

On Connecting Stamps – Network Analysis and Epigraphy

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Résumé

L'analyse des réseaux, qui est à la fois une méthode et une théorie, vise à explorer les relations inhérentes aux données archéologiques. Dans cet article, je m'intéresse aux sources épigraphiques qui sont porteuses de liens sociaux manifestes et qui permettent, si on les envisage du point de vue archéologique, de discerner de nouvelles relations. J'en donne l'exemple à travers deux courtes études de cas traitant de briques romaines estampillées découvertes dans la vallée du Tibre. L'analyse des réseaux ne cherche pas à prouver une théorie particulière à partir de ces données mais à les considérer d'une nouvelle manière pour produire de nouvelles connaissances. Quand d'autres ensembles, archéologiques plutôt qu'épigraphiques, seront étudiés, elle intégrera sans mal la boîte à outils de l'archéologue.

Introduction

Network analysis in archaeology is a growing method for rigorously examining the interplay of relationships across space and time, within a formal theoretical framework (Brughmans 2010, 2012, 2013). Most archaeological network analyses operate on local or regional scales, creating nodes from sites and links (or edges) based on some measure of similarity of artefact assemblages (as for instance Mills *et al.* 2013). Alternatively, some archaeological network analyses draw the connections between sites based on measures of geographic proximity, as in for instance proximal point analysis (e.g. Collar 2013; Blake 2013). In this paper, I suggest that one of the richest skeins to unpick for network analysis in archaeology should naturally be that branch of archaeology wherein social relationships are at their most clear: epigraphy. Epigraphic materials, especially in the Roman world, are dense with multi-dimensional data that can be examined through space and time. A network analysis framework is one way of visualizing and analyzing those patterns. I first demonstrate how one could begin to reconstruct some aspects of social experience from the *dominius - officinator* relationships recorded in Roman stamped bricks. I then explore another aspect of the multi-dimensionality of stamped bricks through a consideration of the relationship of the figurative devices, the *signa*, to the texts of the stamps, to explore something of the logistics of the industry. Neither brief case study is meant to be exhaustive or definitive; rather my purpose is to illustrate what can be achieved quite quickly by network analysis on what ought to be low-hanging fruit for archaeological network analysis, and to encourage other scholars to begin to explore the method.

Named individuals in stamped bricks

Stamps on bricks in the city of Rome and its hinterland are, especially by the second century, extremely dense with information. There can often be an indication of the brick maker, the land owner, the estate, and the year. There are a range of standard shapes and internal arrangement of the epigraphic data (semi-circular or circular shape, with a small or large *orbiculus* on the edge of the stamp, with text in one,

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two, or three rows). There can often be a figurative device (the *signum*) in the centre. Consider also the physicality of the brick itself. Its fabric may be studied for provenance. The findspot of the brick may be compared with the findspots of other bricks carrying the same stamp, or having been made from the same clay source. All of these elements can be combined into a network where a single node exists in a multiplicity of dimensions – networks of exploitation, of production, of power, of construction (Graham 2006). While it is computationally possible to deal with such *multigraphs*, it may be more tractable and comprehensible to deal with one dimension of the information present in stamped bricks at a time (cf. Weingart 2011).

Let us begin by considering the relationship between *domini* and *officinatores*. Steinby (1974), Helen (1975), and Setälä (1977) used this relationship to work out the organization, evolution, and prosopography of the brick industry. The tools did not exist at that point however to analyze the resulting connections on formal network grounds. They were however able to point to the obvious importance of figures such as Domitia Lucilla, or C. Fulvius Plautianus by the simple fact that these names occurred over and over again. What might we also see if we revisit this data through a formal network lens?

Getting started is simplicity itself. One simply lists pairs of individuals on a spreadsheet as one encounters them in a catalogue (as for instance, in the *CIL*). One can even consider the *directionality* of this relationship, that is, the power imbalance. The relationship *officinatore* – *dominus* is not one between equals. The network analysis programme Gephi (Bastian *et al.* 2009) can import such a list by labeling the first column 'source' and the second column 'target'. We might then list every pair of individuals so that the *dominus* is listed in the first column, and the *officinatore* in the second. Other columns or *attributes* could be listed, such as dates, estate information, or any of the other multiple dimensions of data described above. It is important to note however that these *attributes* are not nodes in themselves (and thus avoiding the problems created by multigraphs).

