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Magnetic prospection in the service of uncovering the Hellenistic and Roman port of Berenike on the Red Sea in Egypt

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Magnetic prospection was chosen as a non-invasive survey method for covering the expanse of the Hellenistic and Roman city and port of Berenike on the Red Sea in Egypt. A test run in 1999 confirmed the potential of the method in the specific conditions of the site and its geology; since 2008 the Polish–American project excavating the site has completed a full-site prospection, revealing surprising data for consideration in the interpretation of site topography and individual architectural remains. The article gives background on the topography of the site and explores three areas of the site: the western district, the southwestern bay and the urban mound in the east, where the results of magnetic prospection have been particularly telling and where, combined with archaeological feedback, they have contributed to a new understanding of the ancient remains. The discussion also poses ideas concerning the interpretation of site topography overall and follows up with prospects for the surveyors in the coming seasons.

KEY-WORDS: magnetic prospection, Berenike, port, fortifications, urban insulae, street grid, Hellenistic fort

INTRODUCTION

The port of Berenike Trogodytica, as it was known to the ancients, was said to have been established by Ptolemy II Philadelphus in the first quarter of the 3rd century BC (Pliny, *Natural History* 6.33.168) (Woźniak, Rądkowska 2014: 507) and there is reason to believe that the idea for the undertaking was at least conceived shortly before the death of the king's mother and wife of Ptolemy I, Berenike, after whom the town was named (before 279 or 268 BC). The harbour was part of a strategic plan to network the western coast of the Red Sea (and the Nile Valley via a desert road) with the distant lands beyond the Horn of Africa, from whence issued the wealth of the kingdom, whether it be gold, slaves or live elephants used as veritable 'tanks' in Hellenistic warfare.

Over the next 800 years or so the city was a player in the rising and ebbing global trade that passed through the Red Sea, connecting first the Ptolemaic kingdom of Egypt

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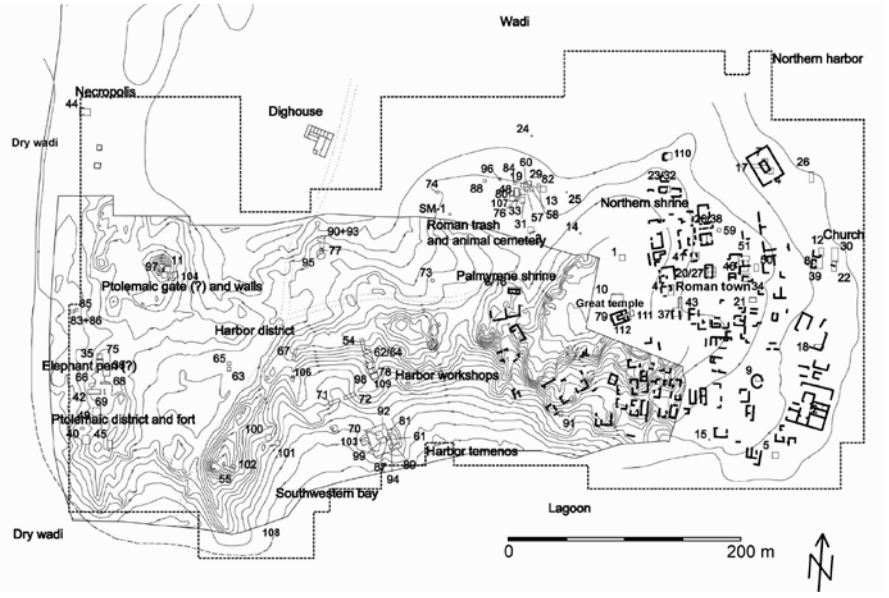

Fig. 1. Map of the site with localization of archaeological trenches and location of walls in the urban area according to a topographical survey carried out in 1994 (Aldsworth *et al.* 1995). The extent of the magnetic survey is outlined with a dashed line. The trenches are marked with numerals, which appear in the text preceded by the abbreviation BE and respective season, from (19)94 to (20)15 (the first trench dug by the Polish–American project was BE09-54. Plan update B. Wojciechowski, 2014)

and then the Roman Empire with the nearer regions of Arabia Felix and East Africa and the more distant and exotic lands around the Indian Ocean. Its role is highlighted by numerous mentions in ancient written sources, e.g., Strabo, *Geography*; Pliny the Elder, *Natural History*, *Periplus of the Erythraean Sea*, and its location was marked in a number of ancient maps and itineraries, suffice it to mention Claudius Ptolemy's *Geography*, the *Tabula Peutingeriana* and *Itinerarium Antoniniana*. The latest source speaks of the town still existing in the early 6th century, on the eve of the first wave of the plague that decimated Egypt in this century. There is no direct evidence for why the port was abandoned in this period; all that is clear is that other harbours to the north and south of Berenike took over its role in the early Islamic period (Sidebotham 1999).

The magic of the name drew explorers in the Modern Age, the first to attempt to identify its location being the Portuguese Dom João de Castro in the mid-16th century and the French J.B. Bourguignon D'Anville in the 18th century. The first explorer to write at length about the site was Giovanni Belzoni, who visited the site in 1818 (Belzoni 1822). Close in his footsteps came the Englishman John Gardner Wilkinson, who produced the first and notably accurate plan of the town in 1826. He also excavated the site of the Great

Fig. 2. View of the urban mound. Tops of walls are marked by low ridges covered by coral heads (Photo T. Herbich)

Temple, giving it the monicker of the Serapis Temple (Wilkinson 1835), an identification that has recently been put into doubt (Sidebotham, Zych forthcoming b).

In 1994, an American–Dutch expedition from the Universities of Delaware and Leiden started regular investigations of the site. The team concentrated on the visible remains around the temple (Fig. 2) as well as testing the area immediately to the west of the city mound. Following a break in the work due to external circumstances beyond the archaeologists' control, excavations were taken up again, in 2008, by a Polish–American expedition from the Polish Centre of Mediterranean Archaeology of the University of Warsaw and the University of Delaware. A total of sixteen seasons to date in the field (and the project is ongoing) have confirmed beyond all doubt the identification of the city in epigraphic sources and its far-flung commercial network extending from the Roman Mediterranean to Arabia, Africa and distant India.

