The Periplus of the Erythraean Sea : A Network Approach*

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Abstract

The Periplus of the Erythraean Sea is a Roman period guide to trade and navigation in the Indian Ocean. Justly famous for offering a contemporary and descriptive account of early Indian Ocean trade, the work has been subject to and a point of departure for numerous studies. Its extensive influence on scholarship is, however, also problematic, as it reflects the limited information and cultural and personal bias of its unknown author. Arguably this might have led scholars to overemphasise so-called western or Roman participation in early Indian Ocean trade. Network analysis allows us to map, visualize and measure interconnectedness in the Periplus Maris Erythraei. Many of these connections are not explicitly mentioned in the text, but by connecting not only places with places, but also products with places that export and import them, we get a partly different impression of Indian Ocean trade from that conventionally gathered from the Periplus. It allows us to ask questions about the relationship between coastal cabotage and transoceanic shipping, to identify regional trading circuits, and unexpected centres of long-distance exchange.

Key words

Indian Ocean, trade, navigation, Periplus of the Erythraean Sea, Social Network Analysis

A MERCHANT'S GUIDE TO THE INDIAN OCEAN

An anonymous, Greek work of some 6 300 words, the *Periplus of the Erythraean Sea* is primarily concerned with trade, but it also touches on production, navigation, geography, ethnography, history, and geopolitics from Egypt in the west to the Malay Peninsula in the east. Date, authorship, and even the purpose of the text are subject to debate. Traditionally, most scholars have assumed that the work was composed in the second half of the first century CE by a single author who, although native to Egypt, had a degree of personal experience in parts of the Red Sea and western Indian Ocean. Recent studies have questioned this, raising questions about whether the work, although written in the form of a single author, might be of a cumulative nature and later date, thus placing it in the tradition of ancient geographical scholarship rather than as a practical guide.[1] Even if the traditional single hypothesis of a merchant or captain-author is maintained, it is clear that this person relied on information obtained from others along with his own experiences. These issues, however, do not challenge the unique position held by the *Periplus* among historical sources on early Indian Ocean commerce n in its comparably wide geographical scope, its focus on trade, and its partial first-hand perspective (whether by its author or his informants). This has made it a natural point of departure for any study of the Indian Ocean in the pre-Islamic/early historical period. Nevertheless it is clear that the information offered in this text reflects the limited knowledge, personal interests, and cultural biases of the person and his informants. Over-reliance on the *Periplus* will inevitably reproduce the shortcomings of the source. One example is the emphasis on shipping from Egypt to Africa, Arabia and India. This was the trade that the author of the *Periplus* or his sources had experience of and special interest

[1] Pascal Arnaud, Le Périple De La Mer Érythrée, "Une Œuvre De Compilation Aux Préoccupations Géographiques," *Topoi Supplement* 11(2012); Didier Marcotte, "Le Périple De La Mer Érythrée Dans Son Genre Et Sa Tradition Textuelle," *Topoi Supplement* 11(2012).

in. Throughout the text the *Periplus* also acknowledges the wider trade originating in Arabia, Africa, India, the Persian Gulf and the Malay Peninsula, but mostly as a backdrop to the primary objective.

Modern scholarly interest in Indian Ocean trade started in the British colonial period, and Roman activities in the region were seen as forerunners of later European commerce and imperial interest with a focus on western over indigenous Indian Ocean agencies.[2] Indian Ocean archaeology started as the search for Rome beyond the imperial frontiers.[3] In reflection of this and as a result of the longstanding scholarly tradition of classical studies and Roman archaeology compared to that of Indian Ocean studies, Roman trade with India has received comparably more attention than networks based in the ports of Arabia, India, the Persian Gulf, and Africa south of Egypt, which, however, have also attracted considerable interest in recent scholarship.[4]

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[2] E. H. Warmington, *The Commerce between the Roman Empire and India* (New Dehli: Munshiram Manoharlal, 1995 [1928]), 1-2; Himanshu Prabha Ray, *Colonial Archaeology in South Asia: The Legacy of Sir Mortimer Wheeler* (New Delhi: Oxford University Press, 2008).

