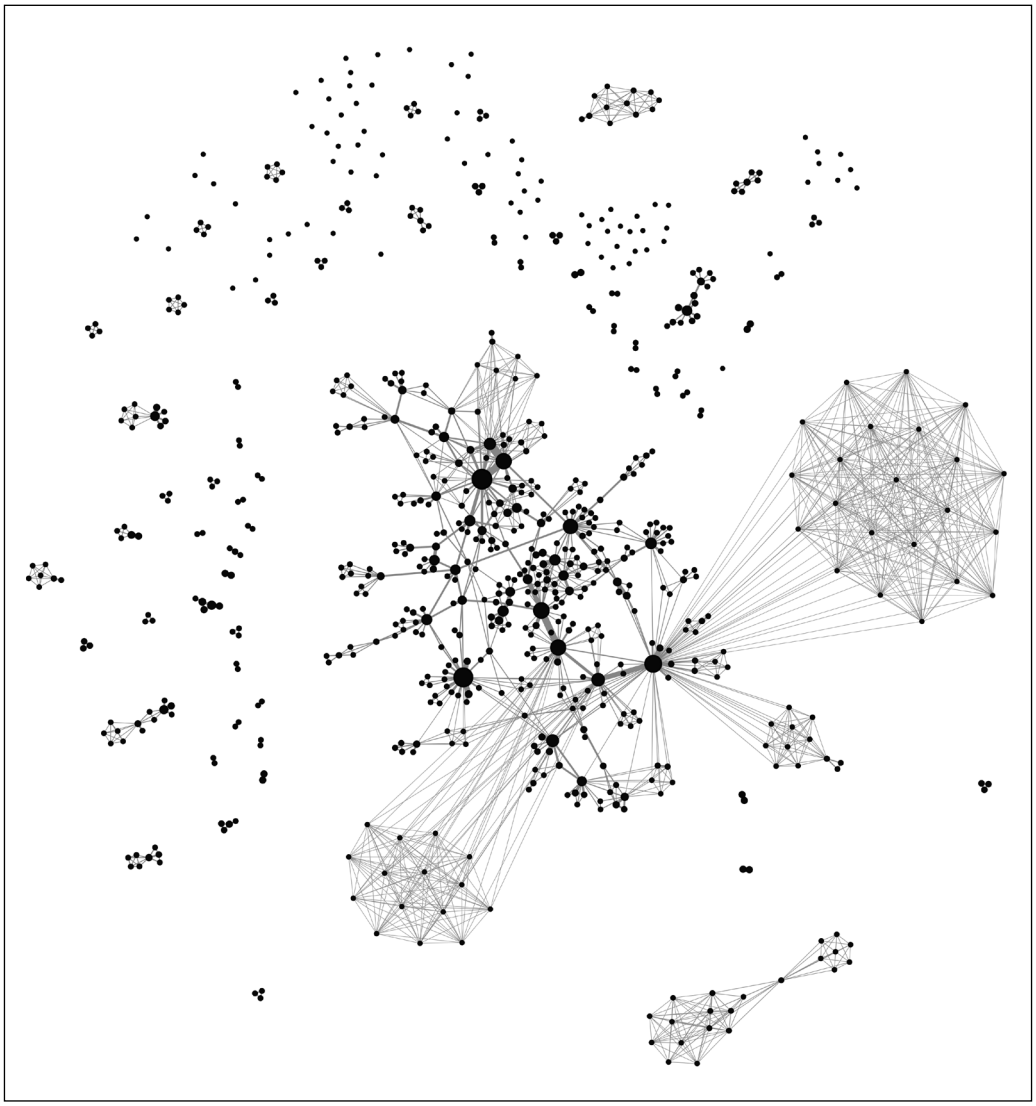

Fig. 4 The 1-mode whole network of people attested in documents from the reign of Sargon II, but with Sargon II and the ties involving him removed. Node size reflects the nodes' weighted degree (25–100). Graph by L. Tambs, created in Gephi.

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In addition to giving insight into the structural significance of the king within our dataset, excluding Sargon II allows other personalities to step into the foreground. This is reflected in node size variations showing how weighted degree centrality scores are more evenly distributed in N2 than N1 (Fig. 4 and Fig. 3, respectively). Again, this is an expected result, as no one node sits as comfortably at the center of N2,[61] but through SNA we move beyond mere assumptions and can quantify the tendency.

In summary, removing the node representing Sargon II and the ties involving the king proved to significantly impact the structure of the whole network, as well as the size and characteristics of the giant component. In the studied documentation, the king does appear frequently as an active participant. At least to some degree, his prominent position in N1 therefore reflects historical realities, so simply removing him from the equation was not deemed a viable option. At the same time, a concern for the degree to which discussed centrality metrics are affected by the king's dominance favored a cautious approach. Proceeding with two versions of the network was thus preferred over simply cutting Sargon II out of (or leaving him in) the dataset. We also tried removing the maximum weighted *k*-core identified in N1, which included both Sargon II and the governor Ṭab-ṣil-Ešarra. However, the additional removal of Ṭab-ṣil-Ešarra in N3 proved to have little to no effect on the tendencies already observed in the comparison of N1 (with Sargon II) and N2 (without Sargon II).[62] We therefore continued by focusing on N1 and N2.

4.2 The (in)stability of centrality measures

At an early stage of the research, we tested how robust the networks are with regards to the number of texts included in the study.[63] In order to assess the ability of weighted *k*-core centrality to highlight members of the elite in our networks, we also needed to check the degree to which our weighting scheme and deliberate node and tie removals affect centrality measures. To facilitate an appropriate 'reading' of the models and interpretation of results, we conducted a series of robustness tests (summarized in Table 1 and discussed in detail in Appendix D).

For these tests, we ran six centrality measures on N1 and N2 before comparing the results.[64] Those deemed 'stable' had similar results, whereas those deemed

61 An absolute center was also identified in the giant component of N2, but the node with the lowest eccentricity score – Šamaš-belu-uṣur_4, on whom see section 6 – has far less control over this network than Sargon II does in N1.
62 For network characteristics, see above and Appendix B.
63 See section 2 and footnote 34.
64 For the results to be comparable, Sargon II was consistently ignored in N1.

Robustness Consideration	*k*-Core	Weighted *k*-Core	Degree	Weighted Degree	Eigen-vector	Between-ness
Are the five most central persons in N2 identical to those in N1?	Yes (100%)	No (0%)	Yes (100%)	No (40%)	No (10%)	No (10%)
Are the five most central persons in N2 found among the top ten in N1?	Yes (100%)	No (20%)	Yes (100%)	No (60%)	No (10%)	No (10%)
Are the five most central persons in N2 found among the top 10% in N1?	Yes (100%)	Yes (100%)	Yes (100%)	Yes (100%)	No (10%)	Yes (100%)
How many appear in the top twenty lists of both models?	100% (20/20)	65% (13/20)[a]	100% (20/20)	60% (12/20)	5% (1/20)	40% (8/20)
Spearman's rank correlation of the whole networks	0.984	0.480	0.987	0.512	0.739	0.982
Pearson's correlation of the whole networks	0.993	0.563	0.998	0.797	0.326	0.579

[a] Keeping to a strict three-point selection criteria of (1) centrality rank (2) personal name in alphabetic order, and (3) index numbers in ascending order (for namesakes), there is a 45% (9/20) overlap. For details, see esp. footnote 9 of Appendix D.

Tab. 1 Summary of robustness tests, including correlation analyses of N1 and N2.

'unstable' had dissimilar results across the two models. For the first four tests, the higher the percentage given in Table 1, the more robust, or stable, is the metric. For the correlation analyses performed on the full list of nodes, the value '1' would represent a perfect positive correlation, '-1' a perfect negative correlation, and '0' that no correlation was found.

Based on these robustness tests, we found the following ranking (from most to least stable): degree, *k*-core, weighted degree, weighted *k*-core, betweenness and eigenvector centrality. A key point is that the metrics that do not take the tie strengths into account proved to be either highly stable (degree, unweighted *k*-core) or highly unstable (betweenness, eigenvector). Both extremes proved problematic and, as will be demonstrated below, our weighting scheme better preserves some of the historical reality found within the correspondence. For our purposes, it is therefore reassuring to find the weighted metrics (weighted *k*-core, weighted degree) at the middle of the stability scale.

