ROADS FROM BAHARIYA TO FAIYUM: A STUDY IN REMOTELY SENSED DATA

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Abstract: *This paper focuses on the probable land route between the Faiyum region and Bahariya Oasis during the Pharaonic period. Literary, archaeological and remote sensing data are analysed and discussed in this study. The possible ancient termini of this route are also taken into account in order to shed new light on trade connections in so far scarcely explored sectors of the Egyptian Western Desert.*

Key-words: *Remote sensing; Desert Archaeology; Desert trade routes; Faiyum; Bahariya Oasis; Gurob; Medinet Maadi; Western Desert amphorae*

Introduction (VG)

While the existence of dynastic trade connections between the oases and the Nile valley (Fig. 1) in the southern sector of the Egyptian Western Desert has already been demonstrated,[3] investigation of similar economic activities, exchange models and trade patterns in the northern portion of the same desert is still lacking, despite considerable archaeological research into the area.[4] The trade network connecting Bahariya oasis and the Faiyum region (Fig. 2), which was probably in use even before the beginning of the Roman period, is still to be 'proven archaeologically'. Eichhorn[5] briefly proposed a series of trails across the desert in this area, but it was not the focus of their research. They did not investigate the Bahariya – Faiyum routes in any detail and did not consider evidence for their Pharaonic antecedents.

This paper proposes that the historical trade route between Bahariya oasis and the Faiyum followed a much more ancient trail attested since the Roman period and probably extending back into the Pharaonic age. Analysis of two types of satellite imagery confirms that traces of this route survive to the present day and suggests avenues for further investigation on the ground and using remote-sensing techniques.

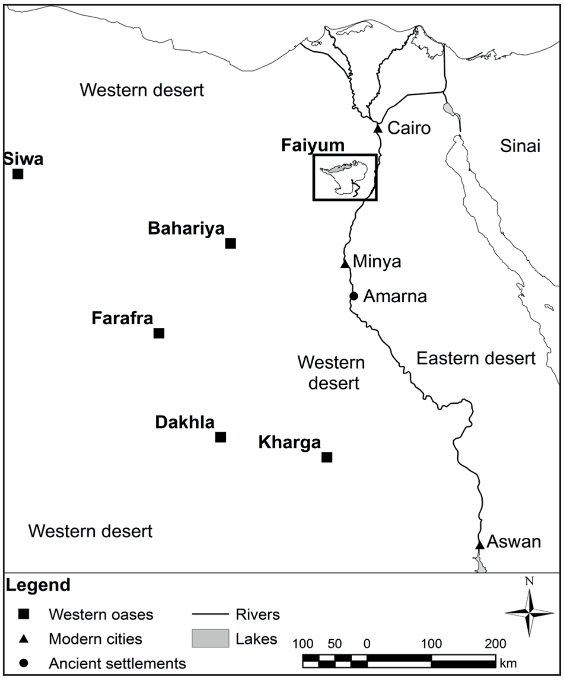

Fig. 1 The location of the Faiyum region and the oases mentioned in the text (made with data from Natural Earth).

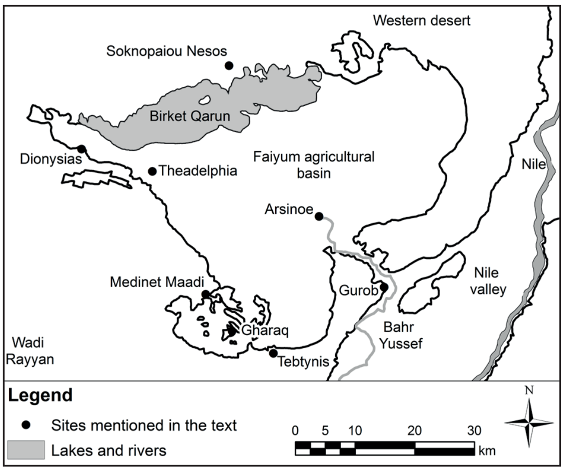

Fig. 2 The Faiyum, showing ancient settlements mentioned in the text (adapted from a map by A. Morini).