There is a problem, however. Do we imagine that *officinatores* and *domini* are the same kind of node? If we do (they are both humans, for instance) then we can proceed with the analysis since Gephi and most other network analysis programmes run various statistics under the assumption that we are computing them for a *one-mode* network (ie, relationships tying one kind of thing together). If, however, we think that *officinatores* and *domini* really are two different kinds of things, then we have to transform this *two-mode* network into two separate one-mode networks. Otherwise the resulting metrics are entirely misleading. The key to unraveling this conundrum lies in our research question. If we are interested in the connections among the land-owning elites in the hinterland of Rome, and how they manage their land resources (as evidenced by ceramic building materials), then we really perhaps ought to look at a one-mode network of *domini* connected to other *domini* by virtue of the *officinatores* who worked for both. That is, we turn the *officinatores* into the ties that bind.

Conversely, if our research question is centred on the social world of the *officinatores*, we might wish to have a network of *officinatores* tied to other *officinatores* by virtue of exploiting the clay of the same *domini*. Making this transformation by hand is extremely tedious and prone to error; fortunately, Gephi has a plugin (the 'multimode transformation') that can do this quite quickly.

The visualization of this network of *domini* to *domini* via shared *officinatores* (drawn from Setälä 1977) is not, in itself, of much analytic use. We can however recast it to visualize also various kinds of metrics. We could search for sub-groups within this network. We could ask, which *domini* are in a position to influence the industry by virtue of their connections? This is a question of *centrality*. Is Domitia Lucilla as important as other scholars have long surmised? We could then arrange the network so that the nodes are scaled in size according to a centrality metric (in this case, PageRank, as it ranks nodes based on how often a user will reach that node following the links. Clearly, this is the language of the internet, but here it translates into the language of power). The PageRank metric agrees that Domitia Lucilla is indeed the most central individual. What about subgroups? Gephi can compute modularity, or the degree to which nodes have similar (though not identical) patterns of connections. The network could then be re-coloured to show subgroups. Now the visualization is becoming more useful.

We can do one final transformation to make the relative positioning of the nodes on the page carry information concerning the overall structure of the network. We can lay out the network so that nodes are arranged in concentric steps or orbits from some central node. Let us put Domitia Lucilla in the centre, and every *dominus* who is one step away in the first orbit. Every *dominus* who is two steps can be arranged in the next circle, and so on until we come to the furthest *domini* away. This layout where graph-distance or number of steps are arranged in progressive orbits, allows us to quite quickly see the social world of Domitia Lucilla, Figure 1. One could then re-visualize to the social world of this industry from others' perspectives. In Figure 2 the network is from the perspective of L. Publilius Celsus (consul under Trajan). The action, so to speak, is about four steps removed from him. Can we read in this distance some of the factors in his eventual downfall under Hadrian? That is perhaps a step too far, but the idea is seductive.

Far more complicated and sophisticated analyses could be done. One could generate random networks with the same number of nodes and proportions of ties, to act as a kind of null hypothesis. In what ways does the observed network differ from the random network? Or one could generate small-world networks (which are assumed to have particular social implications) to ask, to what degree does the observed network resemble the small world? Or one could look for *holes* in the network, patterns of *non-connections*, and compare those against the observed or generated networks. One could use the network as a substrate for modeling various kinds of social interaction in an agent-based simulation (Graham 2009). It all begins though with listing relationships.