Whereas the unweighted *k*-core metric proved to be stable to the point where N2 is virtually redundant,[65] the robustness tests revealed that weighted *k*-core is highly sensitive to changes in the top of the ranked lists, but more robust once middle and low-ranking nodes are considered. Since different people shine once the king is eliminated, an assessment of the weighted *k*-core metrics' ability to highlight elites should not be confined to N1. For the bulk of the nodes there is, however, a strong positive correlation between a node's weighted *k*-core centrality in N1 and N2. The latter point is important, since it indicates that non-elite people are likely to be identified in the lower ranks, regardless of whether or not the king is included.

5. The impact of the weighting scheme on *k*-core centrality

With the datasets and network models at hand, we explored the degree to which unweighted and weighted *k*-core centrality tend to highlight 'elite' nodes in our datasets. To do so, we (1) identified and studied the distribution of unweighted and weighted *k*-shells in N1 and N2, before (2) checking and supplementing the network analysis with more traditional and qualitative methods.

5.1 Distribution of unweighted and weighted *k*-shells

In this section, we present the *k*-shell distribution analysis, focusing on the unweighted and weighted *k*-shells identified in N1 (with the king) before looking at the distribution of unweighted and weighted *k*-shells in N2 (without the king).

To explore which individuals are positioned in the lower and higher shells of either model, *k*-shell distributions are visualized as heatmaps where those in shells with high internal support are represented by larger and darker nodes than those in shells with low support (see Figs. 5 to 8).[66] A visual comparison of these heatmaps demonstrates how the unweighted and weighted metrics highlight very different people overall – with only the weighted version highlighting nodes with a structurally significant network position. That weighted *k*-core centrality performs significantly better for our purposes is further cemented by the qualitative analysis of the highest and lowest ranked people (below), which helped us eval-

65 The same is true of degree centrality.

66 In the heatmaps, node color intensity represents the running *k*-shell index numbers, whereas node size reflects the internal support shared by the persons within a given shell. This serves to highlight the position of persons in relatively high *k*-shells (by node color), while at the same time indicating the size of the jumps in internal support level between identified *k*-shells (by node size). Digital versions of these illustrations, which include labels denoting the *k*-shell indexes, can be found in the Zenodo repository (see Appendix A). For the concept of support, see section 3, esp. footnote 46.

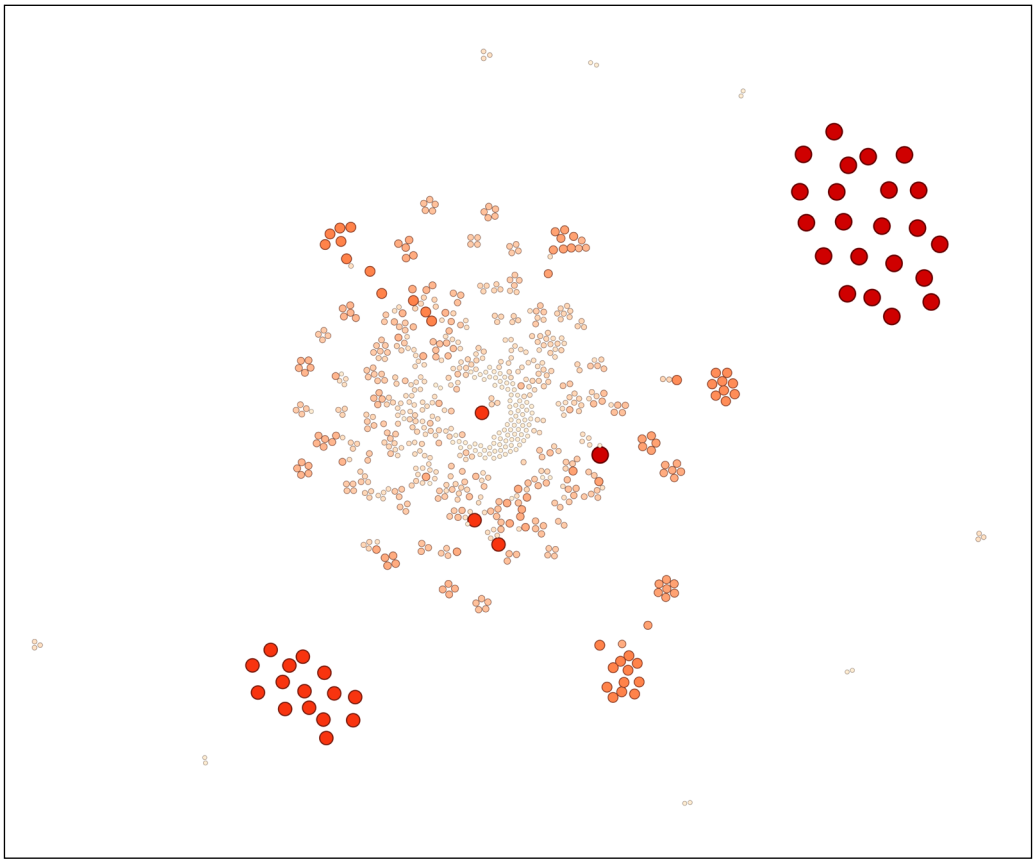

Fig. 5 Distribution of unweighted *k*-shells in Network 1. Here, node size reflects the 'support' shared by persons in a given *k*-shell, and node color intensity signals their respective '*k*-shell numbers'. Graph by L. Tambs, created in Gephi.

uate the impact our weighting scheme has on the measure's relevance for finding elites in this dataset.

In N1, a total of 12 unweighted (Fig. 5) and 44 weighted (Fig. 6) *k*-shells were identified. As expected, both highlight the king as an important agent: Sargon II (represented by the dot in the center of the graph) belongs to the second highest unweighted *k*-shell (11) and the highest weighted *k*-shell (44) respectively.

However, the weighted *k*-core measure proved to be more fine-grained, separating the nodes of N1 into significantly more shells. The maximum weighted *k*-core (weighted *k*-shell 44) is thus restricted to Sargon II and the governor of the important Assyrian city Assur, Ṭab-ṣil-Ešarra_1,[67] whereas the second

67 For the effect of removing this *k*-core from the network data, see Appendix B.

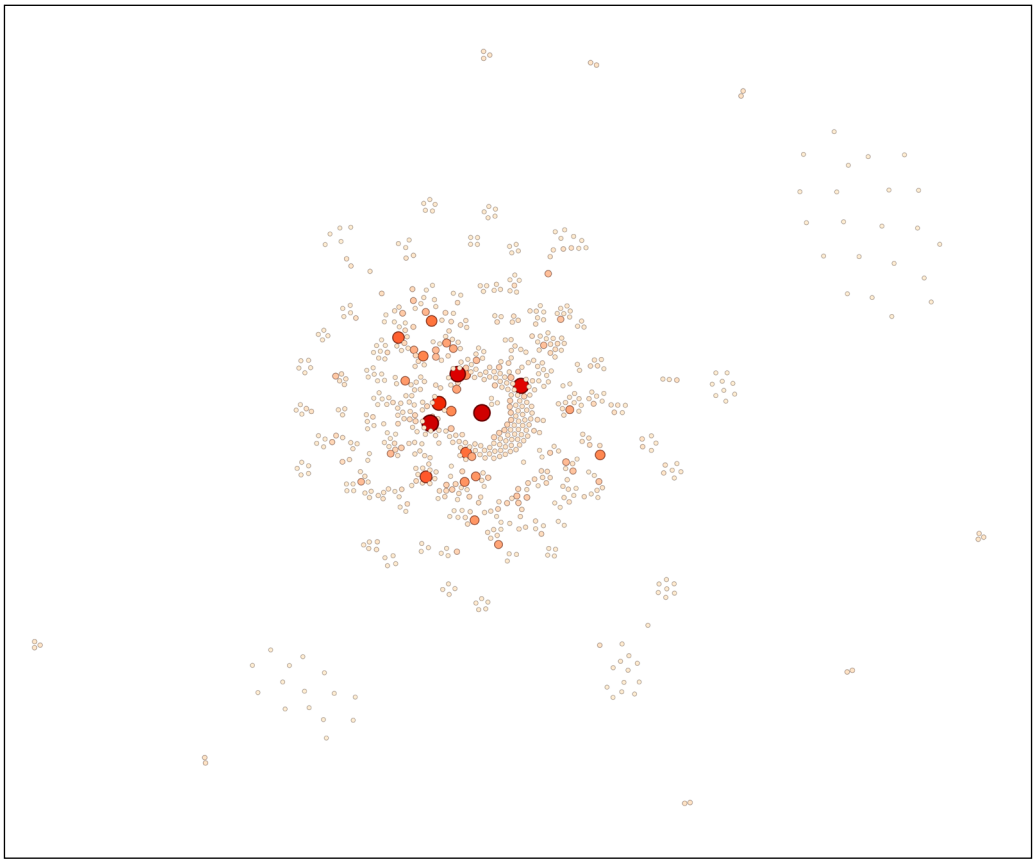

Fig. 6 Distribution of weighted *k*-shells in Network 1. Node size reflects the 'weighted support' shared by persons in a given *k*-shell, and node color intensity signals their respective 'weighted *k*-shell numbers'. Graph by L. Tambs, created in Gephi.

