Networked spaces: the spatiality of networks in the Red Sea and Western Indian Ocean
Archéologie(s) 8, MOM Éditions, Lyon, 2022

Berenike – why there?

Environmental, economic and logistic conditions of the Hellenistic port/base location

Marek Adam Woźniak
Institute of Mediterranean and Oriental Cultures of Polish Academy of Sciences

The last 25 years of archaeological excavations at Berenike Trogodytika have revealed the remains of the only scientifically researched Red Sea port/base from the Hellenistic period. These works made it possible to study the size of the base and its location in the local environment, the construction of the buildings, the methods of supplying the city and the types of goods sent there. It was even possible to reconstruct such elements of everyday life as diet and ways of preparing meals. Research also led to the conclusion that during the location and construction of the port/base, Hellenistic builders took into account not only geographic, logistic and economic factors, but even geological and climatic ones (such as the strength and directions of prevailing winds). Their choices were so accurate that the entire network of precisely operating port centers existed over many centuries and survived all the drastic political and climatic changes. Developed by successive rulers, it connected the ancient Empires of the three continents with one of the most important trade and communication routes in human history.

Les vingt-cinq dernières années de fouilles à Berenike Trogodytika ont révélé les restes du seul port hellénistique de la mer Rouge qui ait fait l'objet d'une fouille scientifique. Ces travaux ont permis d'étudier les dimensions de ce port, son insertion dans l'environnement local, la construction des bâtiments, les moyens d'approvisionnement de la ville et les différents types de marchandises expédiées. Il a même été possible de reconstituer des éléments de la vie quotidienne, comme les habitudes alimentaires et la préparation des repas des habitants. Nos travaux ont aussi conduit à la conclusion que les bâtisseurs de l'époque hellénistique avaient pris en compte non seulement les facteurs géographiques, logistiques et économiques, mais aussi géologiques et climatiques (telles la force et les directions des vents dominants). Leurs choix furent si adaptés que le port a continué d'être occupé durant de nombreux siècles et a survécu aux changements politiques et climatiques. Développé par des pouvoirs successifs, il permettait de connecter les anciens empires de trois continents à l'une des plus importantes voies de communication et d'échange de l'histoire de l'humanité.

Introduction

For Antiquity, the Hellenistic period was what the later "great geographical discoveries" period was for the Renaissance.[1] These were not only times of incredible political changes, intercontinental war campaigns and conquests, but also periods of great development in science, art and culture. The collapse of the gigantic Achaemenid monarchy opened for the Greeks (already very mobile and

1. Research on Hellenistic Berenike was financed by the Polish National Science Center UMO-2015/17/N/HS3/00163.

DE GRAAUW <arthur.degraauw@outlook.fr>

curious about the world) the opportunity to look into the achievements of the old civilizations of the Near East, Egypt and India. It also allowed broad access to distant lands, previously only known from myths and legends, and gave the means and political support for the exploration of areas that were hitherto beyond the reach of Hellenic science, culture and trade. It initiated the period of the first world globalization lasting for the next several centuries. A chain of bases/ports emerging on the wild shores of the Red Sea was part of this extraordinary phenomenon.

The construction and maintenance of a network of Hellenistic ports on the west coast of the Red Sea (*fig. 1*) over the centuries revived and developed the idea of the old Pharaonic expeditions to the land of Punt. Under Ptolemies, however, this venture was prepared with the methods and impressive

Fig. 1 – Ancient ports of the Red Sea (M. Woźniak).

DE GRAAUW <arthur.degraauw@outlook.fr>

scale that characterized most Hellenistic projects.[2] Expeditions exploring the African coast of the Red Sea were supervised by high-ranking officers.[3] It also seems that (due to the efficiency, developed organization and experience in the field of engineering and logistics) the Egyptian army supervised the entire undertaking. This seems to have been the result of the first Ptolemies' ambition to dominate the territory rich in natural resources of economic and strategic significance (wood, metal ores, minerals, luxury products, etc.).[4] Resources from the Red Sea region[5] ideally supplemented the range of raw materials and commodities which were available in the Mediterranean basin. However, it was an extremely logistic and organizational challenge to get hold of the resources in East Africa or South Arabia, although it was very much easier than, as far as politics was concerned, gaining access to strategic areas e.g. on the Greek Islands or in Asia Minor.[6]

Bases/cities founded on the coast of the Red Sea were built in inhospitable areas of desert or semi-desert environments, populated by small local nomadic or semi-nomadic communities. Moreover, these areas were separated from the densely settled regions of the Nile Valley by a range of high mountains, which were difficult to pass.[7] Nevertheless, the mountains of the Eastern Desert were cut across with deep wadis and trails could be organized (or even already existed as e.g. in Wadi Hammamat)[8] along these formations (*fig. 2*). The alluvial deposits on their bottoms contained fresh water reservoirs, accumulated

Fig. 2 – Communication routes of the Eastern Desert in the Hellenistic and Roman periods (S. Rempel).

2. Cohen 2006, pp. 305-344; Mueller 2006, pp. 47-50; Burstein 2008; Cobb 2018, pp. 28-60.
3. Strabo, 16, 4, 7; 16, 769, 771; Pliny, *HN*, 37, 108; Peremans, Van't Dack 1952, no. 4419-4428; Fraser 1972, pp. 173-184, 308, 370-374.
4. Bresson 2011; Manning et al. 2017, p. 1.
5. Sidebotham, Hense, Nouwens 2008, pp. 213-226.
6. Gates 2005; Sidebotham 2011, pp. 28-31; Cobb 2018, pp. 56-59.
7. Burstein 1996, p. 801.
8. Bagnall, Bülow-Jacobsen, Cuvigny 2001; Sidebotham et al. 2019.

DE GRAAUW <arthur.degraauw@outlook.fr>

from the winter rainfall.[9] The whole region was also an extremely rich source of ores, semi-precious stones and minerals (including gold above all), which might have significantly influenced the economy of the planned project.[10] The Red Sea was an important, although difficult and challenging, route south to the lands of former Punt (mentioned in Pharaonic texts, and stretching somewhere around the southern part of the Red Sea, probably mainly in today's Eritrea and Ethiopia),[11] a source of exotic and desirable commodities such as ivory, incense, spices, precious furs, exotic wood, etc.[12]

The selection of the most convenient locations for new centers was the greatest challenge and the greatest opportunity for the whole project. Most likely all experience gained in the course of Pharaonic trade-exploration expeditions reported in Egyptian archives were exploited in the process.[13] However, a field survey must have been the most essential.

Methodology

Some of the archaeological research of the recent few years in the Berenike project focused on studies on the remains of the city from the Hellenistic period.[14] With this objective in mind, a series of trenches grouped in clusters were excavated in seasons 2010-2019 (*fig. 3*). This research, however, was not based solely on archaeological material.[15] It was combined with an analysis of satellite images of the area around the site and geomagnetic survey.[16] In the course of this work (especially the last two seasons), the researchers conducted a number of observations in the field of geology, geomorphology, hydrology (particularly in trenches BE 14/18-97/104 and BE 19-125) and climatology (particularly regarding the strength of the winds in Berenike in different seasons of the year in the past and presently, their directions, humidity, temperatures, precipitation intensity, etc.). These observations combine information from the fields of archaeology and natural sciences, and thus significantly contribute to the data collected in the course of geological and sedimentology research mainly based on a series of cores drilled by Dr. Anna Kotarba-Morley and Prof. James A. Harrell.

Throughout the years of the archaeological mission in Berenike, in a few parts of the site:
- to the south and east of the ruins of the "Roman city", in the eastern part of the site (in the 1995 season);[17]
- in the northern part of the site, area east of the necropolis (in the 2001 season);[18]
- in the so-called "northern port", northeastern part of site;
- and in "southern port", in the northern part of the southern lagoon (2011-2012 season);[19]

9. Raschke 1978; Sidebotham, Hense, Nouwens 2008, pp. 151-195, 329-343; Sidebotham 2011, pp. 7-8, 11-13, 125-175; McLaughlin 2010; McLaughlin 2016.

10. Burstein 1996; Sidebotham, Hense, Nouwens 2008, pp. 213-226; Klemm, Klemm 2013; Brun et al. 2013; Redon, Faucher 2015; Redon, Faucher 2016.

11. Tallet, Mahfouz 2012; Tallet 2016; Wicker 1998; Bard, Fattovich 2018.

12. Sidebotham, Hense, Nouwens 2008, pp. 151-192; Sidebotham 2011, pp. 221-258.

13. The earlier use of Berenike, probably as an anchorage for Egyptian ships heading south, if not a small port, is suggested by the discovery of a stela dated to the Middle Kingdom at the main temple at Berenike: Great Temple or Isis Temple (Hense, Kaper, Geerts 2015; Zych et al. 2016, pp. 339-340, fig. 17; Hense 2019, pp. 259-261). Wooden clamps with cartouches of New Kingdom pharaohs came from the same temple (found in the early 20th century), while Middle Kingdom scarabs, etc. were unearthed in a Hellenistic-Early Roman trash dump.

14. Woźniak, Rądkowska 2014; Woźniak 2017; Sidebotham, Zych 2016; Osypińska, Woźniak 2019; Sidebotham et al. 2019, pp. 8-12; Woźniak et al. 2021.

15. Osypińska, Woźniak 2019; Woźniak et al. 2021; Woźniak, Harrell 2021.

16. Woźniak, Rądkowska 2014; Woźniak 2017.

17. Harrell 1996, pp. 112-126.

18. Harrell 2019; Kotarba-Morley 2017, p. 69, fig. 4.

19. Kotarba-Morley 2017, pp. 68-90.

DE GRAAUW <arthur.degraauw@outlook.fr>

a total of several hundreds of cores were drilled along 19 transects.[20] A similar program of drilling, carried out in the silted lagoon of the Quseir el-Qadim site, identified with Myos Hormos, brought excellent results allowing, among other things, the delineation of a part of the coastline and the location of the port basin of this famous and important city.[21] At both sites (Berenike and Myos Hormos), drilling was carried out in clearly lowered parts of the terrain, in which there were no visible remains of permanent structures (e.g. walls). Also, the amount of archaeological material was significantly less. The abovementioned observations, made during the field surveys, and combined together with the results of satellite image analyses, suggested that in Antiquity, in the studied areas, a silted part of the lagoons existed, that was used as an internal port.

Observations of a geological nature were constantly carried out in archaeological trenches (mainly measurements of the level of the bedrock's top – e.g. in trenches BE 94/95-01, BE 96-11, BE 00-36, BE 00-40, BE 10-66, BE 10-69, etc. – and measurements of the highest sea level in each period – e.g. in trench BE 11-71, etc.). In recent years (2014-2019 seasons), a large amount of geological and hydrological data was gathered by works carried out in the western area of the site. In the trenches related to so-called "gate building" – trench BE 14/18-97/104 – and a cistern 001 – trench BE 19-125 (*fig. 3*), two rock-cut shafts were discovered, one of which reached 3.7 m deep into the bedrock of this part of site. Both shafts provided a unique opportunity for analyzing the geological structure of the site's rocky core which is