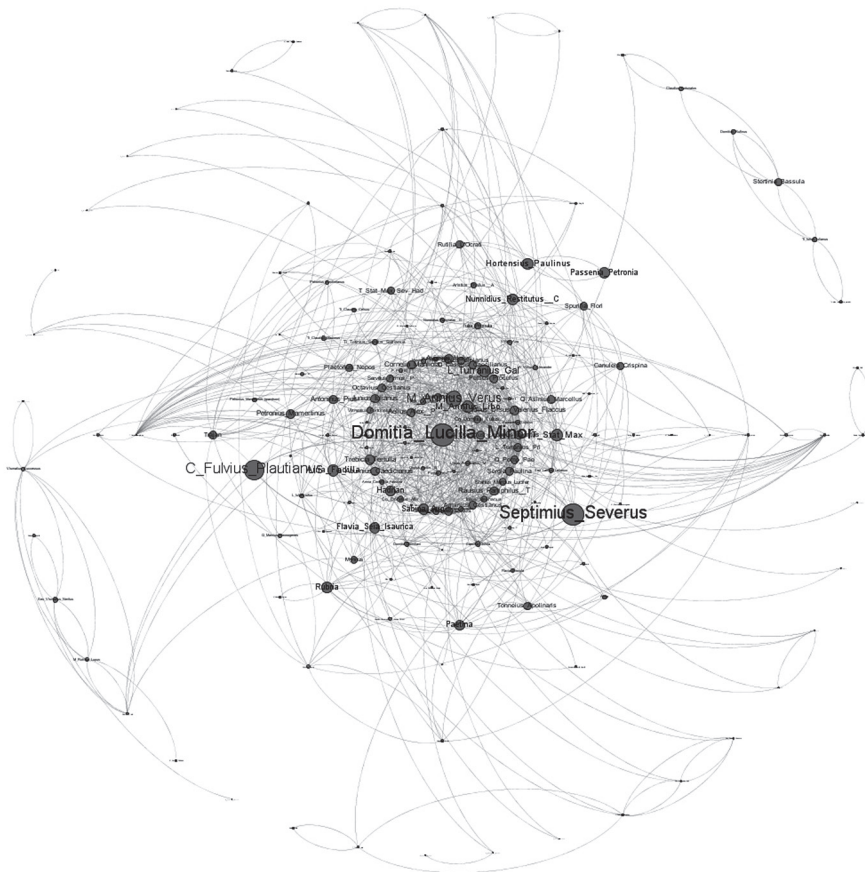


Fig. 1 – Network of *domini* to *domini* via shared *officinators*. Concentric-circle layout based on link distance from Domitia Lucilla. Node size is scaled to reflect pageRank centrality scores. Nodes and edges are coloured* according to modularity (subgroupings).