highest weighted shell (weighted *k*-shell 43) consists solely of the treasurer Ṭab-šar-Aššur_1 (Fig. 6). By contrast, the maximum unweighted *k*-core (unweighted *k*-shell 12) contains 19 men and four women,[68] all of whom were mentioned in SAA 17 139 together. Similarly, the king shares the second highest *k*-shell

68 The women are Arrābātu_1, Binītu_1, Huluttī_1 and Namirtu_1. As shown in Appendix D, Arrābātu_1, Binītu_1 and Huluttī_1 were found to be amongst the twenty most central agents identified by *k*-core (in N1 & N2), degree (N1 & N2) and eigenvector (N2); Namirtu_1 by *k*-core (N1 & N2) and eigenvector (N2) centrality. A future avenue of research we would like to raise, but cannot include here, is to experiment with the support threshold to decrease the sensitivity of the measure. Potentially, this could help us identify a meaningful boundary between 'elite' and 'non-elite' groups from the perspective of weighted *k*-core centrality.

(unweighted *k*-shell 11) with 16 other men and one woman (Fig. 5), all of whom were mentioned in SAA 15 181.[69]

The pattern of having few individuals in the weighted *k*-shells is not just found in the highest weighted *k*-shells, but across N1.[70] A much lower number of weighted *k*-shells identified in N2 (discussed below) suggests that this is at least partially caused by the highly centralized structure of N1.

What is already clear is that without the weighting scheme, *k*-core centrality highlights persons who are attested together in texts that mention many people. While they are often peripheral to the network structure, weighted *k*-core centrality mostly highlights people that are centrally positioned in the network (cf. Figs. 5 and 6). That this observation is less dependent on the presence or absence of the king is confirmed by conducting a similar *k*-shell distribution analysis of the N2 data.

In N2, we identified a total of eleven unweighted (Fig. 7) and 14 weighted (Fig. 8) *k*-shells. Again, the weighted measure is more fine-grained, but the difference is far less dramatic than in N1. As shown by the robustness tests,[71] this reflects the weighted *k*-core metric's sensitivity to the structural changes of the modified model, but also that the unweighted measure is comparatively stable and unaffected by such characteristics.

In the maximum unweighted *k*-core of N2 (unweighted *k*-shell 11), we find the same 23 persons as we did in the maximum unweighted *k*-core of N1 (unweighted *k*-shell 12). In the maximum weighted *k*-core of N2 (weighted *k*-shell 14), on the other hand, we find five men,[72] none of whom were part of the maximum weighted *k*-core of N1 (weighted *k*-shell 44). That Sargon II is not included in the weighted *k*-core is a given, since his node is excluded from N2. More telling is therefore the weighted *k*-core centrality of Ṭab-ṣil-Ešarra_1 (the governor of Assur who shared the maximum weighted *k*-core with the king in N1), who dropped from weighted *k*-shell 44 (of 44) to weighted *k*-shell 10 (of 14) once the king and his ties were eliminated.

69 The woman is called Paltaṣi or Baltaṣi_1. As shown in Appendix D, Paltaṣi or Baltaṣi_1 is only included amongst the twenty most central agents identified by eigenvector centrality (in N1).

70 Of the 44 weighted *k*-shells, 32 (running weighted *k*-shells 12–44) consist of fewer than five individuals.

71 Full results can be found in Appendix D.

72 These are Arije_1 (king or Kumme), Aššūr-rēṣūwa_2 (intelligence agent), Ariazâ_1 (co-ruler of Kumme), Hu-Teššub_1 (ruler of Šubria) and Ša-Aššur-dubbu_1 (governor).

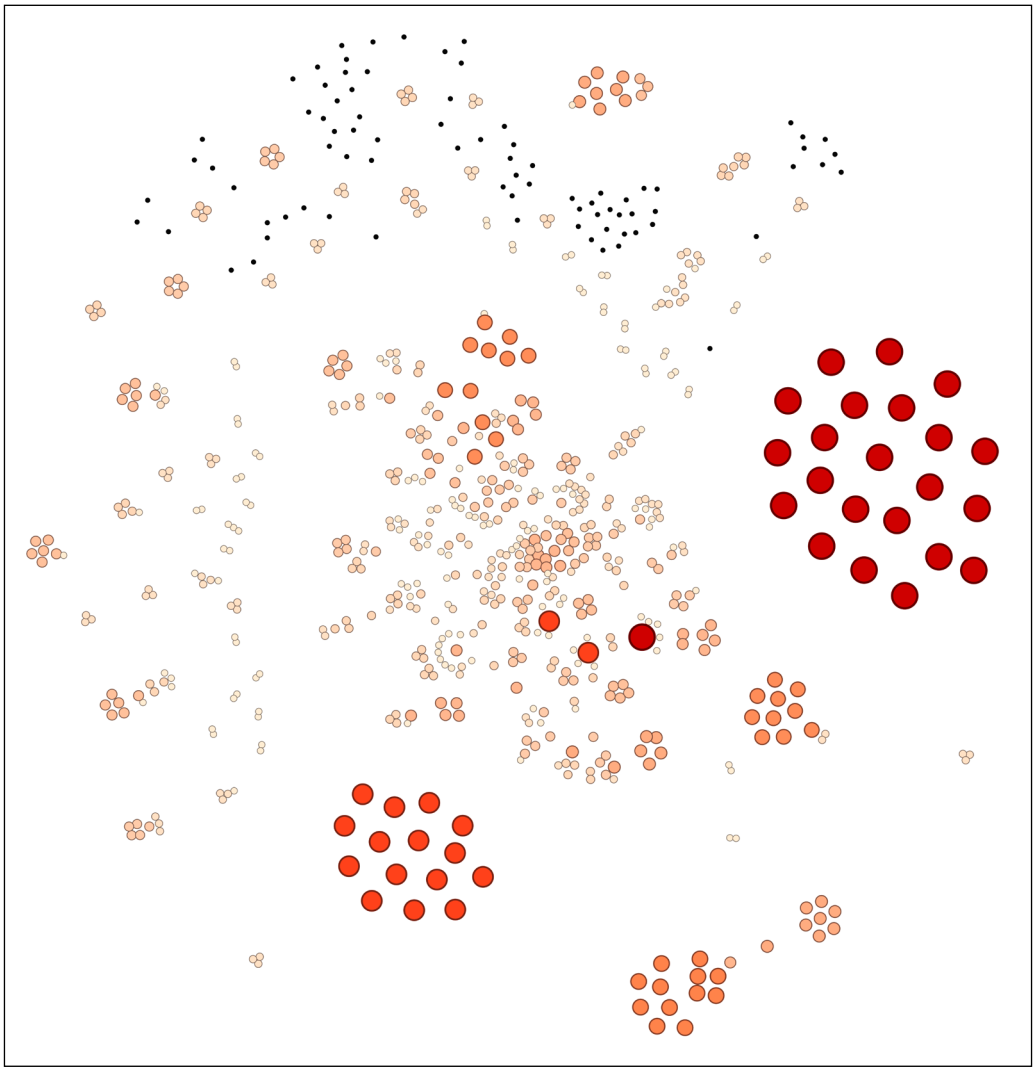

Fig. 7 Distribution of unweighted *k*-shells in Network 2. Node size reflects the 'support' shared by persons in a given *k*-shell, whereas node color intensity signals their respective '*k*-shell numbers'. Black nodes are people that became isolated from everyone else once the king was removed. Graph by L. Tambs, created in Gephi.