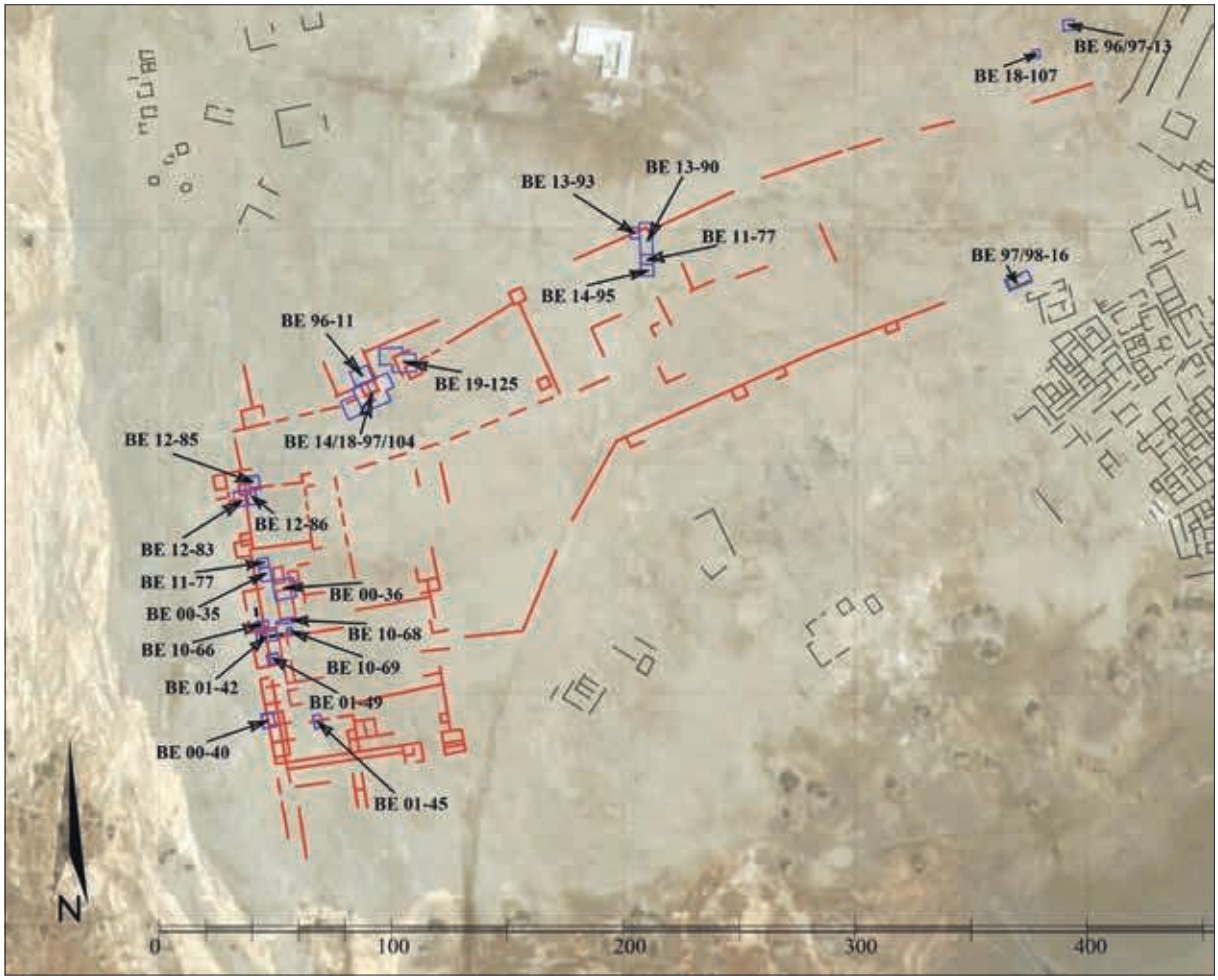

Fig. 3 – Hellenistic trenches in Berenike (map: R. Ryndziewicz, D. Święch, T. Herbich; interpretation: M. Woźniak; drawing: S. Popławski).

20. Kotarba-Morley 2017, p. 69, fig. 4.

21. Peacock, Blue 2006; Blue 2007.

DE GRAAUW <arthur.degraauw@outlook.fr>

usually difficult to penetrate. They also contributed to the discovery of an aquifer in this area containing a significant amount of water, slightly saline but suitable for drinking and industrial purposes.[22]

The analysis of hundreds of drill cores, together with the observations made in the archaeological trenches and during geological field surveys in the vicinity of the site, allowed the reconstruction of the complete geological structure of the site from its rocky core, through the arrangement of geological, alluvial strata to the highest anthropogenic layers with human-made structures and other archaeological remains. In the outskirts of the "Roman City", it was initially possible to reconstruct the course of the coastline. In the silted northern part of the "southern lagoon", except for the course of the coastline (in the Late Hellenistic period), it was even possible to date the individual layers accumulated in the port basin from the Hellenistic and Early Roman periods.[23]

The shape of Hellenistic Berenike and the topography of the region

The appearance and landform of the area selected by the Hellenistic engineers, headed by the strategos Philon (high-ranking military official in the time of Ptolemy II and founder of Berenike),[24] to build the future port/base has changed significantly today. Nevertheless, the most important elements of the local landscape and components of its geological structure remain the same.[25] As a result of recent research, it can be concluded that these factors – together with a convenient location in the context of accessible and economy-efficient routes leading across the mountains (*fig. 2*) – were the key influences for the selection of this particular area of the Red Sea coast for the foundation of the most important Hellenistic center in the whole region.

The city was situated on the northern shore of the lagoon (the so-called "southern lagoon"), connected with a big open bay (modern Foul Bay). It opens to the open sea in the southeast and is shielded by the rocky Ras Benas peninsula, which is 32 km long, in the north.[26]

The Hellenistic "fortress" of Berenike itself was established on two perpendicular promontories, connected almost at an angle of 90º (*fig. 4*). One of them (the so-called "western ridge") is aligned roughly along the north-south axis. It is 530 m long, 170 m wide and (as indicated by measurements taken in trenches BE 96-11, BE 10-61, BE 12-83, BE 12-85/86, BE 14/15-97/104) 3-3.5 m above sea level. It is almost completely built of a hard but heavily eroded Late Pleistocene coral reef.[27] The other peninsula, with ruins of a Roman city still present at its tip, stretches roughly from east to west. It is approximately 560 m long and 200 m wide. It is only built of the Late Pleistocene coral reef in its eastern part and its highest point (as indicated by cores sampled in trenches BE 94-1, BE 94-5 and BE 95-3) is located at 2-3 m above sea level.[28] In its western portion, the base of the "central promontory" is formed only by a sandy spit. It connects the reef formation situated at the tip of the "central promontory" with the central area of the eastern border of the "western ridge". This is where the former relatively wide (220-250 m) channel running from the north to the south and probably sculpted by water in a less condensed part of the reef terrace, was gradually filled with alluvial and aeolian material. The core drilled in its northern part did not reach the rocky bottom, however, it was sufficient to study the stratigraphy of this portion of the site.[29]

22. Woźniak, Harell 2021.
23. Kotarba-Morley 2017.
24. Pliny, *HN*, 37, 108.
25. Harrell 1996, pp. 99-102; Sidebotham 2011, p. 9; Kotarba-Morley 2017, pp. 63-66.
26. Sidebotham 2011, p. 9; Kotarba-Morley 2017, pp. 63-66; Woźniak 2017, p. 47.
27. For this topic, see: Veeh, Giegengack 1970, pp. 155-156; Hoang, Taviani 1991, pp. 268-271; Arvidson et al. 1994, pp. 12, 184; Plaziat et al. 1995, p. 18; Pugh, Abualnaja 2015, p. 326; Mansour, Madkour 2015, pp. 381, 388-389.
28. Harrell 1996, pp. 102-104; Harrell 1998, p. 125; Harrell 2019.
29. See core 1 in Harrell 2019, fig. 4-2.

DE GRAAUW <arthur.degraauw@outlook.fr>

On the basis of the information in Strabo's[30] and Pliny the Elder's[31] texts, as well as discoveries in Berenike, it can be concluded that such rocky and rocky-sandy promontories were preferred by the builders of the Red Sea bases for the selection of their locations in Hellenistic times. Out of necessity, they were defensive structures and thus were located in places easy to fortify. Both at Berenike[32] and Ptolemais Theron,[33] they were separated from the mainland with lines of defensive walls. The small city/base of modern Marsa Nakari (ancient Nechesia?), also situated on a rocky promontory, was most likely fortified in a similar manner, although its fortifications have been tentatively dated to the Early Roman period.[34]

The excavations which revealed the remains of the structures dated to the Hellenistic period were first of all concentrated in the central and western part of the archaeological site of Berenike (*fig. 3*).[35] The location of the trenches was determined by the accessibility of the oldest port/base structures. In the central and western part of the site, the remains of Hellenistic structures (or the traces of their robbing) are just under the surface. In the Roman period, the city first occupied eastern and southern parts of the present-day archaeological site. The soils from the Roman period (sometimes up to several meters thick) make it difficult for archaeologists to reach older structures here.[36] Also, the more intense robbing of construction materials in the eastern and central parts of the site, when compared to the western part (whose traces are visible in all the structures from the Hellenistic period), caused the greatest damage here.[37]

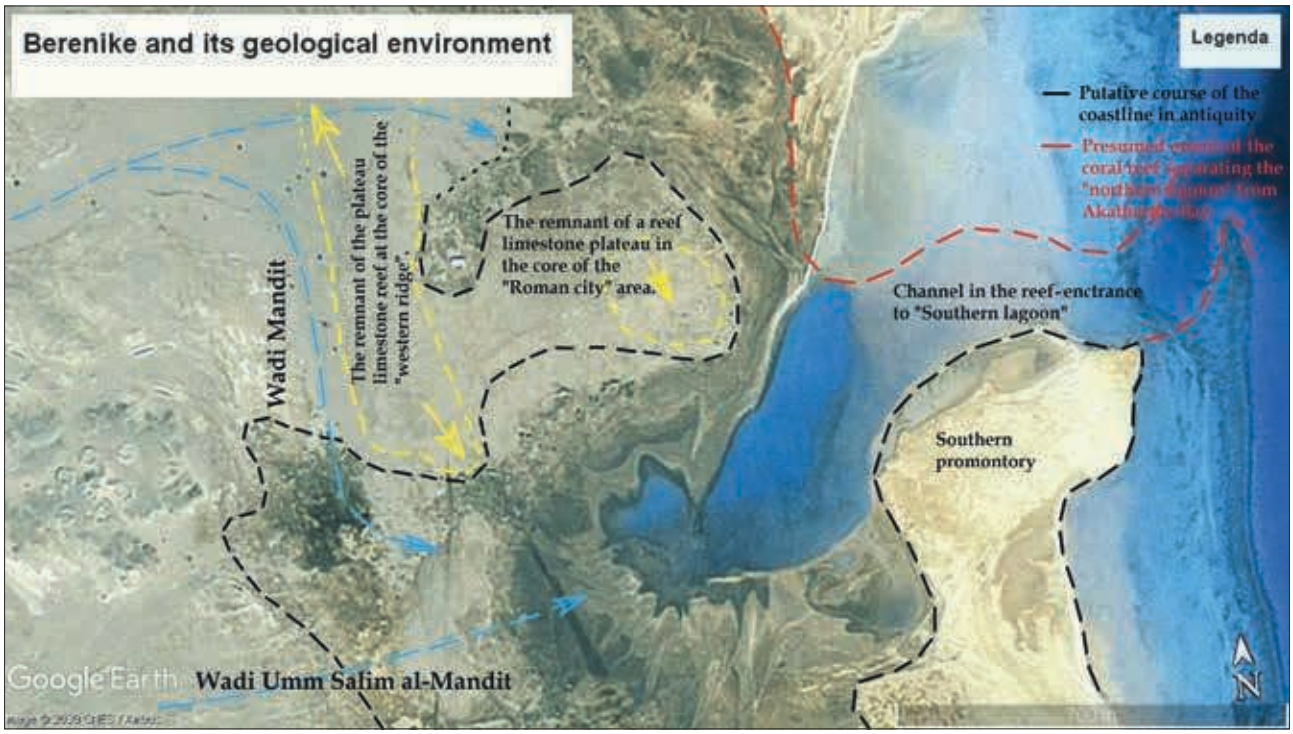

Fig. 4 – Berenike map with geological background (J.A. Harell, M. Woźniak).

30. 16, 4, 7.
31. *HN*, 6, 171.
32. Woźniak 2017, pp. 43-46.
33. Strabo, 16, 4, 4-7; Roeder 1959, pp. 125-126.
34. Seeger 2001, p. 81; Sidebotham 2011, p. 186.
35. Osypińska, Woźniak 2019, pp. 368-369, fig. 2; Woźniak 2019, p. 241.
36. Aldsworth, Sidebotham, Wendrich 1995, pp. 13-21; Sidebotham 2007, pp. 56-77; Woźniak et al. 2021.
37. Woźniak, Rądkowska 2014; Woźniak 2017.