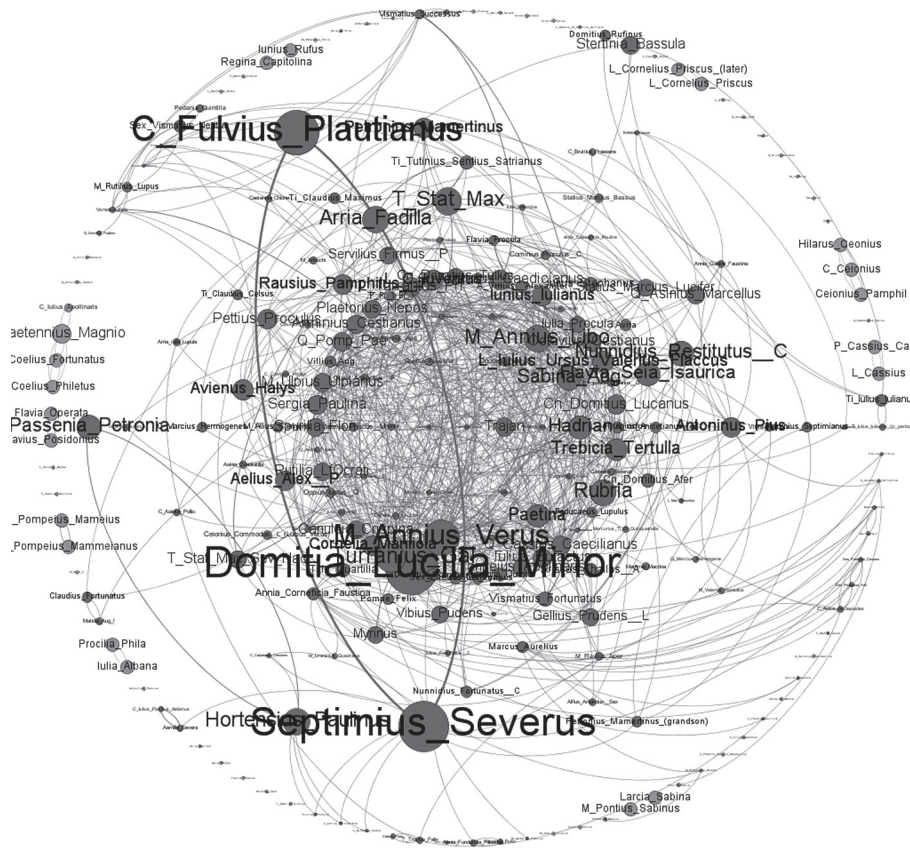


Fig. 2 – Network of *domini* to *domini* via shared *officinators*. Concentric-circle layout based on link distance from L. Publilius Celsus. Node size is scaled to reflect pageRank centrality scores. Nodes and edges are coloured* according to modularity (subgroupings).

* Colour versions of these figures may be viewed online at <http://dx.doi.org/10.6084/m9.figshare.102163>

Networking the language of stamps

We can begin to examine more abstract relationships in our material, for instance, to consider the relationship in stamped brick between the text of the brick (the indication of *figlinae* or the property from which the brick was made) and the *signa* that often appear in association with it. The data used in this section comes with a caveat: the database from which it draws is problematic and incomplete (see below; Graham 2012), but this brief consideration (or proof-of-concept, if you will) represents an example of what a more rigorous and thorough examination might accomplish.

Understanding the organization of the Roman brick industry outside of Rome has long relied on making connections between various stamps on the basis of shared language, or shared *signa*. The obvious connection for example between 'Rutilius Lupus' and the signum of his brick stamps—the wolf—make that a logical inference. That said, certain of the *signa* do not seem to fit into this pattern. The pine nut for instance appears on stamps from a wide variety of *figlinae* and *domini* (Graham 2006: 14). *Portus Licini* stamps all carry the same text, but with different *signa*. Elsewhere I have mused on the possibility of *signa* being tied into the exigencies of the infrastructure along the Tiber for loading and unloading bricks (Graham 2005). Navigation within the Roman city used among other things the symbols emblazoned on fountains, or major landmarks. Mocchegiani Carpano (1984: 39) argued for docks on the Tiber being reserved for the trade in specific goods, while Steinby argued for specific warehouses for brick (Steinby 1974: 74). Contracts for the specific warehousing of goods in particular spaces are known (Rickman 1980: 236-8). I have argued in the past, by analogy to the docks of Georgian and Victorian London, that the owners of warehouses might also have owned the specific docks where the goods were unloaded. The docks could also have been tied to the warehouse owners through bonds of patronage (Graham 2006: 82). In Rome there exists the 'Tor di Nona', a breakwater along the Tiber some 96m long with a temple to Hercules on its end (Quilici 1986: 202). Hercules appears as a *signum* in brick stamps *CIL* XV.1 156, 214-6, 241, 324-5, 686, 715, 768, 772, 1247, 1497 *Figlinae: Domitianae, Favoriana, Geniana, Marciana, Voconiana*.

As a graduate student, I copied out the transcription for every stamped brick listed in the *CIL* XV.1. It was a rough-and-ready copy, meant to help me with a question concerning the numbers of stamped bricks recorded. While not without errors, there might be enough data within that copy that could enable us to look at the patterns of *figlinae* and their use of *signa*. I imported this data into Gephi as a two-mode network, where there are two kinds of nodes, the *figlina* and the *signa*, connected when they both appear in the same stamp. Clearly this is a messy process, as the compilers of the *CIL* sometimes were not entirely sure what the *signum* might mean. Is it a dog? Is it a wolf? I cleaned this table up by merging such cases together. Within Gephi I recast this two mode table into two one-mode tables, where the nodes are either *figlinae* or *signa*, thus a network graph of *figlinae* tied to other *figlinae* by virtue of shared *signa*, and a network graph of *signa* tied

to other *signa* by virtue of appearing in stamps marked with the same *figlinae*.