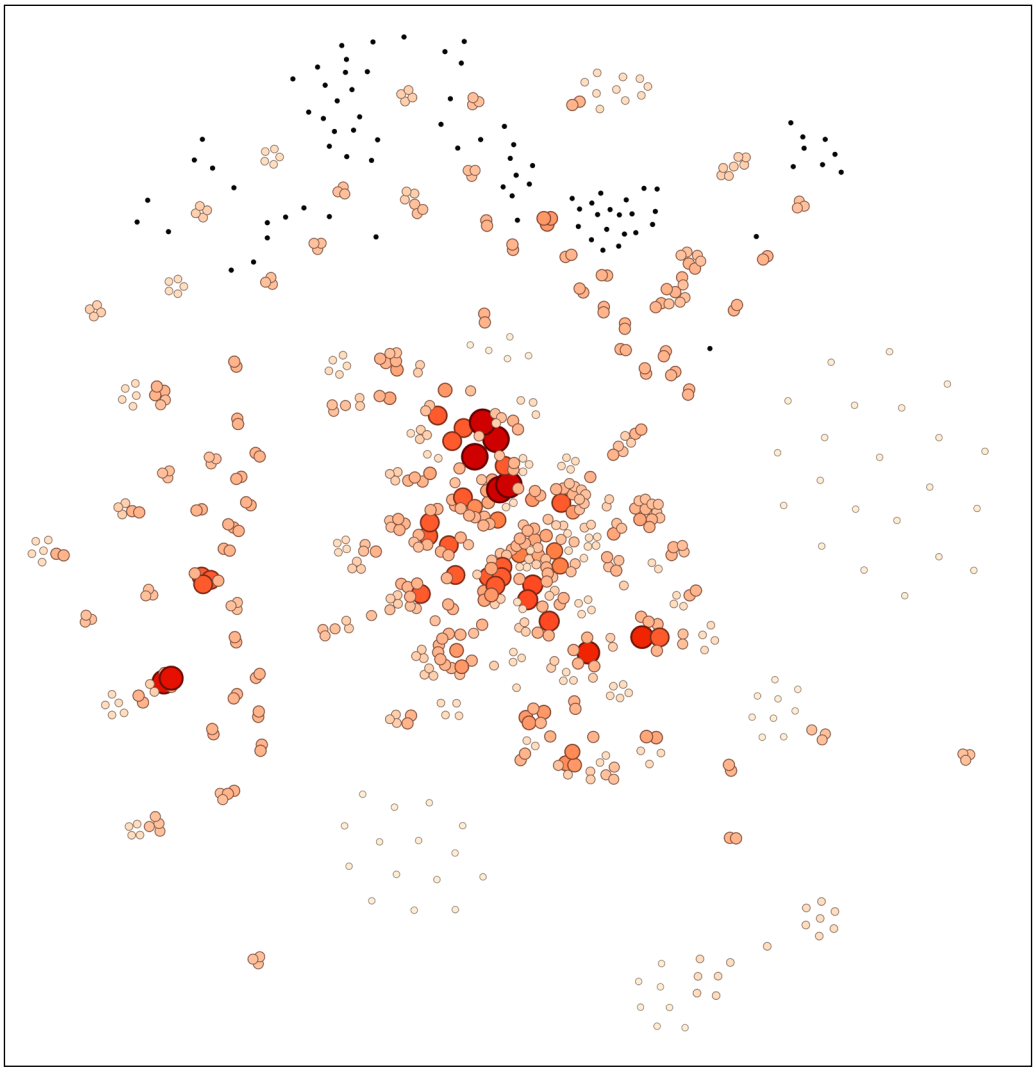

Fig. 8 Distribution of weighted *k*-shells in Network 2. Node size reflects the 'weighted support' shared by persons in a given weighted *k*-shell, whereas node color intensity signals their respective 'weighted *k*-shell numbers'. Black nodes are people that became isolated from everyone else once the king was removed. Graph by L. Tambs, created in Gephi.

Again, we also observe that more people positioned near the center of the networks' largest components are highlighted once the tie strengths are taken into account. Assuming that elite members are likely to have integrated (and/or bridging) positions in our models,[73] particularly since our data is correspondence to and from the imperial center, this suggests that the weighted *k*-core is significantly more relevant for identifying 'elite' individuals in such co-attestation networks than the unweighted *k*-core measure.

5.2 People in high and low *k*-shells

The formal network analyses presented above shed some light on individuals and groups that, if our hypothesis has any hold, are likely to have formed part of the 'elite' during the reign of Sargon II. To test this notion, we engage in a qualitative analysis of the top and bottom *k*-shells in the following section. While supplemented by network analysis, this analysis is based on the more traditional method of close reading of ancient texts, and has the aim of assessing whether those individuals highlighted by (un)weighted *k*-core are members of any of the four 'elite' groups outlined in the beginning of this study: the royal family, members of the imperial administration, the scholarly 'elite', or palace personnel.[74]

In order to gain an immediate impression as to which individuals were highlighted by the two *k*-core measures, we limited ourselves to the ten top and ten bottom individuals listed by these metrics. This means we have generated the top and bottom ten individuals for both the unweighted and weighted versions of the *k*-core measurement in both N1 and N2. However, in several of these lists the tenth position shares a *k*-shell with at least one other individual who would be in eleventh place. In these circumstances, we have included that shell in our analysis.[75]

In N1, the top unweighted *k*-shell included 23 individuals (3.133% of the overall network). As demonstrated in Fig. 5, this group is not centrally distributed in the network, and upon closer inspection the individuals were all mentioned together only once, in SAA 17 139.[76] In this letter, Šumu-ukin_3 writes to Nergal-nāṣir_3 about how silver loans were distributed amongst ten named

73 For a recent study discussing the link between individuals' social roles, eigenvector, betweenness centrality, and network position in an ancient co-attestation network, see King and Pirngruber 2022.

74 For more on Assyriological research into these groups, see section 1.

75 Full results (graphs and the highest-ranking nodes) can be found in Appendix D_SI.

76 It should be noted that Marduk-apla-iddina_1 (discussed below and in Appendix D) is included in the list of individuals according to the PNA data, but only appears in SAA 17 139 in the dating formula "*ina šatti* 2 *ša* Marduk-apla-iddina *šarru*", or "in year 2 of Marduk-apla-iddina, king" (obv. 15–16). Strictly speaking, Marduk-apla-iddina_1 should therefore not be included as an individual, but was counted as one during the

Profession Tag	Count
Family relationship	7
Unknown or not applicable	8
Ethnicity	3
Messenger	2
Official	1
Eunuch	1

Tab. 2 The 'profession' tags for the top unweighted *k*-shells in N1 and N2. As the top *k*-shell was identical, this list is representative of the results for both networks.

individuals. In the case of N2, the individuals found in the same text are also highlighted by unweighted *k*-core. But would these individuals be considered 'elite' by Assyriologists? A quick look at their 'profession' tags indicates that only two could be considered as such according to current Assyriological research: I-ma'in_1 is a eunuch,[77] and Šumu-ukin_3 (the author of the letter) is labeled as 'official' (Table 2).[78]

construction of the PNA volumes, which carried through into the PNA network data. Luckily this is the only instance of such an error in relation to Marduk-apla-iddina_1. Despite this text mentioning an unusually large number of people and his being the only node linking them to the giant component, erasing this anomaly proved to have little effect on their centrality scores (see Appendix D, esp. footnote 7). Removing this attestation of Marduk-apla-iddina_1 in SAA 17 139 results in the largest clique forming a separate connected component. Still, erasing the attestation also makes little difference for Marduk-apla-iddina_1's perceived prominence. Even when his raw centrality score changes, only minor differences to his ranked position are observed (notably for *k*-core and degree in N1 and for *k*-core, degree, betweenness and eigenvector in N2), since this is just one of the many texts in which he is mentioned. Of prime interest here is that his weighted *k*-core centrality remains the same in both models, although his unweighted *k*-core index drops from *k*-shell 12 (of 12) to *k*-shell 9 (of 12) in N1, and from *k*-shell 11 (of 11) to *k*-shell 8 (of 11) in N2.