UNDERSTANDING SITE TOPOGRAPHY PRIOR TO THE MAGNETIC SURVEY

The 19th and 20th century ground surveys, rounded off with a geological appraisal of the location carried out primarily in the 1995 season by James A. Harrell (1996), situated the urban site on a on a presumed fossil-reef promontory, between the 'pincers' of two large wadis emptying into the sea. Nowadays, the highest parts of this mound, covering the roof of the Great Temple, have an altitude of 7.18 m a.s.l. According to Harrell (1996: 112), the original ground surface on which the first settlement was

Fig. 3. Satellite image of the site. A – western district; B – southwestern bay; C – urban mound. Arrows mark the ridge. Dashed line marks the extent of the magnetic survey (Google Earth, processing T. Herbich)

built would have been less than 2 m a.s.l., thus the accumulations forming the urban mound run more than 5 m deep in the highest parts on the central-western fringes of the mound, that is, where the ruins of the Great Temple are preserved right up to and including the roof of the original structure.

Sand captured in the ruins of the abandoned town has formed a soft blanketing layer over the walls of buildings that were constructed of coral heads, the irregular cobble-sized elements of a fossil reef that were used prolifically in Roman times in wall construction, reinforced at the corners with squared blocks of gypsum anhydrite. The sand accumulated slowly allowing the tops of the walls, unprotected once the presumed wooden roofs had collapsed, to melt and scatter, leaving discernible rows of coral heads marking building layouts (Fig. 2). A thorough topographical survey of the site in 1994, when the Dutch–American project initiated research, produced a plan of the site that recorded all remains visible on the ground surface, set within a topographical grid that

has been used by the project ever since (Aldsworth *et al.* 1995) (Fig. 1). A preliminary interpretation of the town layout was based on this survey and was subsequently verified in point excavations conducted between 1995 and 2001 (Sidebotham, Wendrich 2007).

The highest part of the urban mound encompasses houses organized along at least one major *decumanus,* leading from the Great Temple toward the sea, and at least two major *cardines* intersecting with it, as well as a number of lesser streets organized on a fairly regular grid. To the north, east and south of this city center, proved by excavations to contain the nuclear late Roman city, the present ground surface descends rather abruptly toward the *sabkha* or salt flat that forms the present coastline.

To the west of the Great Temple site, extending in a sweeping arc, is a ridge that is evident both on the ground and in satellite imagery (Fig. 3). The top of this ridge is roughly 5 m a.s.l. and even today it is the most convenient passage from the urban area to the western outskirts of the site. It encloses a bay (referred to as the southwestern bay of Berenike) that appears to have been a natural landing place used during early Roman times, as demonstrated by the results of recent excavations and core-drilling (Sidebotham, Zych 2010; 2012; forthcoming a). The ridge is distinct despite a very gentle falling off on either side and it curves in markedly at the southern end. A kind of 'island' with remains of coral-head architecture was evident from the start in the center of the bay, already close to the edge of the silted up wadi. The course of both wadis encircling the site is marked by the presence of characteristic bushes and turtleback' formations.

Beyond this ridge to the west and northwest rises a rocky plateau separated from the ridge on the east by swathes of sand and delimited on the west by the shallow valley of the wadi, which can be marshy in places even today and which generally shows the cracked dried surface of water-driven seasonal deposits silting it up regularly during the winter seasons. The flatness of this plateau is broken only by occasional small mounds barely rising above the ground in the northern part; the one marked mound in this area has been excavated and proven to contain substantial architectural remains from the Hellenistic and early Roman periods (Sidebotham, Wendrich 1995: xx–yy). An elongated rise in the ground, cut through by the modern road, which is also in all probability the ancient caravan trail leading into the harbour town, conceals the remains of mausolea and masonry tombs, including at least one deep rock-cut shaft and burials in rock-cut pits (Sidebotham, Wendrich 2002: xx). More tombs were identified in 2015 on a rock outlier rising west of the Berenike site, at a distance of some 100 m beyond the western wadi (Sidebotham, Zych forthcoming a).

The lie of the land to the north of the described bay ridge and west of the town mound recalls a gentle hollow that extends all the way to the rising ridge of the cemetery in the west and passes gently into the plateau on the west. Surface finds from this area, especially the northeastern and central parts, suggested from the start that the rubbish dumps of the town were located here. Since the caravan road leading from the Nile Valley led straight into this area, through a dip in the ridge with the ancient necropolis (as described above), it is conceivable that the infrastructure necessary to service the

Fig. 4. General view across the site of Berenike; archaeologist/geophysicist Dawid Święch directing his two-man team of Ababda workmen during the prospection of the site in 2009 (Photo I. Zych)

transport industry to and from the harbour — at the very least, the water and fodder, as well as temporary shelter for animals, and the loading and unloading of goods and their provisional storage — had been located here. On the surface, however, there is nothing to be observed, except for gentle mounds marked with middens of broken seashells and potsherds indicative of occupation in the Hellenistic and Roman periods.

TRYING MAGNETOMETRY

The ancient site, including the necropolis, tops 30 ha in area, making it a herculean effort to even try to investigate the whole town by classical archaeological methods. Even as the American–Dutch expedition started to explore the ancient remains, concentrating on detailed interdisciplinary research of finds coming from small-sized trenches, the magnetic method was starting a slow but highly effective march through field archaeology in Egypt (Herbich 2003). By 1999 the time the situation turned for considering geophysical prospection in Berenike. Two methods were logistically possible at the time in Egypt: electrical resistivity and magnetic prospection. However, the dryness of the location and the geological make-up, that is, highly resistive sands and gravel, excluded the former of the two methods. As for the latter one, it seemed that magnetic susceptibility of fossil coral heads and gypsum anhydrite blocks, which were proved by excavations to be the chief building material in Berenike, was too low to contrast them with the sand and gravel matrix, in which they lay concealed. In 1999, a test of the method was carried out, choosing the western part of the site where no traces of architecture could be observed on the surface, but where there was sufficient evidence of slag and copper to suggest some kind of industrial activity. Industrial remains in the form of hearths and furnaces generate high-amplitude anomalies that are easy to trace with the magnetic method (Gaffney, Gater 2003: 156-157).