[3] M. Wheeler, *Rome Beyond the Imperial Frontiers*, 2nd ed. (Middlesex: Penguin Books, 1955); Ray, *Colonial Archaeology*; Eivind Heldaas Seland, "Archaeology of Trade in the Western Indian Ocean, 300 Bc–Ad 700," *Journal of Archaeological Research* 22, no. 4 (2014): 368-70.

[4] Examples include Himanshu P. Ray, *The Winds of Change - Buddhism and the Maritime Links of Early South Asia* (Delhi: Oxford University Press, 1998) ; *The Archaeology of Seafaring in Ancient South Asia* (Cambridge: Cambridge University Press, 2003) ; "Inscribed Pots, Emerging Identities: The Social Milieu of Trade." In *Between the Empires: Society in India 300 Bce to 400 Ce*, edited by Patrick Olivelle, 113-43 (Oxford: Oxford University Press, 2006); Jean-François Salles, "Le Golfe Persique Dans Le Pèriple De La Mer Érythrée: Connaissances fondées et ignorances réelles, *Topoi Suppl.* 11 (2012): 293-328; Alexia Pavan and Heidrun Schenk, "Crossing the Indian Ocean before the Periplus: A Comparison of Pottery Assemblages at the Sites of Sumhuram (Oman) and Tissamaharama (Sri Lanka)," *Arabian Archaeology and Epigraphy* 23, no. 2 (2012); D.T. Potts, "The Archaeology and Early History of the Persian Gulf," in *Persian Gulf in History*, ed. Lawrence G. Potter (New York: Macmillan, 2009); Eivind Heldaas Seland, "The Indian Ships at Moscha and the Indo-Arabian Trading Circuit," *Proceedings of the Seminar for Arabian Studies* 38 (2008); Peter Magee, "Revisiting Indian Rouletted Ware and the Impact of Indian Ocean Trade in Early Historic South Asia," *Antiquity* 84, no. 326 (2010); Ingo Strauch, *Foreign Sailors on Socotra: The Inscriptions and Drawings from the Cave Hoq,* (Bremen: Hempen, 2012); Geus, Klaus. "Mobilität am und auf dem Roten Meer im Altertum: Naturräumliche Bedingungen, lokale Netzwerke und merkwürdige Inseln; Interpretationen zum *Periplus Maris Erythraei* und zu Ptolemaios' Geographie." In *Mobilität in den antiken Kulturen*, edited by Eckart Olshausen, 311-324 (Stuttgart: Franz Steiner, 2014).

Over the last 25 years, archaeology has greatly improved our knowledge of pre-Islamic Indian Ocean commerce.[5] Nevertheless, while Mediterranean demand was certainly one important factor in Indian Ocean commerce, the extent and importance of other networks, and their dynamics, remain imperfectly understood. The aim of this study is to revisit the key text of the *Periplus*, in order to investigate its potential to yield information that was always there, but perhaps not visible in Rome-centred scholarship.

METHODS: THE PERIPLUS AS A NETWORK

In order to extract new information from this much-studied text,[6] we approach it as a linkage of overlapping networks. This applies in three ways. First, the text describes existing networks of people, places and commodities at the time of its composition. Second, the text allows us speculate on possible and potential linkages that are not definitively described. Third, the text itself can be approached as an inclusive macro-network where words, for instance those describing places, relate to other words describing products. It is this latter aspect of the textually conceived network that allows us to reconstruct former networks that were actually in existence or might well have been so.

Network analysis in the manner applied here is a methodology developed from the mid-twentieth century, with major inputs from post World War II social-and mathematical sciences.[7] The qualitative difference between network analysis and most conventional historical and sociological approaches is an explicit emphasis on connections and interaction over individual agencies. Recent technology has developed tools for graphical visualisation and, although less important but also present in this study,

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[5] Overview of recent scholarship in Seland, "Archaeology of Trade."

[6] Text, translation, references and bibliography in Casson, *Periplus*. Review of scholarship, references and bibliography in Eivind Heldaas Seland, *Ports and Power in the Periplus: Complex Societies and Maritime Trade on the Indian Ocean in the First Century Ad* (Oxford: Archaeopress, 2010). New studies in Marie-Françoise Boussac, Jean-Françoios Salles, and Jean-Baptiste Yon, eds., *Autour Du Périple De La Mer Érythrée [Topoi, Supplément 11]* (Lyon: Maison de l'Orient et de la Méditerranée, 2012).