[1] The British Museum

[2] The British Museum

[3] Darnell and Darnell 2013; Darnell and Manassa-Darnell 2016; Förster and Riemer 2013; Friedman 2002.

[4] Colin 2012; Dospel and Sukova 2013; Barich et al. 2014; Marchand In press

[5] Eichhorn et. al 2005, 215.

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Evidence of trade between the oases and the Faiyum region (VG)

There is good evidence of exchange between the oases, including Bahariya, and the Faiyum in the Greco-Roman and Pharaonic periods. Papyri dated to the Roman period shed light on the import of grain, dry legumes, and other goods from the Faiyum to the oases and the movements of camels and donkeys (probably used for the transport of products) between these two areas.[6] The presence of donkeys among the animals which travelled from the Faiyum to the oases demonstrates the feasibility of the same journey before the introduction of camels for long-distance desert travel (on donkeys and their role in caravan routes see below). Among the goods exported from the oases to Arsinoe (modern Medinet el Faiyum – Fig. 2), alum is quoted at least once.[7] The Greek papyri found to date do not mention the import of wine from Bahariya to the Faiyum, although oasis wine was appreciated in the Nile Valley at least since the Middle Kingdom.[8] The discovery at Tebtynis of oasis transport containers for wine and oil, such as *siga* and *siga-barrillets,* dating between the late fourth and the first century BC[9] demonstrates that both commodities were imported from the oases to the Faiyum during the Ptolemaic period.

The inscriptions and scenes carved in the late 18th – early 19th Dynasty tomb of Amenhotep Huy, the Governor of the Bahariya oasis, clearly indicate the production and storing of wine amphorae and grain, for delivery to the Nile valley.[10] The discovery of the Umm Mawagir bakery in Kharga provides further evidence for the transshipment of grain between the Nile and the southern oases during the Pharaonic period.[11] It is worth noting that during the Ptolemaic and Roman periods, grain was traded the other way around, from the Faiyum to the oases (including Bahariya). This change in commerce could be indicative of some alterations in the economy of the area at a later stage of Egyptian history.

Very little archaeological data shed light on goods imported from the oases to the Faiyum before the Roman period, apart from the previously mentioned *siga* and *siga-barillets* from Tebtynis. However, this could also be due to the paucity of information on pre-Ptolemaic sites in the

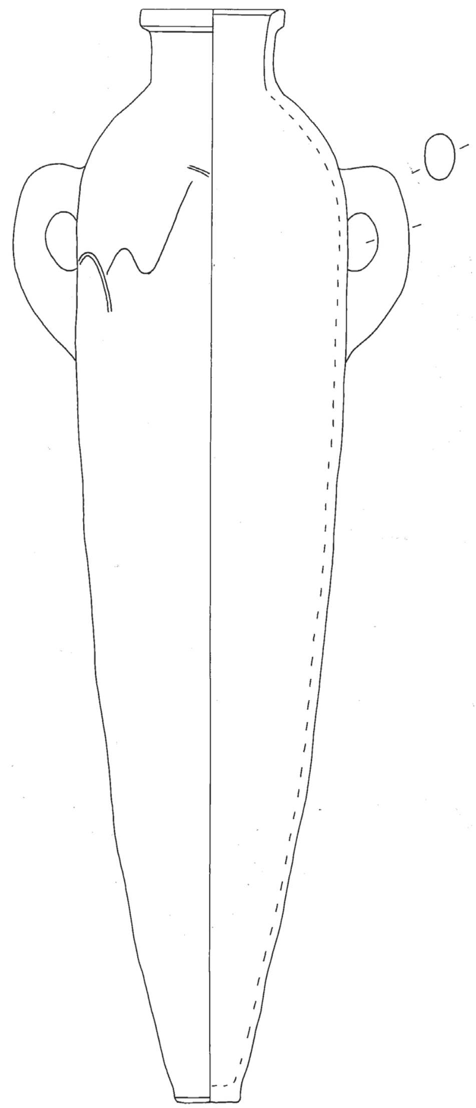


Fig. 3 An oasis amphora from Gurob, in the Manchester Museum (Inventory no. 2136).