A Geoscan Research FM36 gradiometer was used for the test. The results proved satisfactory beyond all expectations. Not only were traces of presumed industrial activity observed

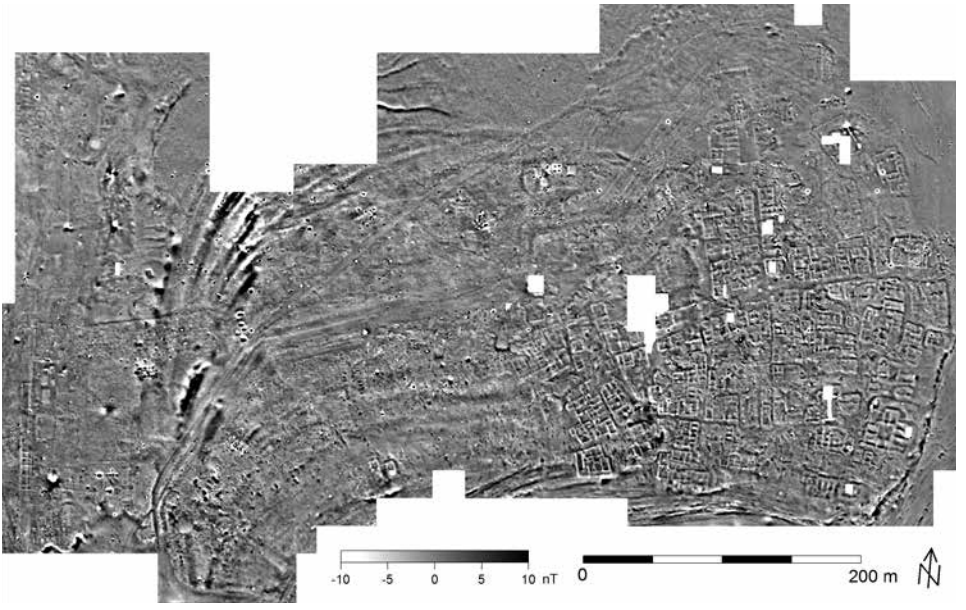

Fig. 5. Magnetic map of Berenike 1999, 2008–2015. Fluxgate gradiometers Geoscan Research FM36/FM256; sampling grid 0.25 x 0.50 m, parallel/zigzag mode. Measurements Tomasz Herbich, Dawid Święch, Robert Ryndziewicz, processing T. Herbich

on the magnetic map, but a surprisingly clear arrangement of architectural remains was also discovered (Herbich 2003: 50-52; 2007). These structures were verified archaeologically and shown to be constructed of large gypsum anhydrite blocks with absolutely no magnetic properties. It was the sand matrix enveloping it that turned out to contain substantial amounts of iron oxides of magnetic susceptibility high enough to make the walls stand out as strong negative anomalies. The test demonstrated the potential of the magnetic method in the investigation of the town topography and only the unfortunate termination of the American–Dutch project in 2001 stopped the survey from flourishing into a full-scale project. When work became possible again with the Polish–American team, magnetic prospection was considered as one of the top priorities. Between 2008 and 2015 practically the whole site (roughly 26 ha) was covered with the survey (Figs 3 and 5) and the results were successively verified in point excavations as well as used to plan further digging.

REVEALING AN UNKNOWN BERENIKE

Archaeological feedback from follow-up excavations has helped to answer questions concerning the interpretation of the survey results. But the opposite has also been true with characteristic magnetic anomalies aiding archaeologists in re-directing their thinking regarding

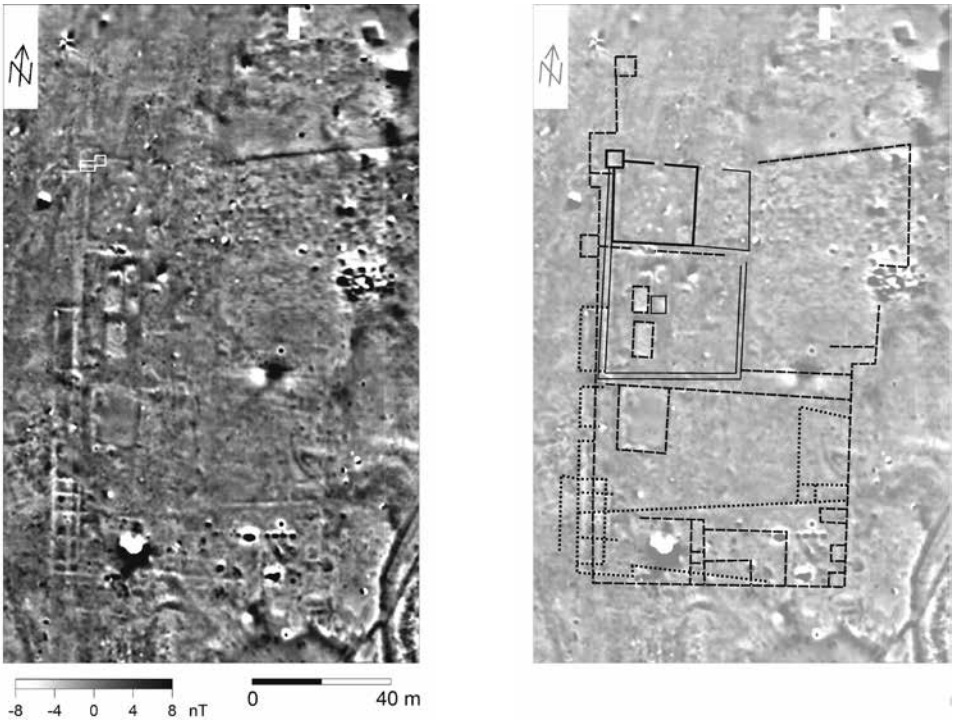

Fig. 6. Western district with the Hellenistic fort and associated architecture. Left: magnetic map; white box - BE12-83/85/86; right: reconstruction of building phases based on an analysis of the magnetic map, supported in a limited extent by archaeological feedback. Solid line – earliest phase (*tetrapyrgion*); dashed line – second phase with elephant pen; dotted line – latest phase (Reconstruction of development phases after Woźniak, Rądkowska 2014: Fig. 8)

Fig. 7. Foundation trench of the northwestern corner tower of the *tetrapyrgion* fort, view after excavations; the stone wall was robbed out completely, leaving pracctically only the trench outline (BE12-83/85/86) (Photo S.E. Sidebotham)

the urban planning of the harbour town and its development over time (e.g. Sidebotham 2011: 60–61, 205; Rądkowska, Woźniak 2011). A more detailed look at three areas of Berenike: the western plateau, the southwestern bay and the town mound, explores the interrelation of archaeology and geophysics on this site and the results that the combined application of magnetic remote sensing and archaeological testing can lead to.

The western plateau: Hellenistic fortifications

The magnetic prospection of the western plateau brought results that left no doubt as to the usefulness of the method. The strong negative anomalies that were revealed in the test and followed up in the survey carried out in 2010 demonstrated not only the presence of substantial architectural remains, but also that these anomalies formed evident, "readable" layouts that could be studied and interpreted. There is nothing on the surface in this part of the site (except for a few low mounds with scatters of coral heads in the northern part of this area) to suggest the presence of what now is believed to have been the core of the early Hellenistic military foundation.