Once we have done this, we can begin to ask the computer to identify groups of nodes that fall into 'natural' communities, based on the similarity of the pattern of their connections (using Gephi's community detection algorithm, 'modularity'). We can re-colour the graph to show these communities and their interconnections, and filter the network so that we only show one community at a time. Moreover, we can also ask Gephi to identify those nodes that are important in terms of their connectivity. Which particular metric we use depends on what we imagine to 'flow' over these connections. I have argued before that networks derived from brick stamp data represent fossilized flows of power and patronage (Graham 2006). If we accept that argument, then one metric worth calculating might be 'PageRank', which we can imagine as the likelihood that someone who 'reads' the stamp would be able to quickly follow the thread back to a central *figlina*.

We can begin to analyze this network of *figlinae* connected by use of common *signa* (476 stamp types tied by 47 816 edges). Looking for communities, I find 18 communities, where the top five capture 94% of the nodes. I visualize this network using Gephi's radial layout, which orders groups of nodes along spars of a wheel to show both the internal structure of the group and the group's ties to other groups. The sequence along the spar is determined by each node's individual PageRank. If we look at the nodes with highest PageRank in the largest group, we find some familiar names: *domitianae veteres; domitianae; favoriana; ab isis; domitianae maiores; vicciana; septimiana; oceanae maiores*. Hercules is a *signum* in many of the stamps of these *figlinae*, but not all of them. If *signa* were either heraldic devices or tied to transport exigencies, we would expect to find much tighter groupings (i.e., we would perhaps expect to find a group tied solely together via the Hercules *signum*).

While family connections or the evolution of *figlinae* over time (*domitianae maiores* and *veteres* split from the main *domitianae*, for instance) was not explicitly incorporated in the data for this network, that patterning still emerges viewed through this lens. *Oceanae Miores* and *Oceanae Miores* presumably are remnants of an earlier single contiguous unit of land; they appear here in different groupings (and the *miores* is strongly tied to *caniniana*). In this instance, the *signa* are functioning not as heraldic devices but perhaps are tied to the transport and infrastructure idea mooted above. The situation is complex, but a network visualization allows us to start teasing apart the different strands.

What is perhaps more interesting is the ways these subgroups (modules; communities) interconnect across groupings. The edges connecting the nodes have *weight*, which was extracted from the original two-mode network. If *terentiana* is connected to *caepioniana* via the shared use of three different *signum*, then when the two mode *figlinae* to *signa* network is transformed into *figlinae* tied to other *figlinae* via shared *signa*, that number of instances is transferred to a single instance as its weight: 3. If we then filter that network so only the strongest connections are shown, we get a sense of not just the internal connections within the groups, but also