DE GRAAUW <arthur.degraauw@outlook.fr>

The first two groups of Hellenistic trenches were located almost on the western limit of the site, where numerous finds dating from the Hellenistic period can be found on the surface (mainly pottery, nails and other pieces of colored metals, coins as well as metallurgical production waste, etc.). The first trenches were located here in the years 1999-2000,[38] following magnetic prospection which revealed the line of structures not visible on the surface.[39] This research was complemented by another series of trenches located in this part of the site after the mission was reactivated in the years 2010-2012. In all, 13 trenches were located here. Archaeological excavations combined with extensive magnetic research and field prospection allowed it to be determined that what was initially thought to be a line of small workshops is in fact a large fortified (150x80 m) warehouse and industrial building which was called a "fort". Three trenches (BE 12-83, 12-85 and 12-86) have revealed the remains of the square northwestern tower of the northernmost, most fortified, fort yard. Although, the walls of the tower were almost completely robbed, the network of foundation trenches cut into the bedrock allowed not only the dimensions of the tower itself to be determined, but also the thickness of its walls as well as the sequence according to which individual elements of fortifications were built (*fig. 3*, *5*).[40]

Ten other trenches (e.g. BE 00-36, 00-40, 01-42, 10-66, 10-68) were located along the westernmost part of the multi-phase "fort" structure.[41] Archaeological excavations combined with the results of

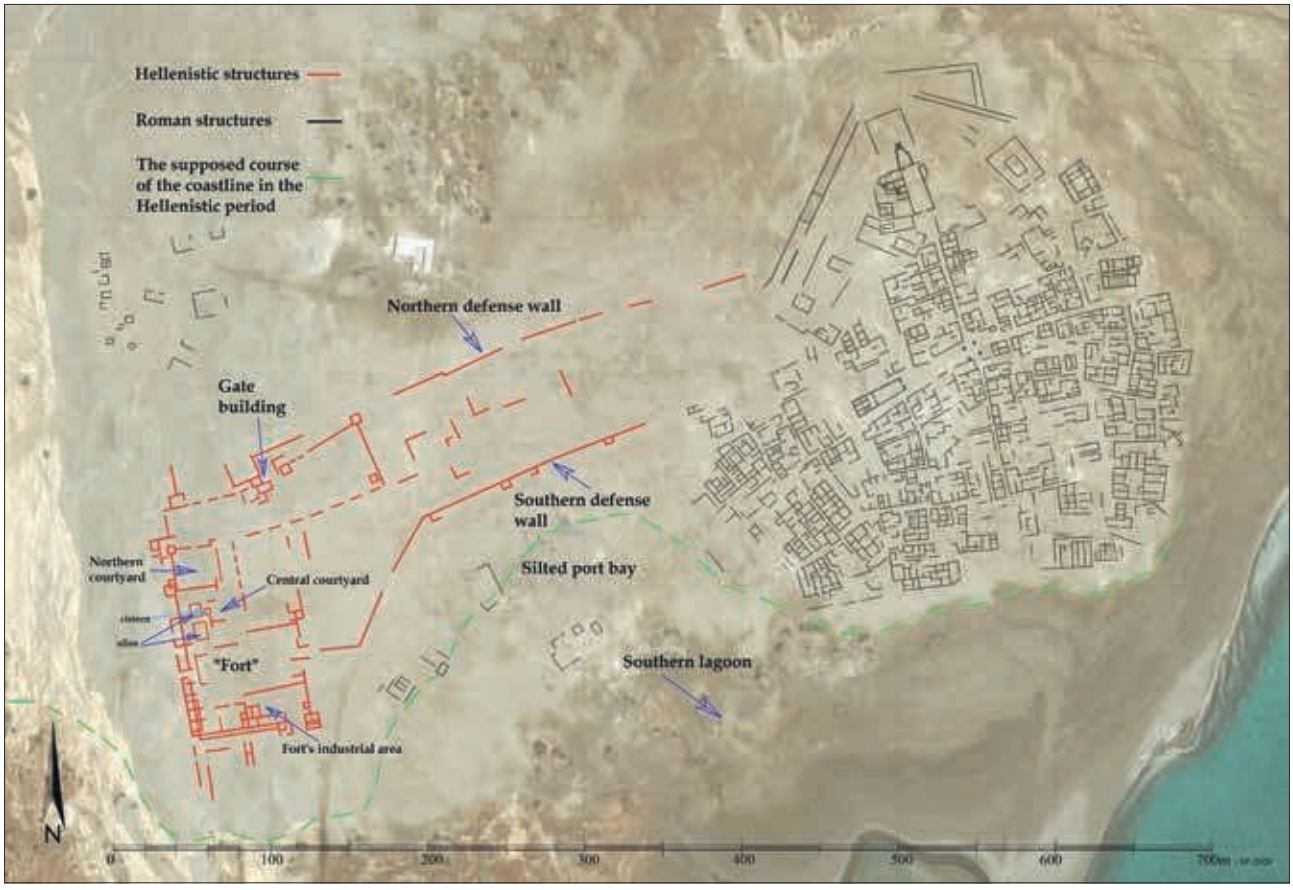

Fig. 5 – Hellenistic structures mentioned in the text on the plan of Hellenistic Berenike; reconstruction based on the magnetic map and field survey (map: R. Ryndziewicz, D. Święch, T. Herbich; interpretation: M. Woźniak; drawing: S. Popławski).

38. Sidebotham 2007, pp. 30-44.

39. Herbich 2007, pp. 23-26.

40. Woźniak, Rądkowska 2014; Woźniak 2019, pp. 241-242.

41. Woźniak, Rądkowska 2014; Sidebotham 2007, pp. 30-44; Sidebotham, Wendrich 2001-2002, pp. 25-27; Woźniak et al. 2021.

DE GRAAUW <arthur.degraauw@outlook.fr>

magnetic research showed that at least three different phases of operation can be identified in the "fort" (*fig. 6*). This phasing, based mostly on relative stratigraphy and ceramic finds (first of all the fragments of the stamped Rhodian amphora handles), was not only identified, but also dated.[42]

The oldest "fort" phase (dated to the second quarter of the 3rd century BC) (*fig. 6a*) was also the smallest one (its size was 55 m N-Sx30-40 m E-W). It most probably consisted of a small (25x25 m) northern square courtyard with four square towers (5x5 m) in each of its corners. Magnetic and archaeological research did not reveal the presence of any structures in the courtyard itself. This does not mean, however, that some other structures built out of non-durable materials, such as wood or mats, typically used as building materials by local tribes, were not built here. The fortress arranged in this way was adjoined from the south by a large square (about 30 m long N-S and of similarly width E-W) surrounded by a V-shaped ditch cut into the rock – whose fragments were uncovered in the trenches BE 01-42, and also later in BE 10-66 and 10-68 (*fig. 3*).[43] The similarity of the V-shaped ditch to moats surrounding zoo animal runs is probably not accidental. In Berenike, the square surrounded by such a dry moat was also used as an animal pen where animals were kept. The find of an elephant molar tooth comes from this pen (trench BE 11-77).[44] The layers on the top of the western plateau where the fort was built (see below) were reduced to 0.3-0.4 m by intense erosive processes. This, unfortunately, makes more accurate dating of this find impossible, and it remains unclear whether the elephant, whose tooth was uncovered, was kept in the animal pen of the first phase of the "fort" or in the courtyard of its second phase, both located in the same area.

Around the middle of the 3rd century BC, the V-shaped ditch was filled up and the northern square courtyard was included into a new large "fort" building representing the second phase of the "fort's"

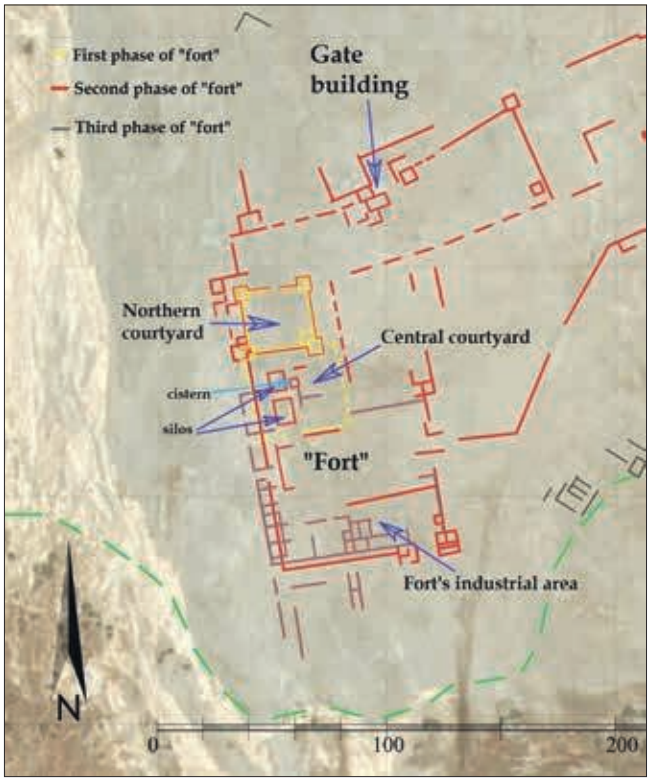

Fig. 6 – Phases of the Hellenistic "fort" in Berenike; reconstruction based on the magnetic map and excavations; a: yellow, first phase; b: red, second phase; c: gray, third phase (map: R. Ryndziewicz, D. Święch, T. Herbich; interpretation: M. Woźniak; drawing: S. Popławski).

42. Woźniak et al. 2021.

43. Woźniak, Rądkowska 2014; Sidebotham 2007, pp. 30-44; Sidebotham, Wendrich 2001-2002, pp. 25-27; Woźniak et al. 2021.

44. Sidebotham, Wendrich 2001-2002, p. 41; Sidebotham 2011, p. 50; Osypińska, Woźniak 2019, p. 374; Woźniak, Rądkowska 2014, p. 517; Woźniak 2019, p. 243.

DE GRAAUW <arthur.degraauw@outlook.fr>

operation (*fig. 6b*).[45] The new fort building housed warehouses, workshops as well as outbuildings concentrated around two new courtyards, both located south of the old northern courtyard. On the basis of archaeological excavations as well as the analysis of the results of both magnetic prospection and field surveys, it can be determined that industrial activity was concentrated mainly in the southern part of the complex and warehousing in its western part. The "fort", phase II was the biggest of the three phases (approximately 140 m N-Sx85 m E-W). In its central courtyard (located directly to the south of the oldest northern courtyard), archaeological excavations have revealed the remains of a cistern carved into the rock and two other rectangular structures, probably a kind of silo used for storing loose goods, perhaps grain (*fig. 5*).[46]

The third phase of the "fort" (*fig. 6c*), a little smaller (approximately 120 m N-Sx80 m E-W) and slightly shifted to the south, was erected on two-thirds of the building from the second phase.[47] The construction of the third phase probably followed either the period of significant reduction in the intensity of activities carried out in Hellenistic Berenike, or complete abandonment of the city. This is reflected in the numerous traces of destruction and reconstruction of the second phase structures as well as in the wide use of materials obtained from the demolition of older walls and structures (including lumps of hard hydraulic mortar from the lining of cisterns or water basins) in the construction of the walls of the third phase.[48] This fact is also probably reflected in the change of the new "fort" building's shape (which was approximately 5-6 m wider on E-W axis than the previous one, and at its southern end it reached approximately 40 m further south). The period of construction of the third phase of the "fort" is also related to the second phase of functioning of the entire Hellenistic base in Berenike, which is manifested, for example, by major changes in the construction of the "gate building" and related hydraulic structures.[49] The construction of the third phase of the functioning of the "fort" can be dated to the last quarter of the 3rd century BC. If, however, we link it with the phasing of the "gate building" and related structures, this dating (based on two other finds of stamped Rhodian amphora handles) can be narrowed to the years 230-220 BC.[50]

The residential part of the "fort", if it existed at all within this large, architectural complex, could only occupy a small part of the western line of its rooms. However, the type and scale of industrial activity carried out in the "fort" is evidenced by the remnants of metallurgical crucibles, furnaces, ash heaps and trails visible even on the ground, as well as finds of thousands of copper nails and tens of kilograms of lead sheets and scraps from this part of the site.[51] Gigantic amounts of ceramic sherds, mainly fragments of amphorae, lay in the western part of the building.