Faiyum. Oasis transport containers dated to the Dynastic period have not been found in the Faiyum, but archaeological evidence from the nearby settlement of Gurob hints at the existence of trade during the New Kingdom. The Manchester Museum (Inventory no. 2136) preserves an oasis amphora that is complete apart from a missing handle (Fig. 3). The Museum accession documents and registers confirm that the amphora

6 Wagner 1987, 148.

7 Wagner 1987, 148.

8 Fakhry 2003, 58; Marchand and Tallet 1999, 307–08.

9 Marangou and Marchand 2007, 257–58 and 285.

10 van Siclen 1981; Giddy 1987, 162–63; Colin 2011, 49–50.

11 Darnell and Manassa-Darnell 2016.

came from Gurob[12] and was excavated by L. Loat,[13] making it the only Late Bronze Age amphora imported from the Western Desert that has ever been found in the Faiyum region.

The closest parallels for this specific type of oasis amphora come from the site of Amarna,[14] suggesting a late 18th Dynasty date for the Gurob item. Oasis amphorae from Amarna are comparable to the Gurob example in terms of their shape (particularly their height of 80 cm), firing surface, fabric type[15] and pottery marks (typically a wavy line), which is incised on the shoulder of the Gurob example. The gray slip which was applied to the exterior of the Gurob vessel is also consistent with oasis ware from Amarna.

Evidence of routes between Faiyum and Bahariya (VG)

There is good evidence of a route between Faiyum and Bahariya in historic times. Both Fakhry[16] and Giddy[17] record a trail between the north-eastern part of Bahariya oasis and the south-western part of the Faiyum basin. This route of 240 km took five or six days by camel, allowing between a half and a full day for the camels to graze and drink in Wadi Rayyan. It is likely that this practical and efficient route was used repeatedly over the millennia, so the historically attested route could have originated in the Pharaonic or Roman periods.

Written sources suggest that this trail dates back to, at least, the Roman period when Greek sources refer to a land route from the "Small Oasis" in the direction of the Arsinoite nome.[18] It is clear from both Ptolemy[19], and several Roman papyri that this "Small Oasis" should be identified as Bahariya.[20] Some Greek papyri refer to the following Faiyumi settlements involved in trade activities with the "Small Oasis": Soknopaiou Nesos, Dionysias, and Arsinoe, the latter connected to the caravan road via Theadelphia.[21] While Dionysias[22] and Theadelphia were founded *ex novo* in the third century BC in connection with the land reclamation promoted by the Ptolemies (250–240 BC), Soknopaiou Nesos and Arsinoe (Shedet in the Dynastic period) have a much longer urban history, dating back respectively to the Old Kingdom[23] and the first Dynasty,[24] providing possible Faiyumi termini for an earlier Pharaonic version of the trail.

Geographically, the Faiyum region is a natural outpost to the northern sector of the Western Desert. The increasing importance of trade with the oases from the reign of Thutmosis III[25] onward, as well as the Pharaonic trade patterns in the southern sector of the Western Desert suggest that the trade route between the Faiyum region and Bahariya was in use before the Roman period.

When leaving Bahariya and going to the Faiyum, this trail must have headed north-east along a similar route to the historical trail, which was used for trading camels. During the Pharaonic period and prior to the introduction of the camel, donkeys were used for long-distance trade.[26] Donkeys can travel up to 40 km a day and endure up to three days without water.[27] Based on 40 km a day, the 240 km route from Faiyum to Bahariya would have taken a minimum of six days without stopping. Donkeys are reasonably flexible about the quality and regularity of food provision,[28] but if the caravan relied upon grazing in the Wadi Rayyan, the trip would have taken longer to allow time for the donkeys to rest and eat. Since it is likely that donkey caravans made full use of the available grazing and only carried their full food supply once they had left the relatively hospitable Wadi Rayyan, the journey probably took longer than the minimum of six days.