[7] Stanley Wasserman and Katherine Faust, *Social Network Analysis: Methods and Applications*, Structural Analysis in the Social Sciences (Cambridge; New York: Cambridge University Press, 1994), 1-17.

the statistical measurement of interconnectedness in such net-works. Network analysis has made major inroads into archaeolo-gy and history over the last decade[8] and has, among other things, proven a useful tool for statistical re-visualising of archaeological and textual material, allowing for explicit, and in many cases testable, modelling of connections.

To give an example of how the text of the *Periplus* can form the basis for network analysis, one must first look at the kind of information contained in the text. The passage below, from the 1989-translation of Lionel Casson, is excerpted from the descrip-tion of the port of Malao. On the basis of its position in the nar-rative and the topographical details provided, this port can be certainly identified with Berbera in present-day Somalia. The other port mentioned, Avalites, remains unidentified, but must have been located on the African coastline very near the straits of Bab al-Mandab, which separate the Red Sea from the Gulf of Aden.

> After Avalitês, about an 800-stade sail distant, comes another, bet-ter, port of trade called Malaô. Its harbour is an open roadstead sheltered by a promontory extending from the east. Its inhabitants are rather peaceable. This place offers a market for the aforemen-tioned as well as for: tunics in quantity; cloaks from Arsinoe, cleaned and dyed; drinking vessels; honey pans (?), in limited num-ber; iron; Roman money, in limited quantity, both gold and silver. Exports from this area are: myrrh, a little "far-side" incense; a rather harsh cassia, duka, kankamom, makeir, which items are exported to Arabia; on rare occasions slaves.[9]

While this passage was highlighted because it gives examples of the different kinds of information contained in the *Periplus* with-

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[8] Works directly inspiring this study include Anna Collar, *Religious Networks in the Roman Empire: The Spread of New Ideas* (Cambridge: Cambridge University Press, 2013); Søren Michael Sindbæk, "Open Access, Nodal Points, and Central Places: Maritime Communication and Locational Principles for Coastal Sites in South Scandinavia, C. Ad 400-1200," *Eesti Arheoloogia Ajakiri* 13, no. 2 (2009); Tom Brughmans, "Thinking through Networks: A Review of Formal Network Methods in Archaeology," *Journal of Archaeological Method and Theory* 20, no. 4 (2013); Irad Malkin, *A Small Greek World : Networks in the Ancient Mediterranean*, Greeks Overseas (New York: Oxford University Press, 2011); Giovanni Roberto Ruffini, *Social Networks in Byzantine Egypt* (Cambridge: Cambridge University Press, 2008).

[9] *Periplus Maris Erythraei* 8, transl. Casson, *Periplus*, 55.

in a few lines, it is also representative of the content of the work in general. There are names of places with relative and absolute positions, although in some cases they are imprecise and hard to identify; products, also including some that cannot be identified, like the 'honey pans' and the untranslateable aromatics at the end of the passage; directions of import and export; groups of people; and statements on the quality and quantity of products. Among this data places, products and directions of movement stand out as interesting and suitable data for network analysis. Data on quantity or volume, which would have been desirable, are mostly absent and when present entirely qualitative: "in quantity," "a little" etc., making any quantification impossible.

In order to turn the text into a database that can be visualised as a network, each of the 57 places and 110 products mentioned in the text were entered into a spreadsheet and assigned a number, running from 1001–1057 and 2001–2110 respectively. The dataset was extracted from Lionel Casson's edition of the *Periplus*, and is available for download from Bergen Open Research Archive.[10] In order to avoid imposing interpretation on the material at present, products that are referred to in the text by different Greek terms were assigned a different number in the database even though they might have been somewhat similar items, such as "drinking vessels" (ποτήρια) and "copper drinking vessels" (ποτήρια χαλκᾶ). The only exception made was "Roman money"/"dinars" and "money" (δηνάριον/χρῆμα) that was treated as the same commodity. Each place mentioned in the text was also assigned a geographical position, approximate in cases where the exact location is not known. These places and products represent the nodes of the networks described below.