77 Eunuchs, or *ša reši,* had a high position within Assyrian society. Their duties appear to have changed during the Neo-Assyrian period, but they consistently held a trusted position in the administration and the military of the Assyrian empire. They have fascinated Assyriologists for a long time, and this is not the space to provide an overview of such a discussion. An excellent starting point for those interested can be found in Pirngruber 2011 and N'Shea 2016.

78 These tags were taken from Jauhiainen and Alstola 2022.

The bottom ten results according to unweighted *k*-core in N1 and N2 are much longer and more diverse. The lowest *k*-shell in N1 includes 103 individuals, who have twenty profession tags. The most common profession tag in this list is 'official' (35 individuals), followed by 'Unknown or not applicable' (22 individuals), and 'Military personnel' (12 individuals, as seen in Table 3). Others include 'City mayor/overseer', 'Major-domo', and 'Member of the elite' – all of whom Assyriologists would consider as members of the 'elite'. The fact that they receive very low unweighted *k*-shell indexes indicates that unweighted *k*-core centrality has limited applicability for highlighting 'elite' groups from a qualitative perspective.

The situation is the same for N2's lowest unweighted *k*-shell, which has 156 individuals and 23 professions tags. This time there is even more overlap between who is at the bottom of the list and individuals whom Assyriologists would consider elite, as the profession tag 'Official' occurs 49 times on this list. The next highest tag is 'Unknown or not applicable' (31 individuals), followed by 'Military personnel' (14 individuals).

For both N1 and N2, it is difficult to find an overall pattern as to who is likely to be found in the lowest unweighted *k*-shell, but it is clear what unweighted *k*-core highlights in our co-attestation networks for Sargon II: relatively large groups of individuals who are mentioned in a single text together. Whilst this is probably a useful outcome for some research projects, these lists further emphasize the need to take the weights of the ties into account for *k*-core centrality for our purpose of assessing whether this measure can identify an 'elite' group.

In N1, the top ten individuals according to weighted *k*-core span the *k*-shells 44–36. As demonstrated in Fig. 6, there is a dramatic shift in where these shells are distributed in the co-attestation network – they are now much more central in comparison to the unweighted *k*-core results (Fig. 5). Inspecting the list of who is in the top weighted *k*-shell in Table 4, the reason for this new distribution is clear. As expected, the top weighted *k*-shell includes Sargon II, the king of Assyria, which immediately indicates the weighted *k*-core is identifying a group that is more aligned with an Assyriological idea of 'elite'. Underscoring this are four governors, the Treasurer Ṭab-šar-Aššur_1, and the Crown Prince Sennacherib. Again, these are people who all align with Assyriological research as those who were considered part of the 'elite': those in the imperial administration and royal family.

In N2, we see a similar shift in the distribution of the top weighted *k*-shells (14–11) to a more central position than in the unweighted version (cf. Fig. 7 and Fig. 8). The removal of Sargon II has a dramatic effect on who is highlighted according to our weighted version of *k*-core – there is only one person in the top *k*-shells who is also in the top *k*-shells of N1: Aššūr-rēṣūwa_2, an official who sent reports to the king about Kumme to the north of Assyria. He shares the top weighted *k*-shell with four others: Ariazâ_1 (a co-ruler of Kumme), Arije_1

N1		N2	
Profession	**Count**	**Profession**	**Count**
Official	35	Official	49
Unknown or not applicable	22	Unknown or not applicable	31
Military personnel	12	Military personnel	14
Ethnicity	9	Ethnicity	12
Family relationship	4	Non-Assyrian ruler	9
Member of elite	4	Governor	8
Non-Assyrian ruler	3	City mayor/overseer	5
Governor	2	Temple personnel and cultic professionals	5
City mayor/overseer	1	Informant/agent	3
Dependent	1	Messenger	3
Enemy of Assyria	1	Court and palace personnel	2
Eunuch	1	Craftspeople	2
Informant/agent	1	Horse and donkey carer	2
Major-domo	1	Tribe/clan member	2
Messenger	1	Builder	1
Owners of property	1	Criminal	1
Prefect	1	Delegate/emissary	1
Servant	1	Dependent	1
Temple personnel and cultic professionals	1	Enemy of Assyria	1
Worker	1	Eunuch	1
		Family relationship	1
		Member of elite	1
		Owners of property	1

Tab. 3 The count of profession tags in the bottom unweighted *k*-shell in N1 and N2, organized according to frequency.

N1			N2		
Name	**shell**	**Short Description**	**Name**	**shell**	**Short Description**
Šarru-ken, Šarru-ukin_2	44	Sargon II, King of Assyria.	Ariazâ_1	14	Co-ruler of Kumme.
Ṭab-ṣil-Ešarra_1	44	Governor of Assur, eponym of the year 716.	Arije_1	14	King of Kumme.
Ṭab-šar-Aššur_1	43	Chief Treasurer.	Aššūr-rēṣūwa_2	14	High-ranking intelligence agent based in Kumme reporting on Urarṭian activities.
Šamaš-belu-uṣur_4	42	Governor, reported on enemy activities to the king.	Hu-Teššub_1	14	Assyrian vassal, ruler of Šubria.
Nashir-Bēl or Nashur-Bēl_3	41	Governor of Amedi and Sinabu and eponym of the year 705.	Ša-Aššur-dubbu_1	14	Governor of Tušḫan and eponym for the year 707.
Šarru-emuranni_6	40	High military official active in Babylonia.	Aššūr-ālik-pāni_1	13	Official on Assyria's northeastern frontier.
Šulmu-beli_4	39	Deputy of the Palace Herald. Among his duties was the surveillance of the Urarṭian border and of the minor independent states in the region.	Nergal-šarrāni_1	13	Official active on the north-eastern frontier of Assyria.
Ašīpâ_3	38	Governor in the northern part of the Assyrian empire, possibly in the city of Tidu.	Aššūr-bēlu-taqqin_7	12	Governor of a location east of the Tigris on the frontier of Babylonia.
Aššūr-rēṣūwa_2	37	High-ranking intelligence agent based in Kumme reporting on Urarṭian activities.	Marduk-apla-iddina_1	12	Babylonian rebel.
Sīn-ahhē-erība_1	36	Sennacherib, Crown Prince of Assyria.	Il-iada'_1	11	Assyrian official active in northern Babylonia.
			Nabû-bēlu-ka"in_1	11	High Assyrian official operating in the Diyala region and governor of Kar-Šarrukin.
			Nabû-iqīša_1	11	Official active in eastern Babylonia.

Tab. 4 Top ten individuals highlighted by weighted *k*-core in N1 and N2.

(the king of Kumme), Hu-Teššub_1 (a vassal ruler), and Ša-Aššur-dubbu_1 (the governor of Tušḫan). By removing the Assyrian king, it appears our version of weighted *k*-shell has highlighted individuals who demonstrate another group: *non-Assyrian* 'elites'. Foreign kings and vassal rulers are in the top *k*-shell, but it should be noted that this was not the case for *k*-shells 13–11, which were populated by Assyrian officials operating in Babylonia and in the northern regions of the empire. These individuals also align with previous Assyriological research into 'elite' groups in the Neo-Assyrian period, as they are all members of the imperial administration; nonetheless, the effect of removing Sargon II should be noted.

To ensure this was not a fluke of the data, we also checked the lowest weighted *k*-shells. In N1 the lowest weighted *k*-shell (1) included 57 individuals who had varied professions tags. Upon closer inspection, the lowest shell represents the co-attestations of five texts: SAA 5 100 (a report from Aššūr-rēṣūwa_2 about the movements of six Kummean smugglers), SAA 15 181 (Aššūr-bēlu-taqqin_7 writes to the king with a report of the 35 people under Hazānu_3's control after being asked to account for them all), SAA 15 199 (which details a plot to take a city called Darati from Marduk-apla-iddina_1 for Sargon II), SAA 17 139 (the letter discussed previously about silver loans), and SAA 17 150 (11 sheikhs from Tubliaš writing to the Chief Tailor[79] asking for military aid). The individuals in these texts include five criminals, five deportees, and one herder. In N2, the bottom weighted *k*-shell includes the same people as those in the lowest weighted *k*-shell of N1,[80] but with the addition of Anu-[...]_1.[81] This is because Anu-[...]_1 in N1 is connected to both those in the text as well as Sargon II, whereas the others in SAA 17 150 were only connected to each other. In N2, when Sargon II was removed, the connection between the king and Anu-[...]_1 was severed, and he was pushed into the lowest *k*-shell.