Wadi Rayyan was a logical stopping point on the way from the oasis of Bahariya to the Faiyum region, both from a geographical point of view and as a resting place after a four to six-day journey in the desert. The Roman caravan road diverged into two different trails: one trail followed the western side of the Faiyum region, in the direction of Soknopaiou Nesos via Dionisyas, while the second one reached Arsinoe via Gharaq.[29] However, it is logical to assume that the settlement of Medinet

12 A detailed study of this vessel will be published soon.
13 Loat 1904.
14 Rose 2007, 290.
15 Amarna Fabric IV.3; Rose 2007, 15.
16 Fakhry 2003, 26.
17 Giddy 1987, 16.
18 Wagner 1987, 146–50.
19 *Geography* IV, 5, 37.
20 Wagner 1987, 134–35.
21 Wagner 1987, 147–48.
22 Cestari 2010, 15–16.
23 Marchand 2012, 65–66 and 72.
24 Zecchi 2001, 23.
25 Fakhry 1974, 59.
26 Förster et al. 2013, 195.
27 Förster et al. 2013, 205–07; Köpp 2013, 115.
28 Förster et al. 2013, 195.
29 Wagner 1987, 148.

Maadi, with its strategic geographical position, at the edge of the desert and approximately 20 km south of Theadelphia, also may have been involved in the same network, as suggested by the satellite imagery presented below.

In comparison to the amount of data available for the Greek and Roman phases, there is relatively little information on the Faiyum settlements before the beginning of the Ptolemaic period. The main exceptions to this are Medinet Maadi, which is discussed below, and Qasr el-Sagha which is on the north side of the Faiyum and appears to be an abortive settlement of the Middle Kingdom.[30] However, if the overland trade routes between the Faiyum and Bahariya oasis, attested by the Greek papyri, originated before the Roman period, it is logical that they terminated at one or more of the Pharaonic settlements in the Faiyum – Medinet Maadi, Shedet (later Arsinoe) or Soknopaiou Nesos.

It is possible that Gurob was one of these termini in the New Kingdom or, at the very least, benefited from the exchange of goods between the Faiyum and the rest of the country,[31] as attested by the discovery of an oasis amphora here (Fig. 3). This commercial role perhaps developed at the same time in the New Kingdom when the oases of the Western Desert became an integral part of the Egyptian economy.[32] The reign of Thutmosis III is moreover a crucial moment for the settlement of Gurob, due to the re-evaluation of this area promoted precisely by this king and embodied by the foundation of his harem-palace.[33] Starting from the mid-18th Dynasty, Gurob became the most important New Kingdom settlement in the region, located strategically at the entrance to the Faiyum depression, facing the Nile valley and thus well connected to the regional water system. Further archaeological investigations at Gurob may help to understand the role it played at a unique regional crossroads, and its relationship with routes to Bahariya and elsewhere in the Western Desert.

The settlement of Medinet Maadi is another likely candidate for the Pharaonic gateway between the south-west sector of the Faiyum region and the Western Desert in the New Kingdom. Medinet Maadi (ancient *Ḏ3* in Pharaonic times) was founded during the 12th Dynasty, probably during land reclamation promoted in the Faiyum region by the kings Senusret II to Amenemhat III. Despite the scarcity of documents belonging to the New Kingdom, Medinet Maadi was doubtless in use during this time. This is demonstrated by the remains of statues dated to the Ramesside period,[34] a stela of the late 18th to the early 19th Dynasty,[35] a fragmentary offering altar,[36] and the carving of the cartouches of Ramesses III on the western wall of the courtyard of the temple that was originally erected during the 12th Dynasty.[37] One of the earliest New Kingdom documents from the settlement,[38] dating to the late 18th Dynasty, refers to the erasure of the name of *Imn* from the cartouches of Amenemhat III in all the inscriptions carved in the temple, no doubt part of the religious programme of Akhenaten, toward the end of the 18th dynasty, and indicates that the royal court took some interest in the site, perhaps because of its strategic position. While the cartouches located in the hypostyle hall were restored at a later time, others are still absent.[39]

The roles of Medinet Maadi and Gurob as gateways to the Western Desert during the Pharaonic period remain to be proven, along with the existence of the Bahariya to Faiyum trail before the Roman period. However, the evidence presented above demonstrates the existence of trade between the oases and the Faiyum region in the Pharaonic period and suggests a possible route from Bahariya to various termini in the Faiyum area. This route would have headed north-east from Bahariya oasis to the Wadi Rayyan, where it probably split into two sections heading north-east to Medinet Maadi and beyond or east, along the southern edge of the Faiyum depression toward Gurob. The satellite imagery research complements these conclusions and reveals that traces of this route remain, suggesting that further archaeological investigations along it would be profitable.