The next step was to create connections, called edges in network terminology. This was done by entering source and target nodes in a table. To exemplify with the passage cited above, the port of Malao had been assigned the ID 1011, the product of iron 2012, and myrrh the ID 2035. The dyad 1011-2035 means that Malao exported myrrh, 2012-1011 that it imported iron. The position in the dyad implies direction. If the order is changed, the hypothetical dyad 2035-1011, which is not included in the dataset,

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[10] Ibid.; Permalink to dataset at: http://bora.uib.no/handle/1956/11470

would imply that Malaô imported myrrh, which in the account of the *Periplus*, it did not. Together, these lists of nodes and edges form the basis for a directed so-called two-mode network, consisting of connections between two different groups of nodes – places and commodities (set 1).

In addition to this set of edges, two others were created recording connections between ports. The first of these lists connections as explicitly described in the text, for instance the description of Malao as a port that imported goods from Egypt was taken as a connection to the Egyptian ports of Myos Hormos and Berenike (set 2). The second of these additional edge-lists connects ports with their nearest neighbours, e.g. in the example above Avalites and Malao, creating a so-called proximal point network based on the premise attested in the *Periplus* as well as in later accounts of Indian Ocean shipping, that some ships would follow the coast on their journeys and put in at ports underway (set 3). These two latter edge-lists are undirected, and do not contain information as to whether connections were inbound or outbound from any given port. The resulting networks are so-called one-mode networks, consisting of connections between nodes of the same kind.

RESULTS

The resulting datasets thus built from the text of the *Periplus* were imported into the graph visualisation software Gephi in order to visualise different networks. Fig. 1 visualises the contacts that are actually described in the *Periplus*, in the sense that the text explicitly mentions that the port was visited by either ships or merchants from another port or region (set 2). Nodes are sized according to degree, which is simply a measure of how many connections each port has (table 1). The nodes have been organised using the Geo Layout algorithm by Mathieu Bastian. They are thus positioned as they would have been on a map, to the extent that we are aware of their position.

While there is no information in this graph that could not be gathered from or expressed in a written summary of the text, the visualisation does highlight that some ports and regions

were more well-connected than others. Barygaza in northwest India, with 25 connections to other places described in the *Periplus*, stands out as the most connected port by far. The Egyptian ports of Myos Hormos and Berenike, with 15 connections each, share the second rank. Barygaza's connectivity is not surprising, given northwestern India's centrality in Western Indian Ocean connectivity as well as its overland connections with Central Asia. Nevertheless it is an example of how a basic visualisation can highlight something that would otherwise require careful textual reading, as the narrative of the text always has Egypt as its regional point of departure.

As the graph only shows connections explicitly mentioned in the *Periplus*, it also demonstrates the limits of the textual narrative. For instance, 20 ports are mentioned in the text without any information on incoming or outgoing trade. These appear as so-called isolates in the graph. One of the most-visible is Naura on the Konkan coast, highlighted in fig. 1 as an example. One must expect that these ports were also home to seafaring communities. Also, the connections described in the text are directly between some primary hubs, including Barygaza, Berenike and Myos Hormos, and secondary centres of commerce. In addition to this, ports are likely to have been connected with their nearest neighbours, even if this is not detailed in the *Periplus*. The text itself contains several references to coastal shipping, as also to ships that travelled along the coast and put in at night.[11] One way of modelling such connections that we either assume to have existed or would like to test the significance of, is to add the proximal point dataset (set 3) to the graph, thus inserting edges between adjacent ports along with those described in the text.[12] While this is admittedly manipulation of the data, it is quite conservative, as one would expect ports with close geographic proximity to be connected not only to their closest neighbours but also to the second closest and so on. The result-

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[11] This is implicit in the division of journeys into "runs" (*dromoi*) eg. sections 9-19, 57.