The preliminary results of the individuals in the top and bottom *k*-shells (weighted and unweighted) indicated that weighted *k*-core did indeed highlight a group who Assyriologists would consider to be part of the 'elite'. The final stage was to investigate this highlighted group in N1 in more detail to confirm our initial hypothesis.[82]

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79 In the text, the title is given as LÚ.GAL-KA.KEŠ (*rab kiṣri,* obv. 8). Groß describes this as an honorific title that is not related to the "House of the Tailor", but to a state office in Babylonia that had experience in military logistics (Groß 2020: 177, 215–226).

80 The 81 isolates in N2 due to the removal of Sargon II did not receive a *k*-shell index, and their professions span from officials to simply being known by their family (see section 4.1). As they did not receive a *k*-shell index, we do not include them in this analysis of the results, but hope to return to them in a future publication.

81 For this person and the rarity of such instances in our data, see also Appendix D.

82 We note that simply counting the number of attestations of a person provides a top 10 list of names, where 7 are also mentioned in the weighted *k*-core top 10 of N1. The di-

6. Qualitative analysis of the top ten in Network 1

In this section, we perform a qualitative analysis of the top ten individuals in N1 highlighted using our weighted *k*-core measure (Table 5).[83] The main goal of this section is to better understand who these people were, and why our weighted version of *k*-core highlighted them. We can then assess whether this group has a unifying feature that could align them to one of the 'elite' groups identified by Assyriological scholarship as outlined in section 1 (the royal family, members of the imperial administration, scholarly 'elite', or palace personnel).

Sargon II (Šarru-ken, Šarru-ukin_2) was the king of Assyria (721–705 BCE), and appears in weighted *k*-shell 44, the highest in the network. This makes sense when regarding his position both within the network (Figs. 3 and 6), but also when looking at the text corpus as a whole. The texts that formed the basis of our co-attestation network were exclusively letters, which were mostly found in the palace archives of Assyrian capitals: Kalḫu and Nineveh.[84] They would naturally be written either to or from the king, or those who had interests in the palace. As such, the Assyrian king would naturally be attested in almost all of the texts. As our weighting scheme sums the scores of every 'share' of an 'event' (or a text), it is only natural that the king would have a high weight, and thus appear in the highest weighted *k*-shell.

Ṭab-ṣil-Ešarra_1 shares the top weighted *k*-shell with Sargon II (weighted shell number 44), and was the governor of the city Assur.[85] Ṭab-ṣil-Ešarra's position in Assur was symbolically important, as he was governing the old seat of power in Assyrian society.[86] Beate Pongratz-Leisten has pointed out that Ṭab-ṣil-Ešarra's activities involved religious tasks that normally required the physical presence of Sargon II in Assur, but the demanding Assur elites meant king Sargon II avoided visiting the city as much as possible.[87] Such an important position would have required close supervision by Sargon II, thus requiring a large amount of reports from Ṭab-ṣil-Ešarra to Sargon II.[88] In addition, he would send reports about vis-

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vergence between the ordered list of attestation counts and the ordered list of weighted *k*-core co-attestations increases when additional positions are considered. The attestation count is not sensitive to removing the king, so the top 12 names in the co-attestation network N2 only have 6 persons in common with the top 12 attestation counts without the king.

83 We hope to return to these results and compare what we found in N1 and N2 in a future publication.

84 See footnote 27.

85 Jones 2021: 453–4.

86 May has suggested that the position of Governor of Assur was given to Ṭab-ṣil-Ešarra by Sargon II as a reward for his role in bringing Sargon II to power (May 2015: 82).

87 Pongratz-Leisten 2015: 332.

88 The correspondence from Ṭab-ṣil-Ešarra constitutes an entire chapter in SAA 1 (SAA 1 75 to 109).

Name	Weighted *k*-shell	Short Description
Šarru-ken, Šarru-ukin_2	44	Sargon II, King of Assyria.
Ṭab-ṣil-Ešarra_1	44	Governor of Assur, eponym of the year 716.
Ṭab-šar-Aššur_1	43	Chief Treasurer.
Šamaš-belu-uṣur_4	42	Governor, reports on enemy activities to the king.
Nashir-Bēl or Nashur-Bēl_3	41	Governor of Amedi and Sinabu and eponym of the year 705.
Šarru-emuranni_6	40	High military official active in Babylonia.
Šulmu-beli_4	39	Deputy of the palace herald. Among his duties was the surveillance of the Urarṭian border and of the minor independent states in the region.
Ašīpâ_3	38	Governor in the northern part of the Assyrian empire, possibly in the city of Tidu. Tasked with protecting the Assyrian-Urarṭian border, he has to take care of the people in the region and supply the king with all the useful things the area offers.
Aššūr-rēṣūwa_2	37	High-ranking intelligence agent based in Kumme, reporting on Urarṭian activities.
Sīn-ahhē-erība_1	36	Sennacherib, Crown Prince of Assyria.

Tab. 5 The top ten individuals according to weighted *k*-core in NI. Included are the names in the format of the PNA data, their weighted *k*-shell number, and a shortened version of the PNA entry for each person. Where more than one person occupies a *k*-shell, they are given in alphabetical order.

itors who traveled through Assur on their way to visit the king.[89] As Ṭab-ṣil-Ešarra was reporting on events in and around Assur to the king,[90] as well as the movement of people through this important Assyrian city, this would result in a high weighted *k*-core score.

Ṭab-šar-Aššur_1 is in the weighted *k*-shell number 43, and was the *masennu rabiu* ("Treasurer") of the empire.[91] Ṭab-šar-Aššur appears in the eponym list before Ṭab-ṣil-Ešarra, which by Assyriological standards means he must have had a higher status within the Assyrian administration in order to be given such an

89 SAA 1 84–89; Jones 2021: 459.
90 Jones 2021: 462.
91 The *masennu rabiu* was identified as one of the seven highest officials in the empire in Mattila 2000: 15, 19–28.

honor.[92] This is reflected in the activities he carried out, which included inspecting goods and work assignments to palaces and temples in several cities, and passing on intelligence about Kumme to the king.[93] He was also heavily involved in the construction of Sargon II's new capital city Dur-Sharrukin, ensuring all the materials for the construction of this vast new project were available.[94] As he was constantly corresponding back and forth with the Assyrian king, this increased his weighted degree and therefore put him in the second-highest weighted *k*-shell.[95]

Šamaš-belu-uṣur_4 was the governor of Arzuhina and then Der, and was in weighted *k*-shell number 42. During his time as governor of Arzuḫina, he was identified as a key center of information for reporting to the king about the territories of Arrapḫa, Mannea, and Mazamua.[96] In his correspondence to Sargon II, he passed on first hand reports about activities in these regions.[97] This position was clearly important, as he was given an eponym in 710.[98] However, soon afterwards, he then became the governor of Der.[99] In this latter position, his correspondence makes it clear that his role was now to keep watch and monitor developments with the Elamites.[100] Reporting on these border regions and monitoring them for rebellions or hostile activities meant writing many reports to the king to discuss individuals who were also interconnected in the network. This is the reason for his high weighted *k*-shell rank.

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92 Millard 1994: 46–47; May 2015: 80–81; Jones 2021: 431–432.
93 Dubovský 2006: 50; Pongratz-Leisten 2015: 330.
94 May 2015: 81–82; Jones 2021: 435–436; SAA 1 62, 63.
95 Ṭab-ṣil-Ešarra_1 had a weighted degree of 23.33334 and Ṭab-šar-Aššur_1 had a weighted degree of 21.666672. These results can be contrasted with their rankings in Jones 2021, who used Bonacich centrality to identify individuals in Assyrian correspondence networks who held the 'soft power' in the empire. In his dissertation, Ṭab-šar-Aššur_1 ranked 10th overall, but Ṭab-ṣil-Ešarra_1 ranked 386th out of 386 individuals (Jones 2021: 421–423). Part of the disparity between the two is because Jones' networks were directed, and only recorded who sent and received correspondence. Ṭab-šar-Aššur_1 sent and received letters and reports and wrote about them to and from Sargon II, whereas Ṭab-ṣil-Ešarra_1 talked to people and reported about the conversations to the king, i.e. they were both the eyes and ears of the king. Jones looked at senders and receivers of correspondence, so Ṭab-šar-Aššur_1 was considered more important as a documented receiver of correspondence. In comparison, our undirected dataset looks at all the attestations of persons in the correspondence, so we pick up both persons as equally important. Because our methodology appears to also pick up on people talked about or passing information through middlemen, it recognizes that Ṭab-ṣil-Ešarra_1 was still actively involved in maintaining the Assyrian empire as one of the 'eyes and ears' of the king.
96 Dubovský 2006: 267.
97 Dubovský 2006: 264.
98 Millard 1994: 47.
99 PNA 3/II: 1193.
100 PNA 3/II: 1194; for example, see SAA 15 112–115.