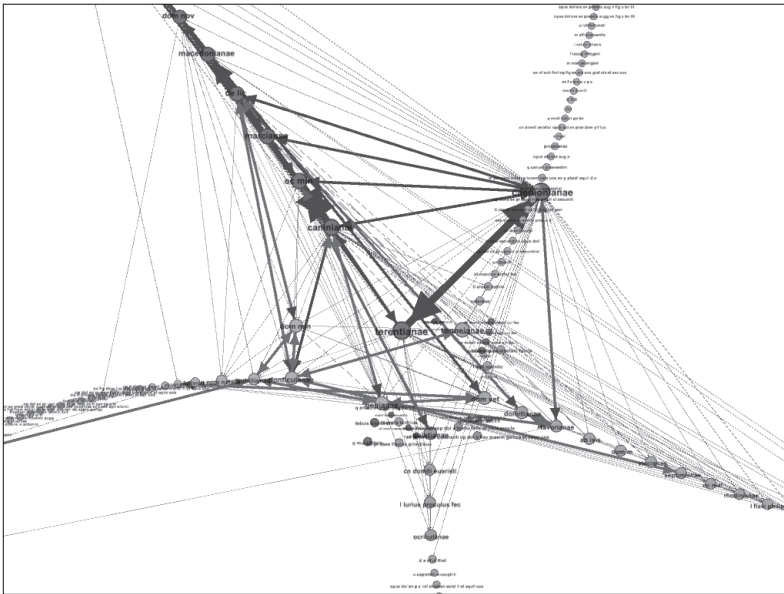


Fig. 3 – Detail of network of *figlinae* connected by use of common *signa*, filtered to show only ties of weight 2 or above. Forced-atlas layout. Node size is scaled to reflect pageRank centrality scores. Nodes and edges are coloured* according to modularity (subgroupings). * A colour version of this figure may be viewed online at <http://dx.doi.org/10.6084/m9.figshare.102163>.

across groups. Figure 3 visualizes *figlinae* to *figlinae* by common *signa* filtered to show ties with a weight of 2 or more. It becomes evident at this point that our largest group (the *domitianae veteres* group) forms a group not so much out of internal cohesion but through patterns of ties to the other groups. That is, it is a group precisely *because* of its internal disunity but external cohesion. On the contrary view, the group headed by the *figlinae terentianae* seems to have much greater internal cohesion as each *figlinae* ties tightly to the others within the same group, and lesser external cohesion. DeLaine (1997: 90-1) argued that the *figlinae ponticulanae* was tied to a locality along the Farfa river near Castello Tribucum, and that this area was a locality for *domitianae maiores*, *bucconianae*, *oecanae*, and *genianae* as well. One of the smaller groups in our network graph is composed of *genianae*, *dom min*, *ponticulanae*, and *publilianae*. It is important to note that the *figlinae* that obviously ‘go’ together, like the various parts of the *domitianae*, still are connected to each other in this graph; it is just that the overall patterning of connections is sufficient that they can be partitioned into different groups. Considering the nature of the different groups may help tease apart the question of what, precisely, *signa* do in stamps.

We can take the inverse of this network, and look at the *signa* themselves as nodes (and where the connections between them are appearance in stamps of the same *figlinae*). When modularity is computed, I find four groups that account for 63 of the 72 *signa* appearing in the graph. Hercules appears in a group with ‘equus’, ‘capricorn’, ‘minerva’, ‘castores’. Since these *signa* are connected by similar patterns of appearing with various *figlinae*, can we assume that this particular *grouping* would have made sense to the Roman worker who saw them?

Might we see in this assemblage of icons a reference to the Circus Flaminius with its adjacent temples to Hercules, Minerva, and the Dioscuri (Petruccioli 2013, entry 37)? There are clear problems with the data that are used in this current exploration, the most obvious being that the source database is not rigorous enough in its categorizations. Ideally, one would create a list with the following headings: unique stamp id; officinator; dominus; praedia; *figlina*; signum; consular date; shape. The data entered into this list would be what was explicitly written on the stamp rather than our suppositions that, for instance, *signa* of type abc always indicate *figlinae xyz*. Then, one could generate networks using any permutation of those data. A two-mode network of *officinatore* to *domini* could be transformed into a one-mode network of *domini* to other *domini* by virtue of the individuals who moved around between *figlinae* (and servile/freed status) over time. What this brief foray into a network visualization of the relationship between *signa* and text on the stamps is meant to

do is to demonstrate the possibilities of this kind of approach for the study of stamped brick, and epigraphy more generally.

Moving forward

The hardest part about analyzing epigraphic materials in the Roman world from a network analysis perspective is making our catalogues and databases available in formats that allow easy import or export into the various analytical packages that exist. Recent initiatives such as the ‘Linked Ancient World Data Institute’ which focuses on creating ‘digital resources that emphasizes connections between diverse information on the basis of published and stable web addresses (URIs) that identify common concepts and individual items’ [http://wiki.digitalclassicist.org/Linked_Ancient_World_Data_Institute], are to be applauded, as these will open more of our data to the kind of analyses envisioned here. In this way, network analysis would become not just a means of understanding the past, but also for organizing our knowledge of it in the present.

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