[12] Here directly inspired by Broodbank's work on the Bronze Age Aegean and Collar's on religious networks in the Roman Empire: Cyprian Broodbank, "Ulysses without Sails: Trade, Distance, Knowledge and Power in the Early Cyclades," *World Archaeology* 24, no. 3 (1993); Collar, *Religious Networks*.

ing graph (fig. 2) is not dramatically different from the previous one, but it does highlight regions with many ports. While the major port of Barygaza goes from 25 to 27 edges, the port of Malao, described in the text with connections to northwestern India (Barygaza), Myos Hormos and Berenike, as well as Muza in present day Yemen, goes from four to six edges by adding connections to neighbouring ports poa 50 % increase in network weight. Arguably this approach allows us to better appreciate regional and coastal trade. In fig. 2 the Gulf of Aden, both coasts of southern India, and northwestern India stand out as regional clusters with groups of well-connected nodes. In contrast the Egyptian ports, although clearly among the most important in the network, are primarily noteworthy for their many long-distance connections, which is to be expected, as this commerce was the main interest of the author of the *Periplus*. Another benefit of this visualisation is that it allows us to appreciate the role of Adulis in Eritrea and Muza in Yemen as regional centres of long-distance trade and as gateways in the network, interconnecting wider regional and Indian Ocean scale networks.[13]

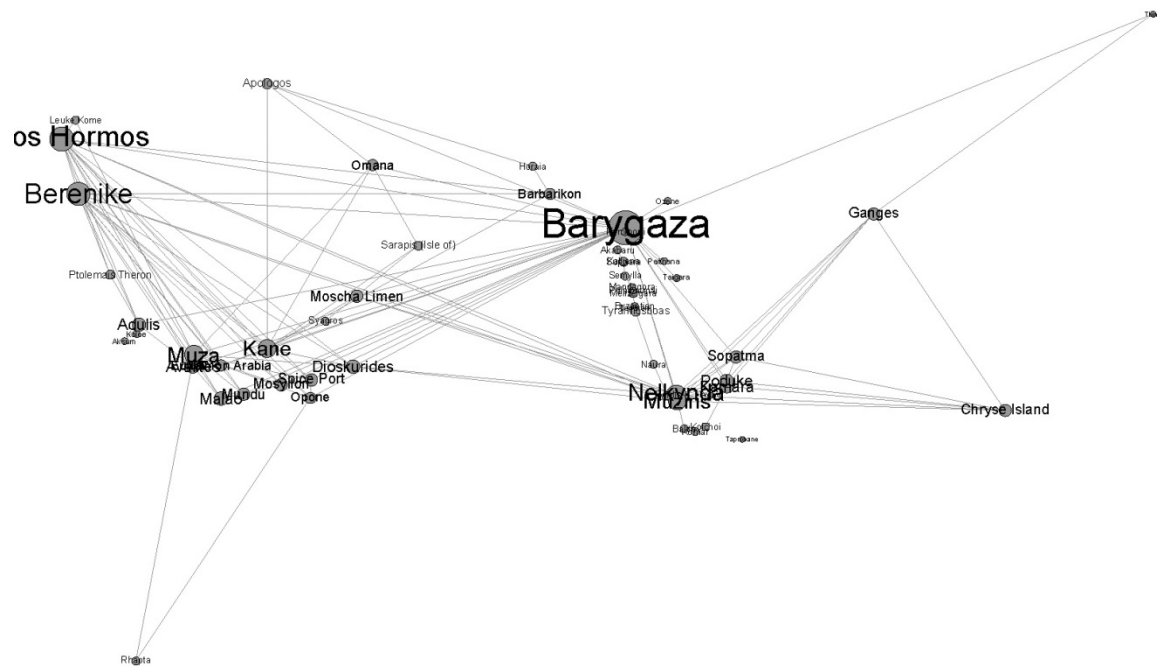Figure 1. Connections between ports as mentioned in the *Periplus*. Graph produced in Gephi.