Archaeological feedback during the original test in 1999/2000 made it clear that the architecture consisted of large, dressed gypsum anhydrite blocks. Based on this conviction, archaeologists opened in 2012 a trench (BE12-83/85/86) to explore a square feature that promised to be a corner tower of a larger establishment, possibly a fort (Fig. 6). This idea was proposed by Marek Woźniak based on his knowledge of early Hellenistic military architecture. The surprising feedback from this trench was that the same strong negative anomaly was produced by 'ghost' walls, meaning shallow foundation trenches cut in bedrock and backfilled with material that was different from the surrounding sand and gravel matrix (Woźniak, Rądkowska 2014: 516ff. and Figs 6–7). For now and based on other examples from the site (see below), it seems that the holes left by the salvage of good quality building material for other construction projects (presumably sometime in the early Roman period, that is, the late 1st century BC or early 1st century AD) were filled with drifted sand that quickly hardened into an impermeable layer thanks to precipitating salt. These concreted sand 'caps' have been found consistently in all the trenches and may be the effect of climatic change occurring in the first centuries AD when global temperatures appear to have cooled and a greater humidity apparently ensued.

Hellenistic amphorae with stamped handles, chiefly an early 3rd century Rhodian "button" stamp, fortuitously dated the original building foundation to the period when the fort known from the written sources was established. Woźniak's combined interpretation (Figs 6 right) of the results of the magnetic survey, the excavations and his analysis of the feedback from earlier trenches dug on the western plateau led him to suggest that the tower was part of a *tetrapyrgion*, a typical rectangular fort that was practically routine-built by Greek army engineers wherever necessary on the fringes of the Hellenistic realm (Woźniak, Rądkowska 2014: especially Fig. 8, on the far left). He has

also suggested at least two further phases in the development of the original foundation (Woźniak, Rądkowska 2014: especially Fig. 8, center and far right), encompassing an area surrounded by a V-shaped ditch (three trenches dug along two sides of this installation) and interpreted tentatively as the outer perimeter of an animal pen intended in all probability for the live wild elephants that were disembarked from ships bringing them in from hunting locations in East Africa. The ditch was shortly filled in and less substantial walls were built instead, parts of which have survived, because they were constructed of smaller broken stones that did not excite the imagination of the early Roman builders who salvaged building blocks for more substantial architecture. In any case, these later walls coupled with the backfilled ditches marked off by the concreted salt deposits can be traced on the magnetic map.

Excavations in another trench located on the spot of a Hellenistic waste dump (BE13-90/93 Fig. 1) furthered the positive feedback regarding interpretation of various linear anomalies crossing the neck of the promontory, from the western plateau in the west to the urban site on the east (Fig. 5). The unexpected discovery of a huge stone wall, mostly robbed out sometime at the turn of the eras, was matched up with anomalies observed on the magnetic map and subsequently traced over most of this area (Zych, Sidebotham forthcoming). It now appears that the early Hellenistic foundation consisted of the fort and attached "elephant pen" (assuming the correctness of this interpretation), a natural landing place in the southwestern bay or lagoon and the expanse of land to the north of the bay and toward the promontory made of the fossil reef, protected from the landside with a regulation wall reinforced with towers.

The most recent part of the magnetic survey conducted around the northern part of the urban mound has revealed distinct linear anomalies, almost like a casemate structure, turning a right angle, as if sheltering the promontory where the civil city was located (Figs 5 and 13 for close-up). Archaeological testing is planned to establish the nature and dating of the feature(s) that have produced this image. They may well be part of the original Hellenistic walls fortifying the site.

As an aside, one can point out distinct irregular, sinuous "spills", looking somewhat like claws, leading away from this anomaly to the west, toward the rubbish dumps of Roman times (Fig. 13). They are present also in other parts of the magnetic map and appear to reflect natural erosion of a slope, caused by heavy water surges carving their way through deposits on the edge of a plateau or higher ground; the material taken down with the water seems to have been of high magnetic susceptibility. In this case, the solitary anomaly along the entire length of this as yet unrecognized linear feature could mean that it had constituted a solid obstacle with just one gap (intentional?) at this spot.

The southwestern bay: early Roman landing place

The southwestern bay, as a highly promising location for the harbour, was mapped during the topographic survey in 1994. The survey revealed a pincer-like rectangular form (see Fig. 1)

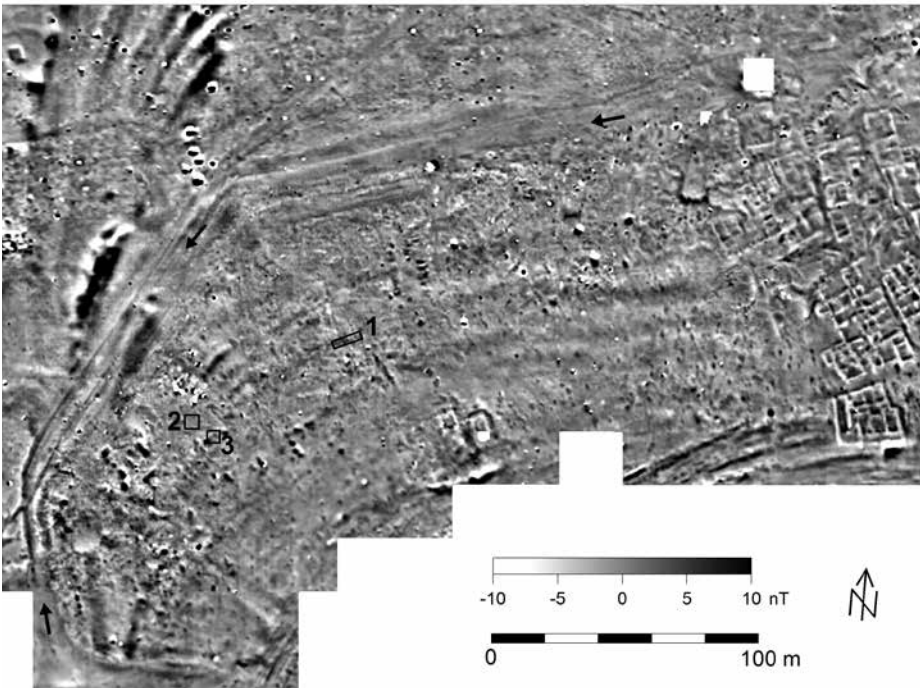

Fig. 8. Southwestern bay, magnetic map. Arrows mark the anomalies corresponding to the ridge. 1 - trench BE11-71; 2 - BE14-100; 3 - BE14-101

that was fondly though of initially as a built port with masonry waterfronts, resembling better known Mediterranean harbours. This hypothesis (used in reconstructions, e.g., Sidebotham *et al.* 2008: Fig. 7.18; see also Sidebotham, Zych 2011: xx–yy). lasted until the excavators realized, based on archaeological stratigraphy, that the sea could not have come up this far into the bay, up to the crescent-shaped ridge at the northern edge where the archaeological remains were recorded at 4–5 m above sea level.