The "fort" occupying the western third of the entire area of Hellenistic Berenike was connected with the residential quarter located in the easternmost part of the base/port by two lines of fortifications: the northern one forming the northern limit of the whole site (only the small part uncovered in the trenches BE 13-90 and BE 13-93 was archaeologically examined) and the southern one surrounding the port on the "southern lagoon" (*fig. 3*, *5*). The exact course of both lines of fortifications is very clearly visible on the map created as a result of magnetic research, meanwhile the dating and construction of the northern line was determined on the basis of the research of archaeological materials and the remains of structures themselves, uncovered in the trenches BE 13-90 and BE 13-93.[52] At the bottom of a 2 m wide and 1.6 m deep robber trench, the remains of a wall, built of not very well worked,

45. Woźniak, Rądkowska 2014, pp. 520-522, fig. 8b.

46. Woźniak, Rądkowska 2014, pp. 509-511, fig. 2; Sidebotham 2007, pp. 31-37; Woźniak et al. 2021.

47. Woźniak, Rądkowska 2014, p. 522, fig. 8c; Woźniak et al. 2021.

48. Sidebotham 2007, pp. 38-40, fig. 4/6.

49. Woźniak, Harell 2021; Woźniak et al. 2021.

50. Woźniak et al. 2021.

51. Sidebotham 2007, pp. 31-44; Woźniak, Rądkowska 2014.

52. Woźniak 2017, pp. 46-47, fig. 1b; Woźniak 2019, p. 246.

DE GRAAUW <arthur.degraauw@outlook.fr>

anhydrite blocks of various sizes, were uncovered. The lowest level of the blocks (most likely a strip foundation dug into the clean sand of the bedrock) was 1.6 m wide. The wall placed on it was slightly thinner and was 1.0 m thick. The exposed fragment of the wall was in the shape of a zigzag and was probably a linking point of two separately built sections of 180-meter-long fortifications. According to the magnetic survey whose results were confirmed by the field prospection, it can be stated that this wall, that bends twice, runs southwest of trenches BE 13-90 and 13-93. One of these bends (forming a corner pointed toward the outside of the fortress) had a square tower (5x5 m), while in the other (facing the inside of the fortress) an unidentified structure, probably an open water cistern, was located.[53]

The fourth group of Hellenistic trenches (BE 96-11, BE 14/18-97/104 and BE 19-125) was located on the same rocky plateau, north of the "fort" (*fig. 3*, *5*).[54] The remains of a small Early Hellenistic gate were uncovered in these trenches. The gate can be dated to the time between the middle of the 3rd century BC and 200 BC with a short period of revitalization probably at the end of the 2nd century BC. This gate was rebuilt at least twice. Its second reconstruction resulted in significant changes to its shape and function. From the moment it was built, the "gate building" featured a well cut into the rock. At first the well was only an ordinary shaft in the shape of an irregular square (ca 1.7x1.8-2.0 m) located in the western part of the internal chamber of the gate. After the gateway was blocked, the well was expanded into a kind of combination of a well and a cistern measuring 2.0x3.9 m. The whole complex of structures related to the acquisition, storage and distribution of water was created around the multiphase "gate building" (*fig. 7*). It included one more rock-cut cistern, located east of the gate (*fig. 8*) and a complex of two large, hydraulic mortar-lined basins (basin 1 and 2) of a total capacity of 17,000 liters (*fig. 7*). There was also a system of small semicircular basins (used perhaps for washing or filling amphorae) connected with the large pools (presumably water reservoirs) by lead pipes. The whole complex (except for the easternmost cistern) was housed in one large building (that has not been fully explored yet), whose ceiling was supported by massive pillars built of anhydrite blocks and whose floors were covered with a thick (approximately 5 cm) layer of hydraulic mortar (*fig. 7*).[55]

In the surveys, in the years 2018-2019, a large number of structures from the Hellenistic period were identified in the central part of the site (between the northern and southern defensive wall) as well as east of the "fort". They are waiting for detailed archaeological study. Also, the Hellenistic garbage dumps located in the central part of the site, north of the port, have been very poorly researched so far.

The "southern lagoon" at Berenike (even today, in the small unsilted part) is 2.5-3 m deep. Nevertheless, the satellite images of it indicate that its extent and depth must have been much greater in Antiquity (*fig. 9*).[56] Such suggestions were partially confirmed by a series of tests conducted in its northern, silted part in 2011-2012.[57] The "southern lagoon" in its northwestern portion[58] forms the combined river mouth of three wadis (Wadi Mandit, Wadi Umm Salim al-Mandit and the northern branch of Wadi Kalalat),[59] which is probably the reason for its depth.

---

53. Woźniak 2017, pp. 45-47, fig. 1b; Woźniak 2019, pp. 243-244.

54. Woźniak 2019, p. 241, fig. 1.

55. Wożniak 2017, pp. 47-59; Woźniak 2019, pp. 246-251, fig. 6-10; Woźniak, Harell 2021; Woźniak et al. 2021.

56. Such a suggestion, initially based on an analysis of satellite images and comparison with a similar lagoon accommodating the inner port of Myos Hormos (modern Quseir el-Qadim), has been confirmed by recently published results of an analysis of geological cores sampled at Berenike by Dr Anna Kotarba-Morley.

57. Kotarba-Morley 2017.

58. Only the northeastern portion of the previously large lagoon remains free of silt. Originally, it was probably the deepest and the tides were the strongest there. The river mouth of the wadis mentioned here is now located in the northwestern, extremely silted area of the lagoon, which is presently much smaller than in Antiquity due to the amount of silt.

59. Harrell 1996, p. 102.

DE GRAAUW <arthur.degraauw@outlook.fr>

The barrier formed by the lowest of the sea terraces, built of eroded Pleistocene reefs,[60] protected it from damage from high waves and sea currents, creating perfect anchorage conditions for all types of sea vessels. Even large (and large draft) Ptolemaic transportation ships (the so-called *elephantagoi*), which carried goods and animals (especially elephants)[61] from the south, would have had enough space for anchorage. The only problems for such big vessels could have been the dimensions and the shape of the bottom of the entrance route. The channel that joins the bay of Akathartos with the "southern lagoon" was wide enough. It was also very deep (more than 10 m), which was the case for many Red Sea lagoons.[62] However, after crossing approximately 400 m of the deepest waters, ships entering the port reached the shallowest point of the route.

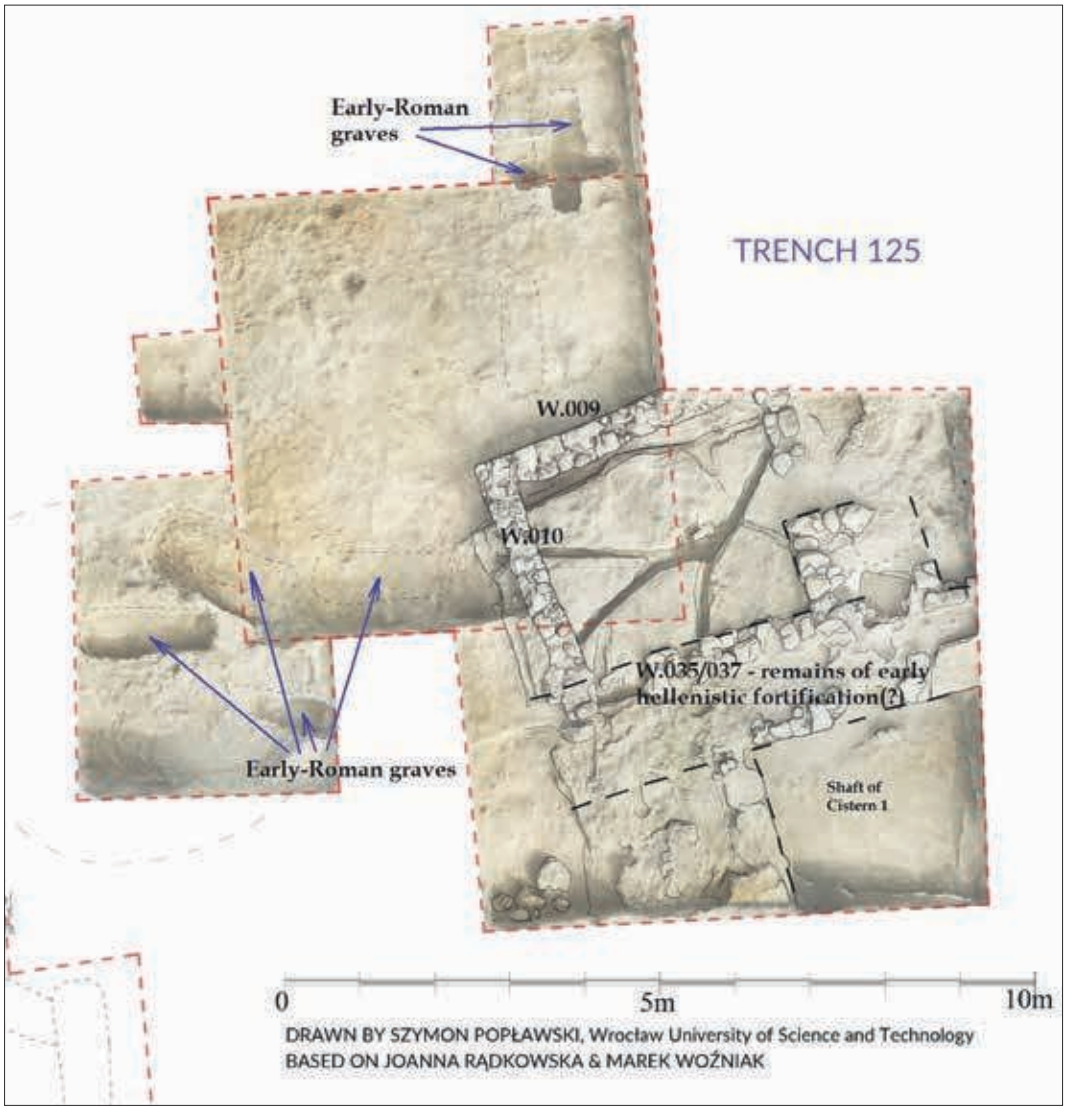

Fig. 7 – Plan and photogrammetry of the gate building in Berenike (S. Popławski, M. Woźniak).

60. Arvidson et al. 1994, pp. 12, 184; Plaziat et al. 1995, p. 18; Pugh, Abualnaja 2015, p. 326; Woźniak, Harrell 2021; Harrell 2019.

61. Wilcken 1963, p. 452; Burstein 1989, p. 141; Whitewright 2007; Sidebotham 2011, pp. 39-53; Bower, Farrar 2015, pp. 329-330.