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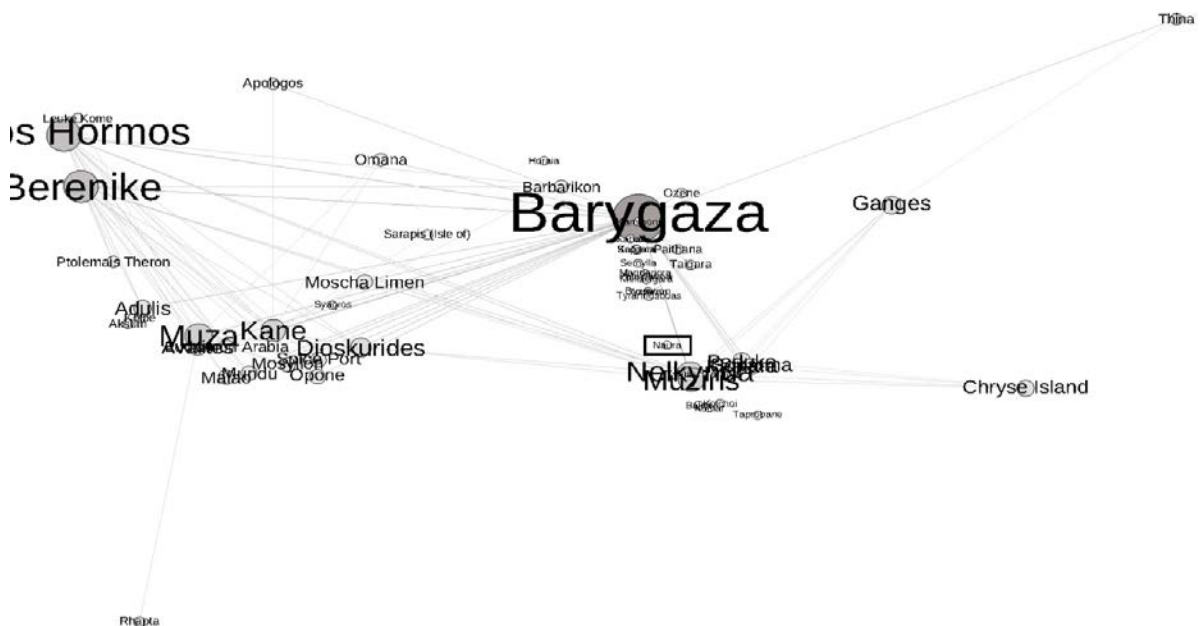
[13] This role is arguably also well attested in the text of the *Periplus,* see Eivind Heldaas Seland, "Red Sea and Indian Ocean: Ports and Their Hinterland," in *Natural Resources and Cultural Connections of the Red Sea*, ed. Janet Starkey, Paul Starkey and Tony J. Wilkinson (Oxford: Archaeopress, 2007).

Table 1. degree (number of connections) of ports and groups of ports treated together as actually described in the *Periplus*.

Port	Degree (number of connections)
Barygaza	25
Berenike and Myos Hormos	15
Muza	11
Nelkynda and Muziris	10
Kane	9
Dioskurides (Socotra)	7
Adulis	6
Avalites	5
Chryse Island (Malay Peninsula)	5
Kamara, Poduke, Soptama	5
Malao, Mundu, Mosyllon, Spice Port	4

Figure 2. Connections between ports as mentioned in the *Periplus* with edges added between adjacent ports. Graph produced in Gephi.

Figure 3. Two mode network showing movement of goods between ports as described in the *Periplus*. Graph produced in Gephi.

Figure 4. Segment of figure 3. showing imports and exports to the port of Malao. Graph produced in Gephi.

The main source of underutilized information in the *Periplus* is, however, not on the connections between ports, but between ports and commodities. The graph in figure 3 represents this two-mode network, with directed edges showing whether a certain commodity was imported into or exported from a certain port. The position of places is no longer geographical. The network has been distributed using the Force Atlas algorithm of Gephi that minimises overlap and crossing edges. Again nodes are sized according to degree, but this time size does not imply the number of connections with other ports, but the number of commodities imported and exported. We might still recognise the important ports of Barygaza (middle right), Myos Hormos and Berenike (lower centre) and perhaps Malao and its neighbouring ports along the coast of present-day Somalia (lower left, marked by an arrow).