Nashir-Bēl or Nashur-Bēl_3 was the governor of Amedi and Sinabu, and was in weighted *k*-shell 41. According to the PNA entry, his main concerns in correspondence with the king were the activities of the region of Urarṭu and the transportation of logs from his province.[101] Just like Šamaš-belu-uṣur_4, the reason for his high weighted *k*-shell rank was due to his monitoring of a potentially hostile neighbor of Assyria.

Šarru-emuranni_6 in the PNA data was a military official acting in Babylonia, and was in weighted *k*-shell forty.[102] Šarru-emuranni_6 sent reports to Sargon II about a wide range of topics in Babylonia, including mentions of the Babylonian rebel Marduk-apla-iddina_1.[103] Already we are seeing a pattern that those in the top ten according to weighted *k*-core were those who monitored key border regions neighboring Assyria that could pose a major threat if they became hostile.

Šulmu-beli_4 was the Deputy of the Palace Herald,[104] and was in weighted *k*-shell number 39. Curiously, the Palace Herald (Gabbu-ana-Aššur_1) was not in the top ten list according to weighted *k*-core. He was in weighted *k*-shell number 26 out of 44, ranking 23rd out of 734. So why was Šulmu-beli's weighted *k*-core rank higher? The answer, we believe, lies in the now familiar description of his duties: he surveilled the Urarṭian empire and reported their activities to the king.[105]

Ašīpâ_3 was in weighted *k*-shell number 38, and although no text preserves his official titles, Bradley Parker has suggested he was the provincial governor of Tušḫan, close to Urarṭu. His role was partly to oversee the economic matters of the province, but also to report on the military and security issues of the border.[106] All of the preserved documents that contain his name are correspondence directly with the Assyrian king, indicating his reports were of significant importance to the running of the empire.[107] Again, we have another individual sending reports on the activities of a neighboring hostile region directly to the king in the top ten according to our weighted *k*-core measure.

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101 PNA 2/II: 932. Nashir-Bēl has not been the subject of much scholarship, and as such this entry relies on the PNA.

102 He has been disambiguated from Šarru-emuranni_4, who was the governor of Mazamua and eponym of 712. However, Stephanie Dalley and Nicholas Postgate suggested these two men were the same (Dalley & Postgate 1984: 172–173). If this is the case, then in future work this individual may need to be merged with Šarru-emuranni_4.

103 PNA 3/II: 1235–1236; SAA 15 218, 219. This person is described in more detail below and in Appendix D.

104 Dubovský 2006: 63.

105 Dubovský described how he monitored the territory of Muṣaṣir and received the Urartian king's brother (Dubovský 2006: 62–63).

106 Parker 2009: 181–183; Dubovsky 2006: 34, 36.

107 Parker 2009: 181.

Aššūr-rēṣūwa_2 was in *k*-shell number 37, and has already been identified in prior Assyriological work as a major link in the chain of intelligence for the king. Karen Radner identified him as an Assyrian official titled a ^{lú}*qepu* in a region called Kumme, which was on the border of the hostile neighbor Urarṭu.[108] He sent reports to Sargon II and Sennacherib (the Crown Prince) about Kummean activities, and was an important center in the communications network in that region of the empire.[109] Here we have another center of intelligence who has been highlighted by our weighted *k*-core scheme.

Sīn-ahhē-erība_1 (Crown Prince Sennacherib), on first glance, seems to break the established pattern of weighted *k*-core highlighting intelligence operatives and reporters. However, a closer look at his activities demonstrates he still conforms to the established pattern. Sennacherib's role as Crown Prince in Assyria involved actively aiding his father in running the empire, including military and administrative activities.[110] Part of his administrative duties was receiving and passing on intelligence reports from the likes of Aššūr-rēṣūwa_2, Kummean kings, and provincial rulers.[111] As with the other individuals in the top ten highlighted by weighted *k*-core, many intelligence reports had to pass through his hands in order to reach the Assyrian king.

From this qualitative analysis of N1, we can conclude that weighted *k*-core applied to our small slice of the PNA network has highlighted individuals who were the most important for passing on intelligence to the Assyrian king. Even Ṭab-ṣil-Ešarra_1 and Ṭab-šar-Aššur_1, respectively the Treasurer and the Governor of Assur, can be thought of in this manner, even though they are reporting on the goings-on within the Assyrian heartland. This activity seems to be a key duty for many in high offices in the empire, and therefore they can be said to be a group that is part of the imperial administration, which traditional Assyriological research has also established was an 'elite' group. However, it should be noted that those highlighted by weighted *k*-core certainly did not represent all of the 'elite'. Those working in the household,[112] the court,[113] royal family,[114] scholars,[115] and generals[116] are missing. We cannot describe the highlighted individuals as representative of all those who encompass the 'elite', but their importance in passing on information – particularly oral information only obtained in

108 Radner 2014: 86.
109 Dubovský 2006: 51, 63, 267.
110 Elayi 2018: 29–42.
111 SAA 1 29; Dubovský 2006: 57–58, 266.
112 Groß 2020.
113 Mattila 2000; Pirngruber 2011; N'Shea 2016; Groß and Pirngruber 2014.
114 May 2017; Svärd 2015.
115 An excellent overview of issues regarding studying ancient Mesopotamian scholars can be found in Radner and Robson (eds.) 2011.
116 Mattila 2000: 107–125.

face-to-face meetings – to the king certainly meant they were a part of this group due to their active participation in maintaining and upholding Assyrian concerns in their regions.

This would be a nice final conclusion if it weren't for a single fly in the ointment. Marduk-apla-iddina_1 was ranked 11th according to the weighted *k*-shell metric in N1, but was included in the top weighted *k*-shell of N2. When we conducted robustness tests, he consistently ranked among the top five individuals in the four centrality measures against which we tested weighted and unweighted *k*-core.[117] Considering our previous conclusions, one might assume this individual actively engaged in activities that maintained Assyrian hegemony across the empire, particularly since those ranked 12th to 15th continue the trend seen in ranks 1–10.[118] However, Marduk-apla-iddina_1 was a key antagonist in Assyrian history, claiming the throne of Babylon at the beginning of Sargon II's reign and instigating a long-lasting rebellion that continued into the reign of Sargon II's successor Sennacherib.[119] This was someone who was not interested in maintaining Assyrian hegemony in Babylonia, so why was he ranked amongst those who were?

The presence of anti-Assyrian Marduk-apla-iddina_1 in the top results for weighted *k*-core amongst the pro-Assyrian officials and vassals quite rightly raises the question of what weighted *k*-core highlights. Since he does not fit the pattern established by the other individuals in the top 15 of weighted *k*-core, one solution would be to simply remove him from the network. However, this would go against a key question we had for this study: what does the weighted *k*-core highlight? By removing one figure who does not meet our expectations of an Assyrian 'elite', we start to impose our preconceptions and assumptions on our data and results. In order to avoid this, and to minimize the amount of assumptions we imposed on our data, Marduk-apla-iddina_1 remained in our data. The presence of this individual who went against the established pattern in the top 15 forced us to critically assess what weighted *k*-core was highlighting in our co-attestation network.

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117 See Appendix D. As is reflected in Fig. 4 – where he is represented by the rightmost node of noticeably larger size, with ties to the largest clique and others – he is only one of several people bridging different parts of the giant component of N2. As such, he upholds a very different network position and function in N2, compared to the king in N1.