The bay was designated as a priority when the Polish–American project reopened research at the site in 2008. The magnetic survey showed linear features, indicating clearly the presence of manmade(?) features within the ridge which runs around the southwestern bay, its top at an altitude of roughly 5 m above sea level (Fig. 8). The top is wide enough even today to act as a roadway, something like the Alexandrian Heptastadium, if it may be said so, running for about a quarter of a kilometer and turning in at the southern end to shelter the natural landing place within the bay from the rapid flow of rainwater down the western wadi, emptying into the lagoon. Flash floods continue to be a real hazard even today, so the southern sheltering arm of the bay may have imaginably protected whatever boats had docked on the beach. It is still

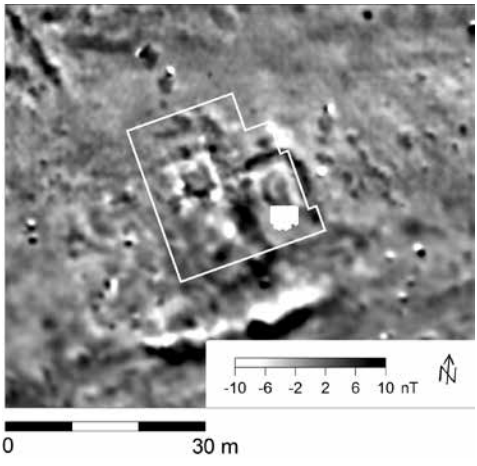

Fig. 9. Magnetic map of the harbour island temenos in the southwestern bay (box outlines area excavated or cleaned)

Fig. 10. The Lotus Temple on the harbour island temenos, original phase from the late 4th/early 5th century AD; view from the south (Photo S.E. Sidebotham)

not clear what this structure was constructed of and to what extent it may have used the fossil reef that has been shown to lie at its base at least in the southwestern part.

The magnetic image of the bay in its lower, southern part shows long parallel anomalies that give the impression of the waterline, possibly at different tide levels. Coring done in the harbour as well as excavations in trench BE11-71 revealed the beach level from the Ptolemaic period. It left no doubt that the sea never reached too far into the bay and that the landing place was a natural sandy beach. The special "elephant" ships, which presumably had flat bottoms, more like a barge, could have easily run ashore and the wild animals, mostly the smaller subadult specimens, could have been disembarked via broad wooden ramps. Later, in early Roman times, ships stayed outside, on the anchorage east of the city or in the deeper waters of the lagoon, while goods were ferried in and out in small rowboats. The loading and unloading took place on the natural beach. Just off the beach but still inside the ridge, sheltered by whatever structure formed this enclosure-like feature, were small workshops and stores, flimsy huts with walls and roofs of palm ribs mounted on low foundation walls of stones and coral heads, fitted with mats and earth floors, set around larger courtyard spaces that were occasionally paved, containing workshop installations, including a mysterious deposit of very finely burned charcoal and ashes up to a meter thick at the deepest place and spreading over an area of about 5 m in diameter (Sidebotham, Zych forthcoming a). All these paltry remains appear on the magnetic map as a an area of disturbed values, with a great deal of point anomalies, which do not form any particular pattern. In the western part of the bay a careful analysis of the map uncovered the remains of a large rectangular complex, possibly units surrounding a large courtyard. Excavations located exactly on top of presumed walls (BE14-100 and BE14-101) expected to uncover the stone-wall remains of this building of apparent substance. However, all that was found was a 'ghost' wall, that is, a trench from which the stone blocks were salvaged at some point and the remaining hollow was filled with deposits concreted into a hard mass by salt precipitation, as in the remains of the Hellenistic tower described above.

More importantly, the combined magnetic prospection and archaeological excavations have yielded data on the nature of the landing place that was apparently the main port of Berenike in the early Roman period. The beach levels uncovered in trench BE11-71, coupled with two structures located in the mouth of the bay, at an altitude not quite one meter above the modern sea level have provided strong evidence in favor of the hypothesis that no significant changes in the sea level have occurred in historic times. The sea ingressed as far as the parallel anomalies on the magnetic map indicate, at high tide, in Hellenistic and early Roman times, before the alluvia flushed down the wadi gradually filled in the lagoon forming the kind of *sabkha* plain that is now found further out. The architecture filling the southwestern bay extended up to the ridge, running no deeper than about 2 m (trenches have been dug in a row, giving a section aligned roughly north–south about 40 m long) and resting on culturally sterile sand, rising from the beach toward the ridge

Fig. 11. Magnetic map of houses on the eastern shore of the southwestern bay and location of trench BE13-91 (white box)

Fig. 12. The corner of a house with steps on either side of a wall (in trench BE13-91), view from the south (Photo S.E. Sidebotham)

surrounding the bay. The more humid climate in the later Roman era may have resulted in a more marshy environment here. In any event, for whatever reason, the landing place went out of use by the 3rd century AD and the port shifted most probably to the eastern and northeastern shores of the urban mound.

Standing out in this landscape were the two structures mentioned above as situated in the mouth of the bay. The eastern of the two structures was evident on the ground surface, the walls rising roughly about a meter high, enveloped in sand. The western structure was difficult to trace (Figs. 5 and 9) on the ground, but it has come up as a regular square feature in the magnetic image. Surprisingly, while the standing walls were well delineated, substantiating the belief that walls of gypsum anhydrite blocks correspond to negative anomalies in the magnetically susceptible matrix surrounding them, the collapsed walls of the structure, pushed down on all four sides of the building and forming a continuous surface in each case of the whereabouts of 20–30 m^2, have left absolutely no trace on the prospection map. A thorough analysis of the anomalies around the two structures have allowed the archaeologist to delineate an island temenos (Rądkowska *et al.* 2013; Zych *et al.* 2014) (Figs 9 and 10). The anomalies are enough to suggest the presence of structures, but are not sufficiently distinct to be able to imbue the results with any intelligible sense. Excavations in the 2015 season (BE15-103) uncovered some coral-head architecture, but without determining either layout or function of these features or installations (Sidebotham, Zych forthcoming b).