The advantage of this network is that it allows us to look at supply/demand relationship in first-century Indian Ocean trade. While the narrative of the *Periplus* relates only what the author knew was traded in each port, the graph gives access to information on all the places where these products were available. To use the example of Malao again, fig. 4 shows imports and exports indicated by incoming and outgoing arrows from this port. The information here is the same as in the passage cited above. One of the goods demanded in Malao is wine, among the imports listed as "aforementioned" in the text. If we shift the focus of the network from the port of Malao to wine as product, we also see all the other ports involved in the wine trade (figure 5). The resulting graph reveals that Roman Egypt was not the only supplier of wine. Wine could also be procured from Muza in Yemen, where the commodity was bought as well as sold and from Apologos in Southern Mesopotamia. We already knew that Malao was in contact with Muza, but we did not know that Mesopotamian merchants could also offer one of the goods demanded in Somalia. Does that imply that Mesopotamian merchants visited Malao? We do not know, and maybe they did not at the time of the *Periplus*, but the analysis reveals a potential connection not described in the text, and Mesopotamian ceramics, alt-

hough of later date, are indeed present in assemblages from ancient port-sites along the coast of Somalia.[14]

As with the network visualised in fig. 1, there is no information in figure 3 that is not present in the text of the *Periplus*. The potential importers and exporters of wine can be gathered also from reading the narrative. The added value of the visualisation is that it allows us to move from product to product and port to port, and thus explore the entire supply/demand network contained in the *Periplus* at the same time. In this way the visualisation allows us to look for possible connections between non-Roman/Egyptian agents in early Indian Ocean trade that are likely to be underrepresented in the *Periplus*.

Figure 5. Segment of fig. 3 showing supply and demand of wine. Graph produced in Gephi.
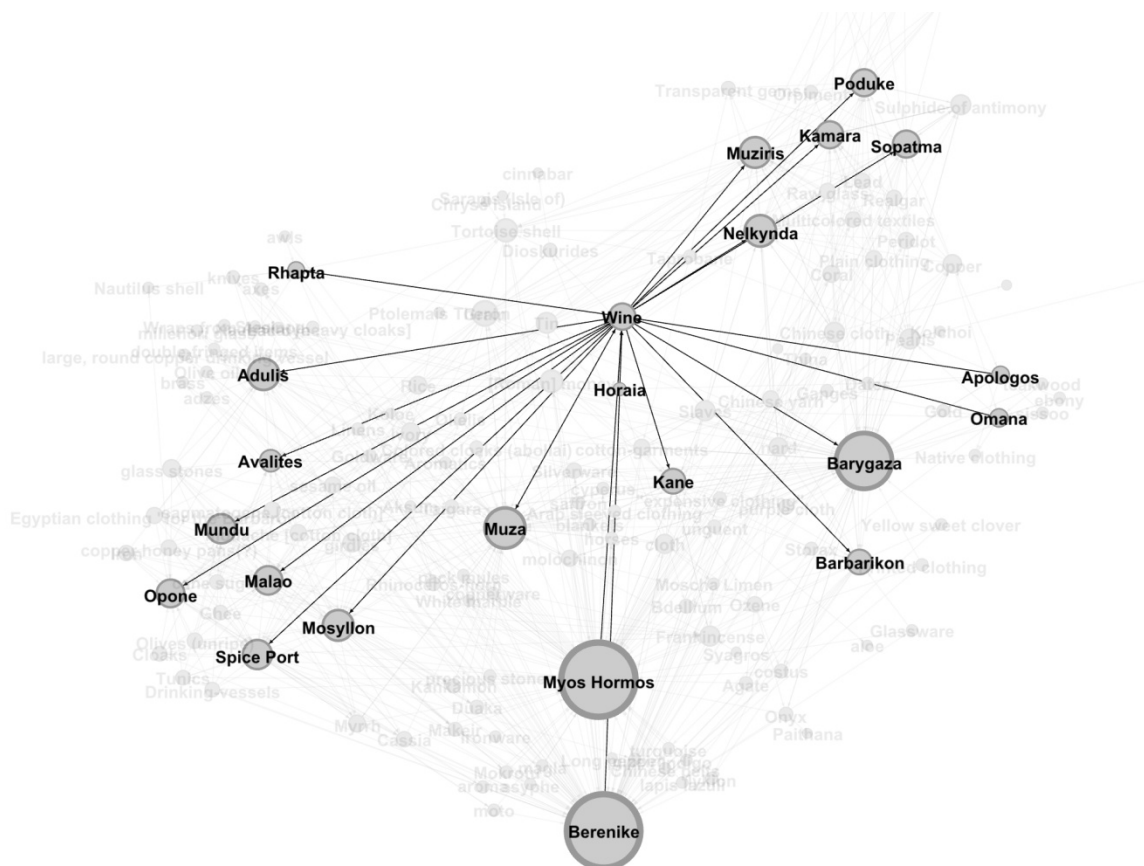
DISCUSSION