118 12th was Na'id-ilu_5, the Chief Cupbearer of Sargon II, who reported on the movements of Urarṭian emissaries and construction works in his province (PNA 2/II: 916–917). 13th was Aššūr-bāni_5, the Governor of Kalḫu, who oversaw construction projects and reported on their progress to the king PNA 1/I: 158–159. 14th was Šarru-emuranni_4, the Governor of Mazamua, a province bordering the Zagros regions. His correspondence reflects this, and is full of reports on the activities of those in this area (PNA 3/II: 1234–1235). The weighted *k*-shell 31 was shared by Il-iada'_1 and Nabû-bēlu-ka"in_1, officials in the Diyala region and who reported on military activities and irrigation in the region (PNA 2/I: 515–516; PNA 2/II: 815–817). Nabû-bēlu-ka"in_1 also reported the activities of Elamites to Sargon II (PNA 2/II: 815–817).

119 Beaulieu 2018: 198–203.

After investigating the network structure and the texts the PNA data is based on, we suggest his high ranking was due to the many intelligence reports that wrote about and discussed Marduk-apla-iddina_1 and his allies, which were then sent to Sargon II. This connected him to many other individuals attested as his allies, and many agents or officials across the empire would need to report on him. With regards to weighted *k*-core, since Marduk-apla-iddina_1 was such a great threat to Sargon II, Assyrian agents had to send many reports on his movements and the actions of his allies. Marduk-apla-iddina_1 was not someone who was writing many reports to the king, and therefore was not in a role that upheld Assyrian hegemony, but he was the *subject* of many reports. This would necessarily mean he would be highlighted by weighted *k*-core due to the sheer number of individuals reporting on his activities to Sargon II. In terms of our weighting scheme, Marduk-apla-iddina_1 shares many 'events' with a minimum of 3 individuals present.[120]

With this in mind, we suggest that weighted *k*-core in the co-attestation network of Sargon II (based on PNA data) highlights those who were actively involved in maintaining the Assyrian hegemony through administratively running the empire, but also individuals who were key subjects of many intelligence reports.

7. Conclusions

In sum, a weighted version of *k*-core centrality used on a co-attestation network consisting of correspondence from the royal archives during the reign of the Assyrian king Sargon II highlighted individuals who passed on intelligence to the king, as well as those who were frequently discussed in the correspondence. The group relaying this information were not on-the-ground spies, but officials who maintained Assyrian interests in the regions under their jurisdiction. As such, this broadly aligns with the officials mentioned in the introduction as the second elite group identified by previous Assyriological research.[121] Furthermore, our method highlights those who this elite group were overly concerned about, such as hostile actors working against Assyrian interests like Marduk-apla-iddina_1. That our results do not differ from traditional Assyriological research suggests our proposed method has potential for identifying 'elite' groups in other historical co-attestation networks.

120 For this terminology, see section 3.

121 For an overview, see section 1. One strength of the method is that it identified numerous people well-known to Assyriologists, but also shed light on less studied people, like Nashir-Bēl or Nashur-Bēl_3, as explained in section 6 and footnote 101.

We were in a unique position where we could test whether our results would be different if we had more data, or if our results were primarily due to the structure of the networks. After performing our initial analysis on texts from SAA 1, 5, and 15, we increased our dataset by 118 texts (a 19.37% increase in data).[122] That the results presented were largely the same as in this preliminary study, and only differed once we removed Sargon II from N1, suggests that the discussed network is based on a representative selection of texts from the period. Adding more (similar) texts are thus likely to emphasize the position of the king and the elite group identified.

Focusing on the larger dataset and comparing the top *k*-shells of N1 (including Sargon II) with those in N2 (without Sargon II), we gained an indication of who was specifically influential due to Sargon II, and who was influential despite Sargon II. Moreover, the robustness tests indicate that the non-influential bulk of the attested individuals remains in the lowest *k*-shells. In this study, we did not pay much attention to the mid-shells of the network. It would be interesting to investigate these to find the *k*-shells of the remainder of those considered 'elite' by scholars of Assyriology, such as members of the royal family (other than the Crown Prince), palace personnel, courtiers, scholars, priests, or temple personnel. They are likely included beyond the top ten results discussed here. However, it is clear that this initial study only highlighted a specific elite group, whose duties were – at least in part – to report on activities throughout the Assyrian empire.

In general, our method needs co-attestation data from the members of a large network. Based on this data, the method can be used to highlight the members constituting an elite group with an interest in running the network, as well as the individuals whom this elite group is concerned with.

Upon reflection, we believe our results were due to two factors. The first is our weighting scheme, which whilst relatively simple and imposing as little bias on the dataset as possible, also achieved meaningful results from a qualitative perspective. The second is the very nature of co-attestation networks. As they were built upon individuals who were mentioned together in the same text, the networks gave us a glimpse of the social relationships 'on the ground', including information about face-to-face meetings. Such meetings would not have been preserved in all types of networks, such as correspondence networks that only recorded the senders and receivers of texts, and as such should be seen as a strength of co-attestation networks.

Despite our success with weighted *k*-core centrality for our data from the reign of Sargon II, there are some limitations with regards to the interpretation of the

122 See section 2 and footnote 34. For a list of the texts, see Appendix C.

results. Most are due to the nature of the source material, which included a large number of intelligence reports written by and for the imperial elite. For the texts selected for this study, it is unsurprising that the method highlights those who were substantially involved in such activities. The source material also necessarily means that communication between key social groups throughout the empire is not reflected in the networks, as the texts were only reflective of imperial interests. Any social structures of communication between groups in different parts of the empire are therefore not included – although this is also the case for traditional close-reading approaches. The PNA co-attestation networks also do not preserve the direction of the letters – i.e. whether they were correspondence sent to or from the king. We are curious to explore in future studies what impact this would have on our results.

Throughout the process of writing this paper, we found ourselves faced with many interesting aspects of the results which we had no space to discuss. We aim to fully discuss the qualitative analysis for N1 and N2, and whether there is a meaningful difference in who weighted *k*-core highlights within them, in a future publication. We also believe there is potential for exploring this method with different datasets. Applying the method to the PNA data from the reign of Esarhaddon will likely produce different results, particularly since there is a much higher representation of court scholars from this time.[123] In addition, the method could be applied to the entire PNA dataset. This much larger dataset offers the opportunity to play with the granularity of the weighted *k*-shells, and might result in a multi-component *k*-core. We wonder if this would identify any salient features in groups across the Neo-Assyrian period, which might in turn aid discussions and research of Neo-Assyrian elites more generally. Furthermore, non-Assyrian datasets, such as the bilingual family archive of Peteharsomtous, son of Panebchounis – living off agricultural, military and religious obligations, as well as private business, in the small town of Pathyris in Upper Egypt during the 2nd-1st cent. BCE – might shed additional light on the nature of weighted *k*-core centrality and its applicability to ancient network data.[124]

123 As given in footnote 6, see Parpola 1993, Luukko 2007, Radner 2009; overviews can also be found in Heeßel 2017 and Fincke 2017.

124 For the archive, see esp. Pestman 1965 and Vandorpe and Waebens 2009: 163–189. For the texts and last owner viewed through an SNA lens, see Tambs 2022: esp. 183–195 and 396–408. With 117 associated documents representing various text types, it constitutes the largest archive from Ptolemaic Pathyris. In addition to their different cultural and social context, geographical extent, etc., it would be interesting to test the weighted *k*-core measure on other network types with different structural characteristics. Although the archive is centered around this person and his family, the 1-mode interpersonal network (with people linked by social and economic ties) extracted from it is less centralized, with no one node dominating the network, as Sargon II does here in N1 (cf. Fig. 3 above with Tambs 2022: Models 15 and 87).

Abbreviations

RINAP 2/1 = Frame 2021
SAA 1 = Parpola 1987
SAA 5 = Lanfranchi & Parpola 1990
SAA 10 = Parpola 1993
SAA 15 = Fuchs & Parpola 2001
SAA 17 = Dietrich 2003

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Appendix A: Zenodo

In order to aid replication and exploration of our method, we have uploaded a series of documents and digital files to the digital repository Zenodo, including data files and three further appendices.

Data files included in the Zenodo repository:

- The networks, saved as .gexf files
- High-resolution images of the network visualizations, as well as labeled versions of Figs. 5–8, saved as .png image files
- Supporting information (Appendix D_SI) for the robustness tests, saved as an .excel file

Appendices included in the Zenodo repository:

- Characteristics of the network Models and analysis of N3 (Appendix B)
- A list of texts included in the data as an .excel file (Appendix C)
- Robustness tests of six centrality measures (Appendix D)

The repository can be accessed via the following URL: https://doi.org/10.5281/zenodo.12567509.