62. Rasul 2015, pp. 281-282ff.

DE GRAAUW <arthur.degraauw@outlook.fr>

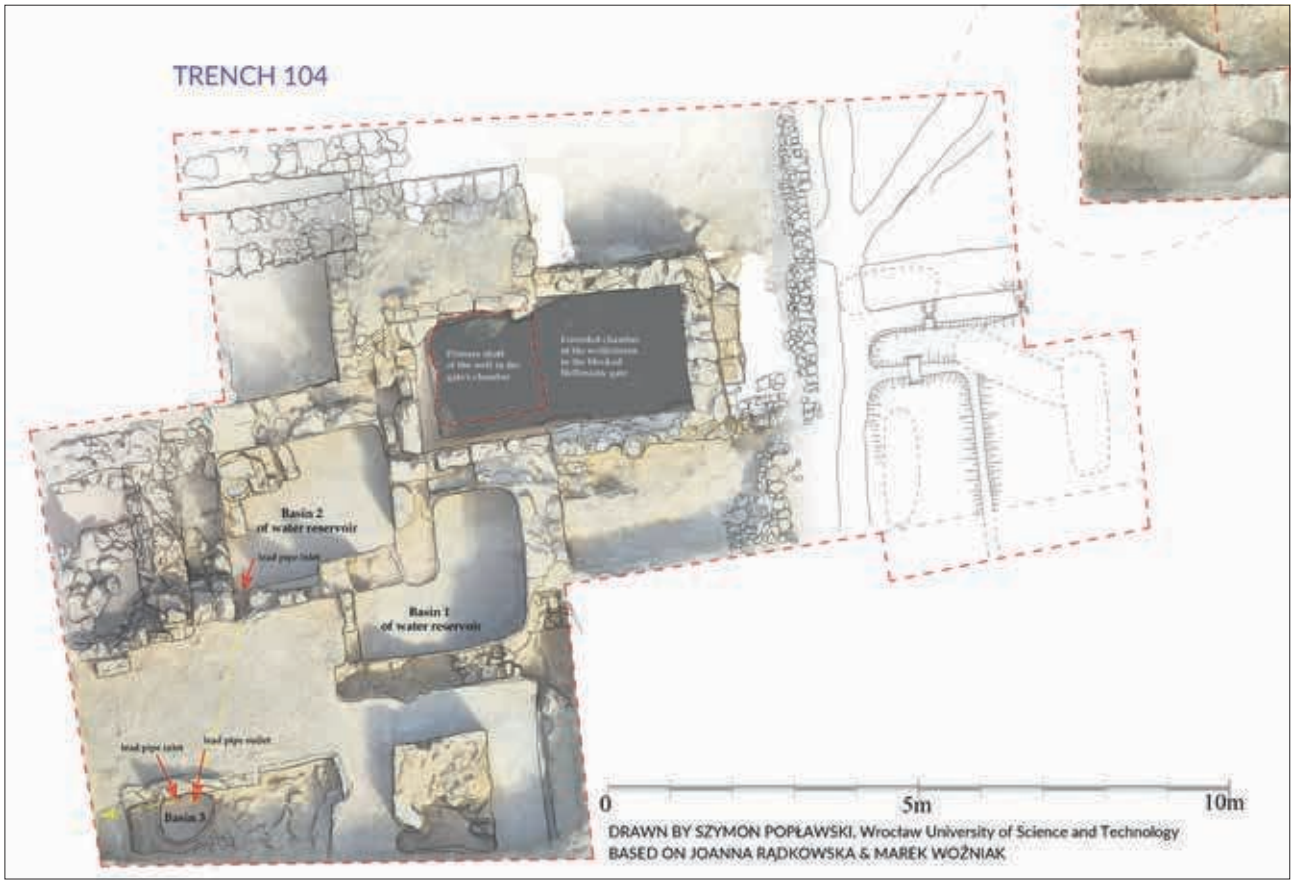

Fig. 8 – Structures to the east of the gate building, plan with photogrammetry (S. Popławski, M. Woźniak).

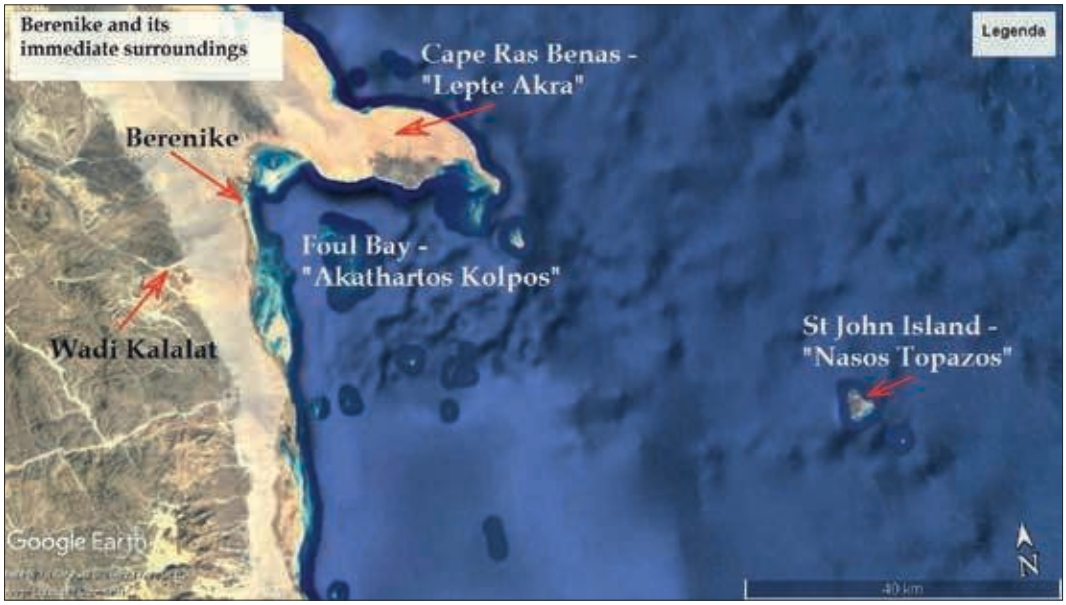

Fig. 9 – Berenike and its immediate surroundings (M. Woźniak).

DE GRAAUW <arthur.degraauw@outlook.fr>

This is where the channel crossed the lowest level of the Pleistocene reefs and the water depth probably decreased to a few metres. Still, it must have been sufficient, even for the large draft *elephantagoi*[63] as most buildings associated with Hellenistic city/base infrastructure as well as animal maintenance were situated far on the northwestern shore, deep into the southern lagoon.[64] The quiet lagoon waters were probably favorable for unloading such a "sensitive" and valuable transported commodity as living elephants. Smaller boats and ships which delivered supplies for the city or which were used for port maintenance and fishing, could easily cross both lagoons surrounding the city/base, anchor or even harbor there and be lifted onto the flat sandy shores. It has not been possible to establish where large seafaring transportation ships harbored or how living animals were unloaded. It seems that a convenient place for that was located near the so-called "fort" used for keeping them.[65] The depth of the channel running across the northern portion of the "southern lagoon" and a particular manner of silting probably resulted in the fact that in Antiquity, like today, the area of very shallow water was located directly next to the deepest waters. The bottom did not descend gradually but dropped away along a steep silt-covered slope a few meters deeper. Therefore, a big seafaring transportation ship could travel along the deepest channel to the southern, rocky edge of the "western range". It could also, if necessary (probably during low tide), use portable ramps[66] to unload its live cargo directly onto the sandy beach, e.g. in the northern part of the lagoon, near the city walls. The animals and commodities could be easily taken from that area to the part of the base used for storage and industrial purposes, located on the "western promontory".

The sandy characteristics of the "southern lagoon" shores had yet another, although no longer visible, advantage. As can be concluded from the botanic and malacological material recovered from the Hellenistic layers at Berenike,[67] the shores of the lagoon (at least in the Hellenistic period) were covered by thick mangrove shrubs.[68] Such vegetation can still be observed several dozen kilometers north of Berenike, in the lagoons neighboring the river mouth of the Wadi Gemal. The thick mangrove shrubs not only perfectly stabilized the shores of the lagoon (preventing it from silting up to a significant degree), but also formed an extremely rich habitat for many aquatic organisms. Additionally, it was a source of valuable wood used for construction and as fuel, located just next to the fortress.

In general, both lagoons at Berenike (especially the northern one), together with their mangrove shrubs, "marine meadows" and sandy shoals, just like the bay of Akatharthos with its coral reefs (*fig. 9*), served as a type of very rich pantry for the Hellenistic and then Roman city.[69] They were populated by countless fish species of many sizes as well as all sorts of marine mollusks and crustaceans.[70] They could have introduced variety into the sufficient but obviously monotonous supplies delivered to Berenike by sea (probably along the channel built already by Darius the Great and the port at Klysma/Kleopatris) as well as by land from the Nile Valley.

63. Diodorus Siculus, 3, 40, 3-5; Casson 1993, p. 253 and n. 28.

64. Sidebotham, Wendrich 2001-2002, p. 26; Woźniak, Rądkowska 2014; Woźniak 2017; Woźniak et al. 2021.

65. The so-called "fort" was in fact a large, fortified warehouse and industrial complex (see above in paragraph 3).

66. Casson 1993, pp. 152-154, Sidebotham 2011, p. 50.

67. Woźniak et al. 2021.

68. A. Carannante, pers. comm.; Vermeeren 1998, pp. 345, 347; Hamilton-Dyer 2011, p. 27, fig. 20, 25 and 272.

69. A. Carannante, pers. comm.; Woźniak et al. 2021.

70. Van Neer, Ervynck 1998, pp. 356-363.

DE GRAAUW <arthur.degraauw@outlook.fr>

The environmental impact on the functioning of the Hellenistic port of Berenike

Despite the narrow (approximately 50 m) channel which allows Foul Bay (in Antiquity called "Akathartos" – "unclean" due to a high number of dangerous reefs)[71] to communicate with the quiet "southern lagoon", such a system of water reservoirs formed a perfect port, practically abolishing the necessity for construction of any additional, artificial structures (*fig. 3*). Nevertheless, lagoons and mouths of wadis inundated with sea water that are the same, or even better, are numerous along the west coast of the Red Sea. A glimpse at the portion between Halayib and Muhammad Qol (*fig. 10*) illustrates this: there are at least eleven lagoons and bays which are sufficiently deep and shielded for an efficient port. Most of them are as large as the ancient (at that time unsilted) "southern lagoon" of Berenike, and the bay located to the south of Jazirat Halayib, as well as the enormous Dungunab Bay, are much bigger. This means that Philon and his engineers did not make their choice solely on the basis of the landscape. The area for the location of the base at Berenike had to be situated in the right spot on the coast with regards to the winds (crucial for sea transport in Antiquity) and destinations in the Nile Valley.[72] Most of the bays and lagoons mentioned above are too far south to organize a route reaching the Nile Valley below the First Cataract. Only Halayib bay meets the criterion and is even more conveniently located than Berenike, or Myos Hormos (*fig. 10*).

Halayib bay is located further south than Berenike and thus, in winter, southerly winds were stronger there (*fig. 11*). These winds also probably reached Berenike in Antiquity, as can be concluded from the fact that heavy *elephantagoi*, loaded with live elephants (which were an extremely sensitive and difficult to transport cargo) also arrived at this port.[73] Nevertheless, every kilometer sailed further north was associated with a decrease in the strength and frequency of southerly winds and an increased strength of northerly winds, which expanded the delay for reaching the port of destination and generated an augmentation in the cost and risk of the journey. In Antiquity, Berenike must have been situated at least at the border of the range of winter, southerly and south-easterly

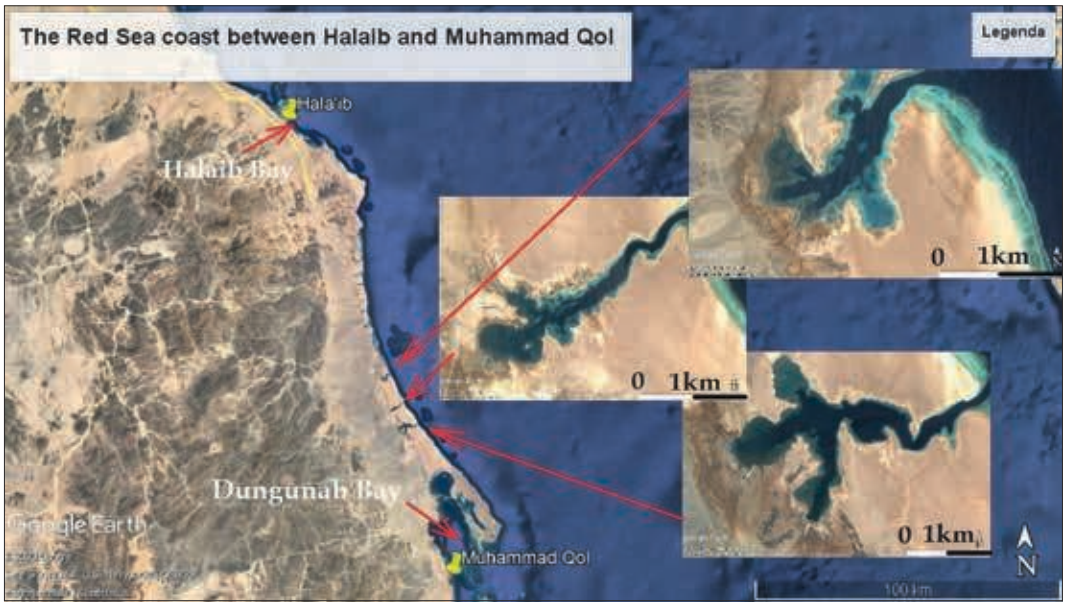

Fig. 10 – A few of the Red Sea bays south of Halayib (M. Woźniak).