This is not the case regarding standing architecture on the eastern shore of the southwestern bay. Here the houses are extremely well delineated, the plans clear and distinct, showing entrances, passages, corridors, rooms with apses and alleys between building complexes (Figs 5 and 11). The latest-phase architecture can be mapped practically without excavation, giving a very good idea of the urban layout of 5th century AD Berenike. An exploratory trench situated at the entrance to a house with a main hall ending in semicircular apses at either end and long units resembling storerooms (BE13-91) has demonstrated that the house had a flight of steps leading up on the outside of a wall lining the entrance passage and another flight of steps on the opposite side of the same wall, inside the room (Fig. 12). The corner of the walls, which were built of coral heads (while the steps were of gypsum anhydrite slabs), were exactly where the anomalies on the magnetic map had suggested they would be. Moreover, point anomalies in the entrance passage proved to be oven-like installations and hearths in use in the last occupation phase of the structure (Zych, Sidebotham forthcoming).

The urban mound: the Late Roman city

The urban sprawl of Berenike, situated on a mound at the eastern end of the site and with direct access to the sea (today limited somewhat by the spread of the *sabkha* sand flat), was evident to the first explorers and the site of the Great Temple obvious enough for J. G. Wilkinson to have started his excavations there (Sidebotham *et al.*

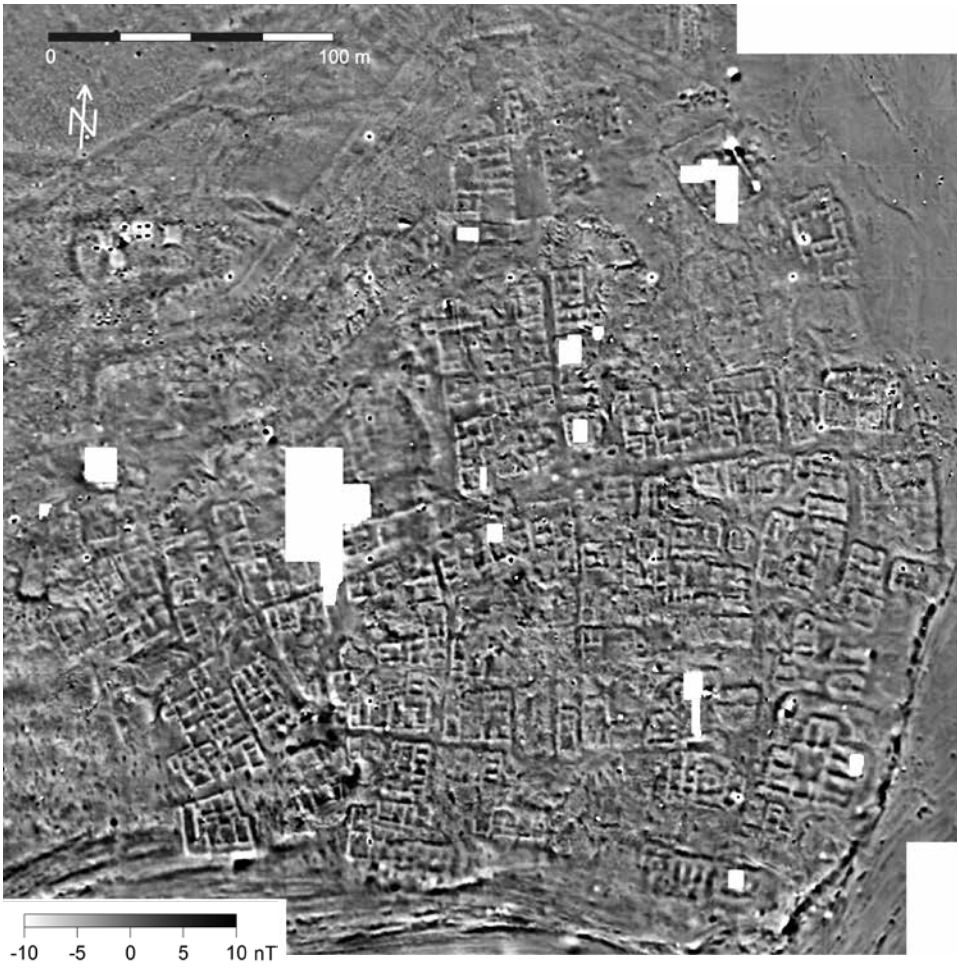

Fig. 13. Magnetic map of the town mound as completed in 2015

2008: Fig. 7.9, see also Figs 6.20 and 6-21; 2011: 60–61, 259 ff.). The American–Dutch project started off in 1994 with the first limited trenches in this area, producing at the same time a topographical plan that largely recognized the layout, so well were the ruins preserved under an obscuring blanket of drifted sand.

The magnetic prospection of this area (leaving out trenches dug earlier and the larger area west of the Great Temple where a huge archaeological dump is located) helped to draw a clearer picture of individual houses and whole insula complexes, already suggested by the topographical plan (Figs 13 and 14), while contributing tidbits of evidence to round off the interpretation of areas where there was nothing on the ground surface to