Network analysis is a toolkit that can be used to visualise and measure data. It does not offer new information, but enables us

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[14] Roberta Tomber, *Indo-Roman Trade, from Pots to Pepper* (London: Duckworth, 2008), 159-60.

to organise and display information in different ways. With regard to the *Periplus* it allows us to depart from the narrative of the text and view Indian Ocean trade as it appeared from different points of view.

With regard to the one-mode place–place networks (figs 1-2) the main advantage lies in the potential for identifying regional clusters of interconnected ports, such as in the southern Red Sea and Gulf of Aden, in the Persian Gulf, in eastern Arabia and northwestern India, in south India and the Bay of Bengal, and also to locate hierarchies within those clusters and identify their place in the wider Indian Ocean system.

The two-mode commodity–port networks have potential in at least three directions: first they arguably enable us to study how places and regions were integrated in Indian Ocean commerce on a more stable basis than the snapshot given in the *Periplus*. Production and demand in different regions is likely to have been relatively stable over time, dependent on which natural resources were locally available, while the fortunes of ports varied with political changes. Thus, even if East Africa was not well known to the author of the *Periplus* or other classical authors,[15] approaching the lists of exports and imports as a network reveals that people in many places on the Indian Ocean rim, for instance in the Persian Gulf, were interested in goods offered on the East African coastline. This warns us against drawing conclusions based on the basis of the absence of reference to contacts in the *Periplus* alone, and also provides the background for the well-attested Iranian and Mesopotamian interest in the East African coast from around 600 onwards.[16]

A second possibility offered by the port-commodity network is to investigate the role of different commodities and groups of commodities. If, for e.g. textiles, minerals, and aromatics move along different trajectories, it is reasonable to assume that they also belonged to different sub-networks, operated by

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[15] Veronica Bucciantini, "The Limits of Knowledge: Explorations of and Information from the Horn of Africa to the East African Coast in the Graeco-Roman Tradition," *Topoi Supplement* 11 (2012): 159-76.

[16] Adria LaViolette, "Swahili Cosmopolitanism in Africa and the Indian Ocean World, A.D. 600–1500," *Archaeologies* 4, no. 1 (2008): 31-4, 38.

different actors.[17] This is a possible way of approaching the elusive coastal and regional networks that are present in the background in the narrative of the *Periplus*, but of which we lack a comprehensive picture.

Finally, and perhaps most importantly, network analysis is neutral with regard to data. All too often Indian Ocean archaeologists use the *Periplus* as a source of identification and confirmation of their sites and finds, while historians and philologists use archaeological data to confirm and illustrate the text. The commodity-port network can seamlessly integrate archaeological sites and artefacts alongwith those mentioned in the text. Thus the finds of ceramics from Tissamaharana in Sri Lanka at Khor Rori in Oman,[18] could add nodes and edges to the network that can be analysed in the same manner as those extracted from the *Periplus*.

The aim of this inquiry has been to highlight the potential of looking at a well-known text from a novel point of view by way of computer analysis. Realizing that potential will go beyond the scope of this study. Limitations apply, as to any research methodology. Data on quantity or volume, for instance, remains absent, and information that is not in the text is also not a factor in the network. While Arabian, Indian, Persian Gulf and Bay of Bengal circuits might become more visible by the above exercise, places and regions that the author of the *Periplus* did not care about, or did not know of, remain in the shadows.

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[17] I intend to pursue this avenue of research in forthcoming separate studies of commodity networks.

[18] Pavan and Schenk, "Crossing the Indian Ocean."