71. Strabo, 16, 4, 5.

72. Gates 2005; Sidebotham 2011, pp. 125-136; Sidebotham et al. 2019.

73. Wilcken 1963, p. 452; Burstein 1989, p. 141; Whitewright 2007; Bower, Farrar 2015, pp. 329-330.

DE GRAAUW <arthur.degraauw@outlook.fr>

winds (according to climatologists, this border is now located approximately in the area of the Tokar Delta in Sudan).[74] Myos Hormos, located to the north of this border, was in a worse location than Berenike, the Halayib area however lay far enough south to be deep in the zone of influence of southerly winds. In the winter season, these winds were strong enough to carry even the largest and heaviest ships there.

While the climatic and geographic conditions in the Halayib area were appropriate, there were other problems with this location. The lack of *hydreumata* (fortified wells with cisterns) on the route between the area of Halayib and Syene suggest that, for some reason, the Hellenistic builders did not choose this route for the purpose of transporting animals from the Red Sea coast to the Nile Valley.

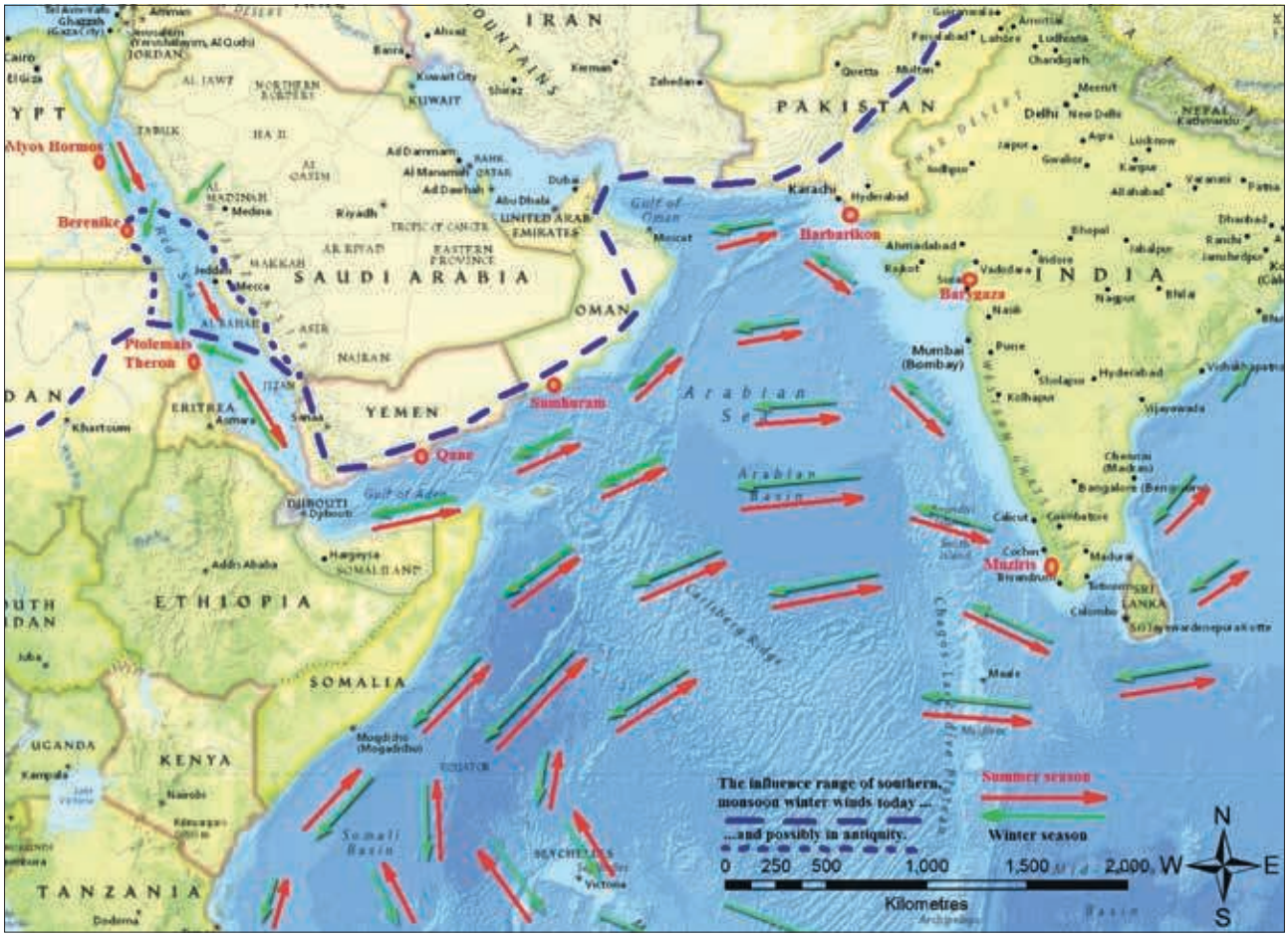

Fig. 11 – Monsoon patterns on the Red Sea and Indian Ocean (University of Southampton, ESRI and National Geographic; interpretation: M. Woźniak).

74. According to recently created climate models, even a minor change in the air and ocean water temperatures can indirectly affect the extent of influence of the opposing north winds (dominating in the northern portion of the Red Sea) and south as well as southeast winds (dominating in the southern part of the sea in winter). In the case of the cooling of the ocean waters (La Niña phenomenon), changes in the high-pressure area extent over north Africa lead to the intensification of cold north winds and a shift in their ranges and also shift the area of precipitation (The Red Sea Convergence Zone) to the south. The opposite happens when the climate warms. The border of the south monsoon winds, which bring humidity, moves northwards together with more intense precipitation and higher temperatures (Dasari et al. 2018). Discoveries of an extensive network of drainage channels and (even in the oldest structures) systems preventing the erosion of anhydrite structures by water imply that Berenike was located in the area of precipitation when the Ptolemaic fortress functioned here in the Early Hellenistic period. In addition, it was most likely situated in the zone which was highly affected by winter south and southeast winds.

DE GRAAUW <arthur.degraauw@outlook.fr>

Economics might have been this factor (prosaic yet so important). First of all, the region of Halayib is situated more than 400 km away (as the crow flies) from Syene (the first city in the Nile Valley located below the First Cataract) while Berenike is only approximately 300 km away from Apollonopolis hé Megalé (Edfu) on the Nile (the two were joined by a well-prepared Hellenistic land route). Secondly, as confirmed by excavation research conducted by the French mission at the Hellenistic mining area in Samut, located approximately halfway between Berenike and Edfu, an important gold-mining centre functioned there from the late 4th century BC (its older part, "Samut North" in the northern part of area).[75] Therefore, at the time of the foundation of Berenike, in the end of first half of 3rd century BC (when the mining center in Samut was also significantly developed by the construction of a bigger fort around "Bir Samut", about 5 km south of "Samut North", with new surrounding mining sites),[76] a big part of the necessary infrastructure (mostly wells) already existed and probably functioned efficiently at the midpoint of the route that linked the new base/port with the Nile Valley (between Samut and Edfu). Furthermore, development of the western half of route facilities and construction of new objects in its eastern part could have been joined together in one building project. It was quite cost-effective if only half the number of wells needed to be dug. Also, the two centers (especially for the delivery of the gold mined from the Samut mines and commodities and animals imported from Berenike) could have been partially serviced simultaneously. It was a great advantage.

Conclusions

These observations provide additional information and a "multidisciplinary" background for the results of typically archaeological research focused on studying the Hellenistic phase of the functioning of Berenike, conducted since 2010.[77] Nevertheless, they make it possible to place the Ptolemaic city/base in a wider environmental context, whose influence on the functioning of past centers and their reality has become increasingly important in the eyes of contemporary researchers. It seems that the information provided here corresponds perfectly with the character of Hellenistic Berenike (and probably of other Hellenistic centers in the region) revealed by archaeological research.[78] The results of the latter reflect an image of the whole Berenike harbor/base as an efficient fortress which resembled big military bases (like the type of one that is located on the northern shore of Foul Bay at the moment) rather than flourishing Hellenistic cities full of sophisticated structures and art pieces. Its striking feature was the perfect planning of each activity and the simplicity, sturdiness and utter utilitarian nature of not only the buildings, but also the structures connected with e.g. sourcing and distribution of water, reception and storage of goods and ensuring security.

The types of deliveries and the ways of supplying goods to the city also reflected efficiency rather than luxury as the priority. Hundreds of amphorae and storage vessels reached Berenike; however, most came from Egypt[79] and are likely to have contained the most basic supplies (mainly olive oil and perhaps also beer). Only a minor fraction of them were imported and could contain wine, one of the basic elements of the Hellenistic diet in other regions. We know from written sources that large amounts of grain for flour (or possibly flour itself) was delivered to all Red Sea centres.[80] On the basis of the material recovered from the Hellenistic contexts at Berenike, it was also concluded that the inhabitants of the city were supplied with rather moderate amounts of meat (mostly goat meat and

75. Brun et al. 2013, p. 115; Redon, Faucher 2015, p. 19; Redon, Faucher 2020; Redon 2018.

76. Redon, Faucher 2015; Redon, Faucher 2016; Redon 2018.

77. Woźniak, Rądkowska 2014; Sidebotham et al. 2015, pp. 300-305; Woźniak 2017; Zych et al. 2016, pp. 322-326; Woźniak 2019; Woźniak et al. 2021; Woźniak, Harrell 2021.

78. Woźniak et al. 2021.

79. Tomber 1998, pp. 164-169 and R.S. Tomber, pers. comm.; Woźniak et al. 2021.

80. Wilcken 1963, p. 452; Casson 1993, pp. 257-258 and n. 40.

DE GRAAUW <arthur.degraauw@outlook.fr>

mutton, but also some beef and pork), which was carefully divided and cooked.[81] Mainly donkeys, but probably also mules, were used as draft animals. The monotonous diet could have been supplemented with fish, marine snails, oysters and other mollusks as well as crabs caught in the local waters.[82]

The results of archaeological and environmental research and information from written sources suggest that the port/base at Berenike acted as the focal point of the entire chain of port centers.[83] Berenike was an intermediary in sending supplies to hunting stations and ports in the southern Red Sea region, the number of which rapidly increased during the Hellenistic period.[84] Here large transport ships, so-called *elephantagoi*, were prepared and equipped, and sailed south carrying most of the supplies for Ptolemais Theron and further stations, and transported live elephant loads from there.[85] For this purpose, a huge "fort" was built in Berenike with a large number of storage rooms, and metallurgical and repair workshops. The enormous number of sherds of storage vessels (mostly amphorae and kegs) "covering" the western part of the "fort" building is probably also testimony to the storing and forwarding of supplies.

Due to its location, environmental and logistic conditions, the main port specialized in storing supplies and preparing their transport was Klysma/Kleopatris. This port, located at the eastern end of the canal connecting the Nile with the Red Sea (navigable only during part of the year, and only by a fleet of small river vessels), had to be a large transshipment hub for all goods shipped south to all other ports/bases.[86] In the Hellenistic Kleopatris (as in the Klysma/Qulzum of the Roman and Islamic periods), large amounts of heavy, bulk cargo (e.g. grains and olive oil) awaited the preparation of the fleet going south, and then were loaded onto small ships, that once empty (probably after leaving the supplies in Berenike), could return back here, sailing against the strong, northerly winds.[87]

Finds of molars and fragments of skull bones of young elephants from Berenike[88] suggest that, in addition to reloading supplies, this port/base was the point where elephants brought from the hunting stations in the south were unloaded. The discovery of the V-shaped ditch also suggests that animals rested here after an exhausting sea voyage, and from here, by the land route, were driven through the mountains to Thebais (to Apollonopolis hé Megalé/Edfu). Theoretically, the first point on the Red Sea coast where animals could be unloaded was the area of modern Halayib. From there, however, elephants would have had to travel a much longer route by the dry, difficult, mountain trail leading to Syene (from where they also had a long and not very safe journey down the Nile). The *elephantagoi* could also sail further north, along the Red Sea coast, and reach Myos Hormos, where the shortest land route connected the Red Sea with the Nile. Due to the strong northerly winds, blowing north of Berenike all year round, such a journey would take almost half as long again as sailing from Ptolemais Theron (the first hunting base) to Berenike. Between Berenike and Marsa Nakari there are also a series of reefs and islands that made this journey riskier.[89] Smaller ships, carrying exotic goods obtained in the south (such as ivory, furs or myrrh), could afford to use this route. The extension of the sea journey did not harm the transported goods, and the shortening of the land route had a positive effect on the economy of the entire transport. In favorable weather (e.g. at the end of winter) in Myos Hormos, goods could also be reloaded to smaller vessels operating in the northern

81. Osypińska, Woźniak 2019, pp. 374-382.

82. Woźniak et al. 2021.

83. Desanges 1978; Rice 1983, pp. 91-92; Casson 1993; Burstein 2008; Sidebotham 2011, pp. 39-53; Cobb 2018, pp. 52-56.

84. See e.g. papyrus discovered in Fayum and dated 224 BC (Wilcken 1963, p. 452).

85. Wilcken 1963, p. 452; Woźniak et al. 2021.

86. Bruyère 1966; Sidebotham 2011, pp. 178-182; Aubert 2015.

87. De Romanis 1996, pp. 19-31; Whitewright 2007; Nappo 2010, pp. 343-44; Sidebotham 2011, p. 52; Bard, Fattovich 2018, pp. 184-185.