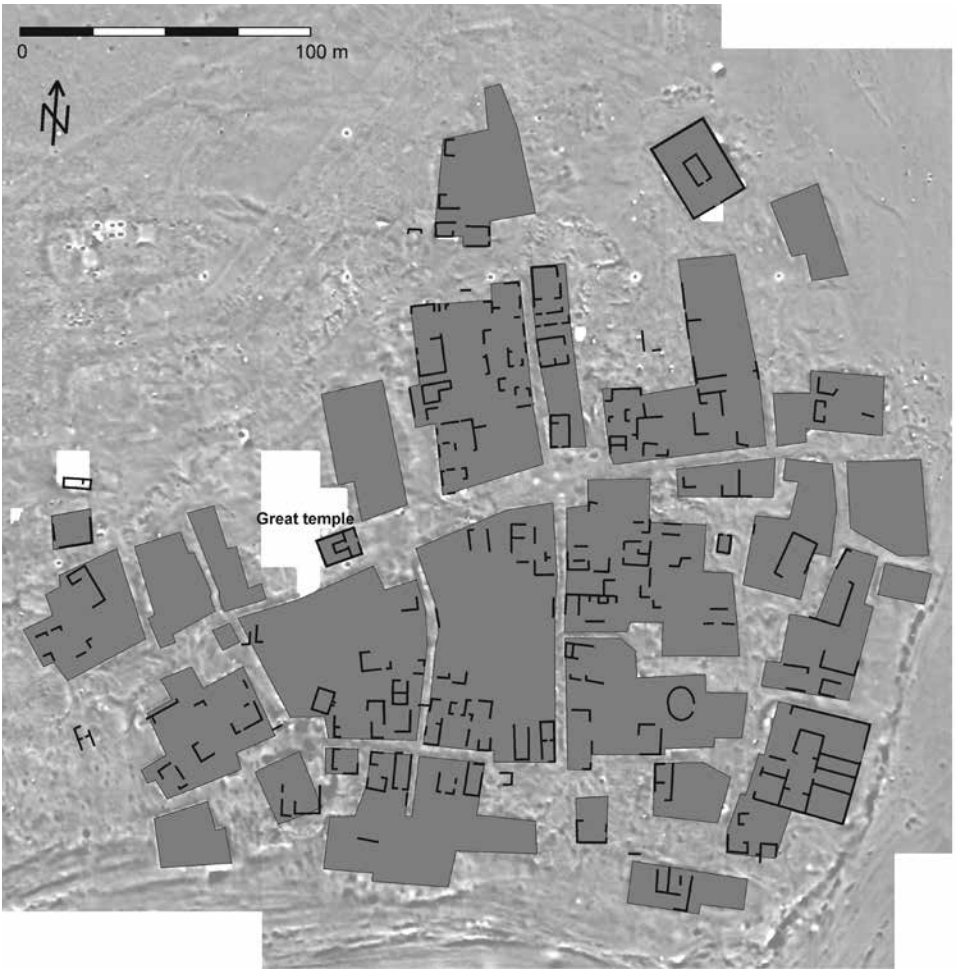

Fig. 14. Magnetic map of the town mound with superposed position of wall fragments recorded during the topographic survey of 1994 (walls after Aldsworth et al. 1995 inserted plan); shaded boxes show presumed insulae

consider (the slightly blurred image of structures in the center, just north of the Great Temple, is the effect of bulldozing activity by the Egyptian military in the 1970s, which was stopped fortunately before too much damage was done). Moreover, in the specific conditions of Berenike the magnetic method allowed structures in the near-surface layers to be registered, practically no deeper than 0.5–1 m, and in the case of the main town of Berenike archaeological evidence has already shown that the buildings from the early Roman and quite possibly late Hellenistic period go down at least 5–6 m in the highest

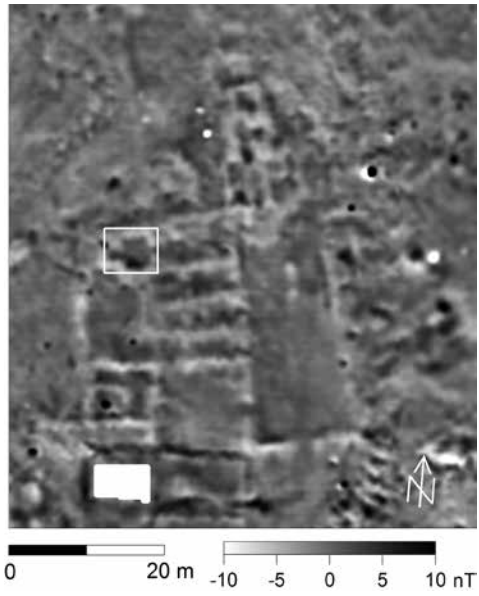

Fig. 15. Magnetic map tracing a building complex located at the northern end of the town mound; location of trench BE15-110 marked

Fig. 16. Square room with niche excavated in the 2015 season in BE15-110. View from the south-east (Photo S.E. Sidebotham)

point of the mound. Excavations have suggested a fair continuity of the Late Roman house layouts compared to the early Roman remains, on which they were superposed, using the old walls partly as foundations for the new structures. To what extent the early Roman architecture followed the earlier Hellenistic structures cannot be said for now, just as it is not clear whether the Great Temple, obviously early Roman in its foundation, had a Hellenistic predecessor on the site. (Recent evidence of fragmentary Pharaonic-age steles found in the late Roman rubble of the temple suggests the possibility of a shrine having existed on the spot in Berenike in the Middle Kingdom/inception of the Second Intermediate Period, that is, around the 18th century BC, see Sidebotham, Zych forthcoming b). Perhaps the fact that the Great Temple does not fit the rectilinear street grid visible in the central part of the mound is proof that it predates the later Roman city (from the 4th/5th century AD?). Another possibility is that it is connected rather with the westernmost insulae, which appear to follow a different grid, at a distinct angle compared to the rectilinear grid in the central district.

An evident crossing of streets in this district gives rise to the latitudinal street which skirts the Great Temple on the south and hits a big *decumanus* that continues straight to the eastern shore, finishing off at the waterfront with the Christian church located to its north. It intersects with a *cardo*, forming a rather large of irregular square marked by three point anomalies characterized by negative values. The three circular anomalies stand at the corners of a square, the fourth being faint, possibly somehow obscured by a wall. It has yet to be verified archeologically whether the anomalies could correspond to some kind of tetrapylon structure at the most important city crossroads. The *cardo* led to the north between densely constructed houses to a large complex consisting of a long rectangular courtyard preceding a number of small units in a row, aligned with the long axis of the complex, and a number of parallel rectangular units positioned laterally, the northernmost giving access to a square room with niche (Fig. 15). This unit started to be excavated in 2015 (BE15-110) and proved to have a large rectangular niche with surviving fragmentary marble facing on a lateral wall and evidence of some kind of wooden framing of the niche opening (Fig. 16). So far a late Roman squatter's phase has been established for the room, but it seems very likely that the original complex was early Roman. More importantly, it closed off the *cardo* and may have towered to some extent over the northern part of the site, the ground falling away to the north rather abruptly. The complex seems to have been fitted snugly into the corner formed by a feature corresponding to the unrecognized linear anomaly that turns at sharp angles in the northern part of the site.

The general impression is of a city that cascades down from the highest point to the south and southwest, opening itself onto the lagoon and southwestern bay (before it silted up), while turning its back on the prevalent northerly winds coming from the direction of the Ras Benas cape. To the east, the buildings also descended to sea level, but the architecture that can be reliably reconstructed based on a very clear magnetic image looks

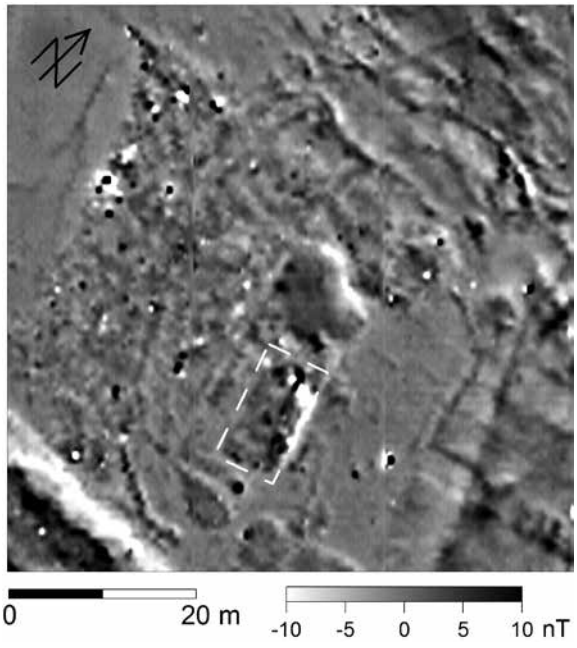

Fig. 17. Magnetic image of the mysterious building with three podia discovered through analysis of Corona satellite imagery (marked location of trench BE15-105)