88. Sidebotham, Wendrich 2001-2002, p. 41; Sidebotham 2011, p. 50; Osypińska, Woźniak 2019, p. 374; Woźniak, Rądkowska 2014, p. 517; Woźniak 2019, p. 243.

89. Casson 1980, p. 22, n. 2; Sidebotham 1989, pp. 198-201.

DE GRAAUW <arthur.degraauw@outlook.fr>

Red Sea. Such efficient navigating ships could take them to Klysma and on along the canal as far as the Nile Delta, which completely eliminated the need for difficult and expensive land transport.

Elephantagoi crews could not afford such an extension to the sea journey. Firstly, these ships were large, with large draft and very heavy, which had a negative impact on the efficiency of sailing against the wind. Secondly, they had to unload their sensitive and dangerous loads as quickly as possible. These factors probably worked in favor of Berenike and influenced the specialization of this port (especially in the Early Hellenistic period, in the times of elephant hunting) in servicing the *elephantagoi* fleet (including loading, unloading and repairs). Myos Hormos at that time, although (like Berenike) also an intermediary in the transport of supplies for the ports and hunting stations in the south, was more suitable (as later, in the Roman period) for transshipment of valuable goods imported from the south.[90] Such a form of activity in both ports can be proved through localization of its trash dumps. Until now, there were not any traces of luxury, imported goods (e.g. ivory, incense or spices) in the Hellenistic strata of Berenike. Unfortunately, such a layer has not yet been discovered in Myos Hormos, so we will have to wait for confirmation of this theory.

After a mysterious period of collapse, possibly caused by an overlap of political and climatic factors,[91] when the importation of war elephants ceased, the activities of Berenike and Myos Hormos became similar. This trend continued for the next three and a half centuries (until the abandonment of Myos Hormos in the 3rd century AD), as the two ports functioned in a complementary way as rich commercial ports in the peak of Roman trade relations with South Arabia and India.[92]

Bibliography

Abbreviations

BibO: *Bibliotheca Orientalis* (Leuven).

BIFAO: *Bulletin de l'Institut français d'archéologie orientale* (Cairo).

PAM: *Polish Archaeology in the Mediterranean* (Warsaw).

Works cited

Aldsworth, Sidebotham, Wendrich 1995: S.G. Aldsworth, S.E. Sidebotham, W.Z. Wendrich, "The town site: survey, plan and description", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1994. Preliminary report of the excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1995, pp. 13-21.

Arvidson et al. 1994: R.R. Arvidson, A. Becker, W. Shanabrook, N. Luo, M. Sturchio, Z. Sultan, A. Lotfy, M. Mahmood, Z. El Alfy, "Climatic, eustatic and tectonic controls on Quaternary deposits and landforms, Red Sea coast, Egypt", *Journal of Geophysical Research – Solid Earth* 99/B6, 1994, pp. 12175-12190.

Aubert 2015: J.-J. Aubert, "Trajan's Canal: river navigation from the Nile to the Red Sea?", in F. De Romanis, M. Maiuro (ed.), *Across the Ocean. Nine essays on Indo-Mediterranean trade*, Leiden/Boston, Brill, 2015, pp. 33-42.

Bagnall, Bülow-Jacobsen, Cuvigny 2001: R.S. Bagnall, A. Bülow-Jacobsen, H. Cuvigny, "Security and water on the Eastern Desert roads: the prefect Iulius Ursus and the construction of *praesidia* under Vespasian", *JRA* 14, 2001, pp. 325-333.

Bard, Fattovich 2018: K.A. Bard, R. Fattovich, *Seafaring expeditions to Punt in the Middle Kingdom. Excavations at Mersa Gawasis/Wadi Gawasis, Egypt*, Leiden/Boston, Brill, 2018.

90. Strabo, 2, 5, 12; Nappo 2010; Tomber 2012.

91. Woźniak, Harrell 2021; Manning et al. 2017.

92. Nappo 2010.

DE GRAAUW <arthur.degraauw@outlook.fr>

Blue 2007: L.K. Blue, "Locating the harbour: Myos Hormos/Quseir al-Qadim: a Roman and Islamic port on the Red Sea coast of Egypt", *IJNA* 36/2, 2007, pp. 265-281, https://doi.org/10.1111/j.1095-9270.2007.00151.x (accessed 25/01/2021).

Bower, Farrar 2015: A.S. Bower, J.T. Farrar, "Air-sea interaction and horizontal circulation in Red Sea", in N.M.A. Rasul, I.C.F. Stewart (ed.), *The Red Sea: the formation, morphology, oceanography and environment of a young ocean basin*, Berlin/Heidelberg, Springer, 2015, pp. 329-342, https://www2.whoi.edu/site/bower-lab/wp-content/uploads/sites/12/2018/03/Red-Sea-Chapter.pdf (accessed 26/01/2021).

Bresson 2011: A. Bresson, "Grain from Cyrene", in Z.H. Archibald, J.K. Davies, V. Gabrielsen (ed.), *The economies of Hellenistic societies. Third to first centuries BC*, Oxford/New York/Auckland, Oxford University Press, pp. 66-95.

Brun et al. 2013: J.-P. Brun, J.-P. Deroin, T. Faucher, B. Redon, F. Téreygeol, "Les mines d'or ptolémaïques. Résultats des prospections dans le district minier de Samut (désert Oriental)", *BIFAO* 113, 2013, pp. 111-141, https://www.ifao.egnet.net/bifao/113/07 (accessed 25/01/2021).

Bruyère 1966 : B. Bruyère, *Fouilles de Clysma-Qolzoum (Suez), 1930-1932*, Cairo, IFAO, 1966, https://archive.org/details/FIFAO27 (accessed 25/01/2021).

Burstein 1989: Agatharchides of Cnidus, *On the Erythraean Sea*, ed. and transl. S.M. Burstein, London, The Hakluyt Society, 1989.

Burstein 1996: S.M. Burstein, "Ivory and Ptolemaic exploration of the Red Sea. The missing factor", *Topoi* 6/2, 1996, pp. 799-807, https://www.persee.fr/doc/topoi_1161-9473_1996_num_6_2_1696 (accessed 25/01/2021).

Burstein 2008: S.M. Burstein, "Elephants for Ptolemy II: Ptolemaic policy in Nubia in the third century BC", in P. McKechnie, P. Guillaume (ed.), *Ptolemy II Philadelphus and his world*, Leiden/Boston, Brill, 2008, pp. 135-148.

Casson 1980: L. Casson, "Rome's trade with the east: the sea voyage to Africa and India", *TAPhA* 110, 1980, pp. 21-36.

Casson 1993: L. Casson, "Ptolemy II and the hunting of African elephants", *TaPhA* 123, 1993, pp. 247-260.

Cobb 2018: M.A. Cobb, *Rome and the Indian Ocean trade from Augustus to the early third century CE*, Leiden, Brill, 2018.

Cohen 2006: G.M. Cohen, *The Hellenistic settlements in Syria, the Red Sea basin, and North Africa*, Berkeley/Los Angeles/London, University of California Press, 2006.

Dasari et al. 2018: H.P. Dasari, S. Langodan, Y. Viswanadhapalli, B.R. Vadlamudi, V.P. Papadopulos, I. Hoteit, "ENSO influence on the interannual variability of the Red Sea convergence zone and associated rainfall", *International Journal of Climatology* 38/2, 2018, pp. 761-775.

Desanges 1978 : J. Desanges, *Recherches sur l'activité des Méditerranéens aux confins de l'Afrique: VI^e siècle avant J.-C. - IV^e siècle après J.-C.*, Rome, École française de Rome, 1978, https://www.persee.fr/doc/efr_0000-0000_1978_ths_38_1 (accessed 25/01/2021).

De Romanis 1996: F. De Romanis, *Cassia, cinnamomo, ossidiana. Uomini e merci tra Oceano Indiano e Mediterraneo*, Rome, "L'Erma" di Bretschneider, 1996.

Fraser 1972: P.M. Fraser, *Ptolemaic Alexandria* I. *Text*, Oxford, Clarendon Press, 1972.

Gates 2005: J.E. Gates, *Traveling the desert edge: the Ptolemaic roadways and regional economy of Egypt's Eastern Desert in the fourth through first centuries B.C.E.*, PhD dissertation, Ann Arbor, University of Michigan, 2005 (unpublished).

Hamilton-Dyer 2011: S. Hamilton-Dyer, "Faunal Remains", in D. Peacock, L.K. Blue (ed.), *Myos Hormos – Quseir al-Qadim Roman and Islamic ports on the Red Sea* 2. *Finds from the excavations 1999-2003*, Oxford, Archaeopress, 2011, pp. 245-288.

Harrell 1996: J.A. Harrell, "Geology", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1995. Preliminary report on the 1995 excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1996, pp. 99-126.

DE GRAAUW <arthur.degraauw@outlook.fr>

Harrell 1998: J.A. Harrell, "Geology", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1996. Report of the 1996 excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1998, pp. 121-148.

Harrell 2019: J.A. Harrell, *Geological studies from the 2019 season at Berenike. Part A: the Early Hellenistic well in trench BE15/18-104 and the Berenike bedrock. A geological report*, Toledo (Ohio), Department of Environmental Sciences at the University of Toledo (unpublished).

Hauben 1990: H. Hauben, "L'expédition de Ptolémée III en Orient et la sédition domestique de 245 av. J.-C.", *APF* 36, 1990, pp. 29-37.

Hense 2019: M. Hense, "The great temple of Berenike", in A. Manzo, C. Zazzaro, D.J. de Falco (ed.), *Stories of globalisation: the Red Sea and the Persian Gulf from late prehistory to early modernity. Selected papers of the Red Sea Project VII*, Leiden/Boston, Brill, 2019, pp. 246-263.

Hense, Kaper, Geerts 2015: M. Hense, O.E. Kaper, R.C.A. Geerts, "A stela of Amenemhet IV from the main temple at Berenike", *BibO* 72/5-6, 2015, pp. 585-601, https://doi.org/10.2143/BIOR.72.5.3139333 (accessed 25/01/2021).

Herbich 2007: T. Herbich, "Magnetic survey", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1999/2000. Report on the excavations at Berenike including excavations in Wadi Kalalat and Siket and the survey of the Mons Smaragdus region*, Los Angeles, Cotsen Institute of Archaeology, University of California, 2007, pp. 22-29.

Hoang, Taviani 1991: C.T. Hoang, M. Taviani, "Stratigraphic and tectonic implications of uranium-series-dated coral reefs from uplifted Red Sea islands", *Quaternary Research* 35/2, 1991, pp. 264-273.

Klemm, Klemm 2013: R. Klemm, D. Klemm, *Gold and gold mining in Ancient Egypt and Nubia: geoarchaeology of the ancient gold mining sites in the Egyptian and Sudanese Eastern Deserts*, Berlin, Springer, 2013.

Kotarba-Morley 2017: A.M. Kotarba-Morley, "Port town and its harbours: sedimentary proxies for landscape and seascape reconstruction of the Greco-Roman site of Berenike on the Red Sea coast of Egypt", *PAM* 26/2, 2017, pp. 61-92, https://doi.org/10.5604/01.3001.0012.1821 (accessed 25/01/2021).

Manning et al. 2017: J.G. Manning, F. Ludlow, A.R. Stine, W.R. Boos, M. Sigl, J.R. Marion, "Volcanic suppression of Nile summer flooding triggers revolt and constrains interstate conflict in ancient Egypt", *Nature Communications* 8/900, 2017, pp. 1-9, https://doi.org/10.1038/s41467-017-00957-y (accessed 25/01/2021).

Mansour, Madkour 2015: A.M. Mansour, H.A. Madkour, "Raised coral reefs and sediments in the coastal area of the Red Sea", in N.M.A. Rasul, I.C.F. Stewart (ed.), *The Red Sea: the formation, morphology, oceanography and environment of a young ocean basin*, Berlin/Heidelberg, Springer, 2015, pp. 379-393.

McLaughlin 2010: R. McLaughlin, *Rome and the distant East. Trade routes to the ancient lands of Arabia, India and China*, London/New York, Continuum, 2010.

McLaughlin 2016: R. McLaughlin, *The Roman Empire and the Silk Routes. The Ancient World economy and the empires of Parthia, Central Asia and Han China*, Barnsley, Pen & Sword, 2016.

Mueller 2006: K. Mueller, *Settlements of the Ptolemies. City foundations and new settlement in the Hellenistic world*, Leuven/Paris/Dudley, Peeters, 2006.

Nappo 2010: D. Nappo, "On the location of Leuke Kome", *JRA* 23, 2010, pp. 335-348.

Osypińska, Woźniak 2019: M. Osypińska, M. Woźniak, "Livestock economy at Berenike, a Hellenistic city on the Red Sea (Egypt)", *African Archeology Review* 36/3, 2019, pp. 367-382, https://doi.org/10.1007/s10437-019-09346-w (accessed 25/01/2021).

Peacock, Blue 2006: D. Peacock, L.K. Blue (ed.), *Myos Hormos – Quseir al-Qadim. Roman and Islamic ports on the Red Sea* 1. *Survey and excavations 1999-2003*, Oxford, Oxbow Books, 2006.

Peremans, Van't Dack 1952: W. Peremans, E. Van't Dack, *Prosopographia Ptolemaica* II. *L'armée de terre et la police, nº 1825-4983*, Leuven/Leiden, Nauwelaerts/Brill, 1952.

Plaziat et al. 1995: J.-C. Plaziat, F. Baltzer, A. Choukri, O. Conchon, P. Freytet, F. Orszag-Sperber, B. Purser, A. Raguideau, J.-L. Reyss, "Quaternary changes in the Egyptian shoreline of the northwestern Red Sea and Gulf of Suez", *Quaternary International* 29/30, 1995, pp. 11-22.

DE GRAAUW <arthur.degraauw@outlook.fr>

Pugh, Abualnaja 2015: D.T. Pugh, Y. Abualnaja, "Sea-level changes", in N.M.A. Rasul, I.C.F. Stewart (ed.), *The Red Sea: the formation, morphology, oceanography and environment of a young ocean basin*, Berlin/Heidelberg, Springer, 2015, pp. 317-328.

Raschke 1978: M.G. Raschke, "New studies in Roman commerce with the East", in H. Temporini (ed.), *Aufstieg und Niedergang der römischen Welt* II. *Principat* 9/2, Berlin, W. De Gruyter, 1978, pp. 604-1378.

Rasul 2015: N.M.A. Rasul, "Lagoon sediments of the Eastern Red Sea: distribution processes, pathways and patterns", in N.M.A. Rasul, I.C.F. Stewart (ed.), *The Red Sea: the formation, morphology, oceanography and environment of a young ocean basin*, Berlin/Heidelberg, Springer, 2015, pp. 281-316.

Redon 2018: B. Redon, "The control of the Eastern Desert by the Ptolemies: new archaeological data", in J.-P. Brun, T. Faucher, B. Redon, S.E. Sidebotham (ed.), *The Eastern Desert of Egypt during the Graeco-Roman period: archaeological reports*, Paris, Collège de France, 2018, https://books.openedition.org/cdf/5249 (accessed 25/01/2021).

Redon, Faucher 2015: B. Redon, T. Faucher, "Gold mining in Early Ptolemaic Egypt", *Egyptian Archaeology* 46, 2015, pp. 17-19, https://desorient.hypotheses.org/files/2016/11/2015_EA-46_Redon-and-Faucher_Samut.pdf (accessed 25/01/2021).

Redon, Faucher 2016: B. Redon, T. Faucher, "Samut North: 'heavy mineral processing plants' are mills", *Egyptian Archaeology* 48, 2016, pp. 20-22, https://desorient.hypotheses.org/files/2016/11/2016_EA-48_Redon-and-Faucher.pdf (accessed 25/01/2021).

Redon, Faucher 2020: B. Redon, T. Faucher (ed.), *Samut Nord. L'exploitation de l'or du désert Oriental à l'époque ptolémaïque*, Cairo, IFAO, 2020.

Rice 1983: Kallixeinos of Rhodes, *The grand procession of Ptolemy Philadelphus*, ed. E.E. Rice, Oxford/New York, Oxford University Press, 1983.

Roeder 1959: G. Roeder, *Die Ägyptische Götterwelt*, Zurich/Stuttgart, Artemis Verlag, 1959.

Seeger 2001: J.A. Seeger, "A preliminary report on the 1999 field season at Marsa Nakari", *JARCE* 38, 2001, pp. 77-88.

Sidebotham 1989: S.E. Sidebotham, "Ports of the Red Sea and the Arabia-India trade", in T. Fahd (ed.), *L'Arabie préislamique et son environment historique et culturel. Actes du colloque de Strasbourg, 24-27 juin 1987*, Leiden, Brill, 1989, pp. 195-223.

Sidebotham 2007: S.E. Sidebotham, "Excavations", in S.E. Sidebotham, W. Wendrich (ed.), *Berenike 1999/2000. Report on the excavations at Berenike including excavations in Wadi Kalalat and Siket and the survey of the Mons Smaragdus Region*, Los Angeles, Cotsen Institute of Archaeology, University of California, 2007, pp. 30-165.

Sidebotham 2011: S.E. Sidebotham, *Berenike and the Ancient Maritime Spice Route*, Berkeley/Los Angeles/London, University of California Press, 2011.

Sidebotham et al. 2015: S.E. Sidebotham, I. Zych, J.K. Rądkowska, M. Woźniak, "Berenike Project. Hellenistic fort, Roman harbor, Late Roman temple, and other fieldwork: archaeological work in the 2012 and 2013 seasons", *PAM* 24/1, 2015, pp. 297-324, https://doi.org/10.5604/01.3001.0009.9914 (accessed 25/01/2021).

Sidebotham et al. 2019: S.E. Sidebotham, I. Zych, M. Hense, R. Ast, O.E. Kaper, M. Bergman, M. Osypińska, A. Carannante, "Results of the winter 2018 excavation season at Berenike (Red Sea coast), Egypt. The Belzoni Bicentennial Report", *Thetis* 24, 2019, pp. 7-19.

Sidebotham, Hense, Nouwens 2008: S.E. Sidebotham, M. Hense, H.M. Nouwens, *The Red Land. The illustrated archaeology of Egypt's Eastern Desert*, Cairo/New York, American University in Cairo Press, 2008.

Sidebotham, Wendrich 2001-2002: S.E. Sidebotham, W.Z. Wendrich, "Berenike: archaeological fieldwork at a Ptolemaic-Roman port on the Red Sea coast of Egypt 1999-2001", *Sahara* 13, 2001-2002, pp. 23-50.

Sidebotham, Zych 2016: S.E. Sidebotham, I. Zych, "Results of the winter 2014-2015 excavations at Berenike (Egyptian Red Sea Coast), Egypt and related fieldwork in the Eastern Desert", *Journal of Indian Ocean Archaeology* 12, 2016, pp. 1-33.

Tallet 2016: P. Tallet, "The Egyptians on the Red Sea shore during the Pharaonic Era", in M.-F. Boussac, J.-F. Salles, J.-B. Yon (ed.), *Ports of the Indian Ocean*, Delhi, Primus Books, 2016, pp. 3-19.

DE GRAAUW <arthur.degraauw@outlook.fr>

Tallet, Mahfouz 2012: P. Tallet, E.S. Mahfouz (ed.), *The Red Sea in Pharaonic times. Recent discoveries along the Red Sea coast. Proceedings of the colloquium held in Cairo – Ayn Soukhna 11th-12th January 2009*, Cairo, Institut français d'archéologie orientale, 2012.

Tomber 1998: R.S. Tomber, "Pottery", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1996. Report of the 1996 excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1998, pp. 163-181.

Tomber 2012: R.S. Tomber, "From the Roman Red Sea to beyond the Empire: Egyptian ports and their trading partners", *British Museum Studies in Ancient Egypt and Sudan* 18, 2012, pp. 201-215, http://www.britishmuseum.org/research/publications/online_journals/bmsaes/issue_18/tomber.aspx (accessed 25/01/2021).

Van Neer, Ervynck 1998: W. Van Neer, A.M.H. Ervynck, "The faunal remains", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1996. Report of the 1996 excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1998, pp. 349-389.

Veeh, Giegengack 1970: H.H. Veeh, R. Giegengack, "Uranium-series ages of corals from the Red Sea", *Nature* 226, 1970, pp. 155-156.

Vermeeren 1998: C.E. Vermeeren, "Wood and charcoal", in S.E. Sidebotham, W.Z. Wendrich (ed.), *Berenike 1996. Report of the 1996 excavations at Berenike (Egyptian Red Sea coast) and the survey of the Eastern Desert*, Leiden, Research School CNWS, School of Asian, African, and Amerindian Studies, 1998, pp. 331-348.

Whitewright 2007: J. Whitewright, "How fast is fast? Technology, trade and speed under sail in the Roman Red Sea", in J. Starkey, P. Starkey, T.J. Wilkinson (ed.), *Natural resources and cultural connections of the Red Sea*, Oxford, Archaeopress, 2007, pp. 77-87.

Wicker 1998: F.D.P. Wicker, "The road to Punt", *The Geographical Journal* 164/2, 1998, pp. 155-167.

Wilcken 1963: U. Wilcken, *Grundzüge und Chrestomathie der Papyruskunde* I. *Historischer Teil, Zeite Hälfte: Chrestomathie*, Hildersheim, Georg Olms Verlagsbuchhandlung, 1963.

Woźniak 2017: M.A. Woźniak, "Shaping a city and its defenses: fortifications of Hellenistic Berenike Trogodytika", *PAM* 26/2, 2017, pp. 43-60, https://doi.org/10.5604/01.3001.0012.1820 (accessed 25/01/2021).

Woźniak 2019: M.A. Woźniak, "Berenike of the Ptolemies: a Hellenistic desert city/fortress", in M. Peterková-Hlouchová, D. Belohoubková, J. Honzl, V. Nováková (ed.), *Current research in egyptology 2018. Proceedings of the nineteenth annual symposium, Czech Institute of Egyptology, Faculty of Arts, Charles University, Prague, 25-28 June 2018*, Oxford, Archaeopress, 2019, pp. 239-252.

Woźniak et al. 2021: M.A. Woźniak, S.E. Sidebotham, M. Osypińska, J.K. Rądkowska, "Hellenistic Berenike: resources, logistics and daily life in a Ptolemaic fortress on the Red Sea coast of Egypt", *AJA* 125/2, 2021, pp. 247-281.

Woźniak, Harrell 2021: M.A. Woźniak, J.A. Harrell, "When the well runs dry. Climate instability and the abandonment of Early Hellenistic Berenike", *Antiquity* 95/380, 2021, pp. 349-366.

Woźniak, Rądkowska 2014: M.A. Woźniak, J.K. Rądkowska, "In search of Berenike of the Ptolemies. The Hellenistic fort of Berenike Trogodytika, its localization, form and development (part one)", *PAM* 23/1, 2014, pp. 505-526, https://pcma.uw.edu.pl/en/2018/05/15/pam-23 (accessed 25/01/2021).

Zych et al. 2016: I. Zych, S.E. Sidebotham, M. Hense, J.K. Rądkowska, M. Woźniak, "Archaeological fieldwork in Berenike in 2014 and 2015: from Hellenistic rock-cut installations to abandoned temple ruins", *PAM* 25, 2016, pp. 317-348, https://doi.org/10.5604/01.3001.0010.1864 (accessed 25/01/2021).

DE GRAAUW <arthur.degraauw@outlook.fr>