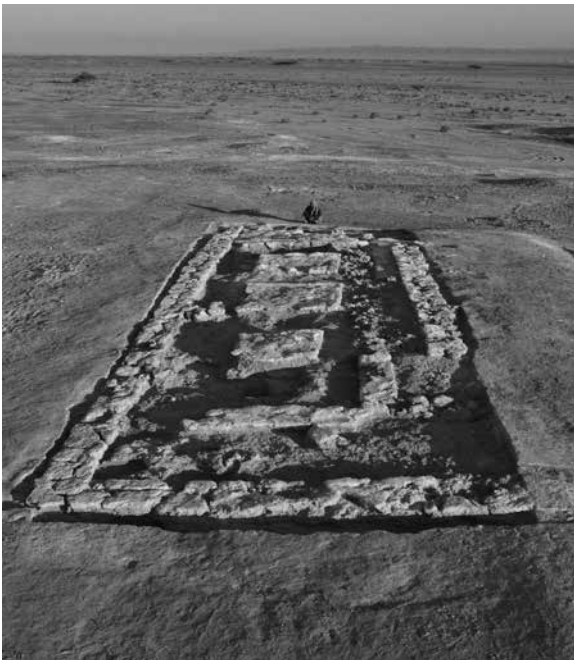

Fig. 18. The building with three podia after cleaning, view from the south (trench BE15-105) (Photo S.E. Sidebotham)

generally more like the warehouse and industrial type. It is also possible that the easternmost fringes of the urban mound may have been developed urbanistically, the ground being artificially leveled and built up with fill from other parts of the site and the eastern coastline transformed into a masonry waterfront for dealing with the intense maritime commercial trade with India among others, known to have taken place in Berenike in the 4th–5th century AD. The southwestern bay was no longer in use and there is no other apparent place where trading could have proceeded on such a scale. Early excavation at the southeastern corner of the site (BE94-5) even uncovered a structure that may have served as a kind of lighthouse or signals tower. Other trenches dug along the northern part of the shoreline revealed earthworks on a massive scale leaving an upturned stratigraphy with loads of fragmented early Roman amphorae being used to create a reinforced platform. The roughly linear anomaly running at an angle around the southeastern part of the urban mound may attest to a similar kind of reinforced waterfront. The curious thing is that this waterfront seems not to have continued beyond the church to the north. Indeed, the entire northeastern quadrant of the urban mound is loosely occupied and one might wonder whether, being on low-lying ground compared to the rest of the urban mound, they were also set off by water, either continuously or at least at high tide (Sidebotham 2011: 60–61). The nature of the magnetic map image immediately to the west of a rectangular enclosure of a temenos nature, as well as around it, could suggest such a situation with access to the evidently important enclosure being via rowing boats perhaps. It could well be the northern and more important harbour of Berenike where officialdom concentrated, leaving the southwestern bay (in early Roman times) as a ship repair and supply yard or else a secondary bay for use perhaps by a given ethnic group of merchants or a given group of merchants with shared business interests.

An added point of interest is the appearance on the magnetic map of the southern fringes of the site. The anomalies here form densely parallel, gently arching lines that follow a sinusoidal line along the shore of the anticipated lagoon (Figs 5 and 13, See also Herbich 2011: 14, Figs 2.3 and 2.4). At the present stage of research, it is reasonable to interpret these anomalies as the steeply falling edge of a fossil reef that formed the promontory on which the town was founded. The same kind of anomalies can be seen also at the southern edge of the western plateau, also suggesting a sudden rocky drop-off of the shore in this area. The strong positive anomalies that run in a flamboyant swoop toward the northeast along the crescent-shaped ridge of the southwestern bay are definitely not anthropic in character. Archaeological testing on the spot of one of these anomalies gave absolutely no evidence of anything that could give such a strong result. Digging to depth of roughly 1.50 m, revealed nothing but pure sand, culturally sterile below the top layer associated with an early Roman midden and cemetery of dogs (see Zych, Sidebotham 2010). It seems, therefore, that these anomalies reflect geological events of a much more distant past than archaeologists digging in Berenike can hope to be interested in and so they will not be considered in the overall interpretation.

PROSPECTS FOR THE FUTURE AND CONCLUSION

The magnetic map of the site is practically complete excepting the northwestern quarter where the cemeteries are located. Some prospection in this area as well as the results of limited archaeological excavations (BE01-44 Sidebotham, Wendrich 2002) have also proven the potential of this method for mapping the mausolea that existed on the land side of the city in the 4th and 5th centuries AD for sure.

A new discovery resulting from an analysis of publicly available Corona satellite imagery, which led to the identification of a curious complex of three podia within a large enclosure, inside a naos apparently facing the sea, was immediately put to the test with a sample magnetic survey. On the ground it was possible to trace extensive walls of gypsum anhydrite blocks and these were faithfully imaged on the magnetic map. Subsequent excavations (BE15-105) demonstrated the most standard arrangement as far as Berenike is concerned: strong negative anomalies corresponding to walls of gypsum anhydrite, even if preserved just one block deep, contrasting with the magnetically susceptible matrix of sand and gravel (Sidebotham, Zych forthcoming b Figs 17 and 18). Just as the excavators thought that they had completed a full survey of the site, these new developments demonstrated that geophysicists will be coming for a few more seasons.

The results of the work, extended magnetic prospection combined with excavation of trenches pinpointing specific locations of interest on the map of magnetic anomalies, exemplify the nature of the cooperation between archaeologists and geophysicists. The archaeological feedback that comes in a continuous stream from current explorations leads to improved and occasionally ingenious interpretations of registered anomalies, which in turn cannot be underestimated in reconstructing settlement processes in ancient Berenike.

Moreover, the results of the magnetic survey at Berenike should persuade all the doubtful critics that field testing of geophysical methods is of paramount importance, even if conditions for applying such methods seem to be definitely unfavorable. Had one gone by the theory of what the effectiveness of the magnetic method should be in the specific geological conditions of the site, knowing how the building material used in Berenike has no magnetic properties whatsoever, the prospection would have never taken place. The loss to science would then have been substantial, what the authors of the present article are convinced of and tried to show above.

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