30 Moeller 2016, 262–71.
31 Gasperini 2014, 10–22.
32 Starting from the reign of Thutmosis III: Fakhry 1974, 59.
33 Petrie 1890, 31; Lacovara 1997, 36–38; Thomas 1981, 7; Serpico 2008, 19; Shaw 2011, 453–55; Yoyotte 2012.
34 Vogliano 1937, 40–42; Donadoni 1952, 9–10; Gomaà 1973, 85; Chadefaud 1982, 49–50; Sourouzian 1989, 107–9; 1991, 226–35.
35 Vogliano 1937, 61–64; Donadoni 1952, 11; Zecchi 2001, 164.
36 Donadoni 1952, 7–9; Gomaà 1973, 55.
37 Donadoni 1952, 12.
38 Donadoni 1952, 4–5.
39 Donadoni 1952, 4–5.

Satellite Imagery (HP)

Previous research has shown that ancient routes can be identified in satellite imagery. The research presented here develops those methods to investigate the putative route between Bahariya and the Faiyum. It combines Bubenzer and Bolton's method of identifying trails across the Egyptian Limestone Plateau in the south of Egypt in low (15 m) resolution multi-spectral satellite imagery[40] and De Laet's[41] method for identifying trails in disturbed and varied terrain at Deir el-Bersha using high-resolution satellite imagery. Given that satellite imagery research into desert trails is still developing and has inherent uncertainties due to the variability of the desert terrain, it was felt appropriate to test whether these approaches would succeed in different parts of the Egyptian desert from those where they were initially developed and if they could be combined to trace trails efficiently and cheaply across large areas of varied terrain.

The first part of this research made use of free multi-spectral, low (15–100 m) resolution Landsat 8 data (USGSa) to examine a large area of the Limestone Plateau between Bahariya and the Faiyum basin and determine whether the historic trails proposed by Eichhorn[42] are extant and traceable. These methods are not sufficient to trace the trails beyond the Egyptian Limestone Plateau where the terrain becomes more varied and the landscape is disturbed.[43] To test whether De Laet's[44] method for identifying trails in disturbed and varied terrain could be applied to trace historic or ancient routes across the disturbed landscape at the Bahariya end, a 25 km^2 study area of very high (0.4 m) resolution multi-spectral Worldview 2 satellite imagery was purchased from European Space Imaging.

Although high-resolution imagery of a similar type to the Worldview 2 image purchased for this research is available on Google Earth, several issues with Google Earth imagery makes it unsuitable for this type of research. Google Earth imagery represents only a small selection of the total quantity of high-resolution satellite imagery that can be purchased and does not permit the user to analyse the multi-spectral image bands. Furthermore, the specific images can change without warning and the tiles exhibit poor geolocation,[45] which would cause problems with future 'ground-truthing' fieldwork. Although there is some potential for the use of Google Earth imagery in subsequent phases of the research, the purpose of this stage was to confirm whether the trails across the northern section of the Limestone Plateau can be traced beyond the Limestone Plateau in higher resolution satellite imagery. Under such circumstances and at this stage of the research it would not be appropriate to use Google Earth imagery, given the many potential problems with that source.

Methods of analysis (HP)

The analysis of the satellite imagery was undertaken in ArcGIS 10.1 Geographic Information System (GIS) and included both visual examination of the highest resolution elements of the imagery and analysis of the multi-spectral bands involving histogram equalisation, histogram stretching and contrast stretching.[46]

The chosen Landsat 8 image LC817704020130-78LGN01 was recorded on 19 March 2013 and included the entire area from Bahariya to Faiyum. The identification of potential trails encompassed all the multi-spectral bands. Modern, tarmac roads were easily identified in the highest (15 m) resolution panchromatic band (8) and excluded. Other linear features were divided into two types, based on their appearance and landscape context. Straight, wide features were identified as modern or 20th century routes. Fainter, winding or variable features were considered potentially historic or ancient following research by Bubenzer and Bolton. They discovered that the Egyptian Limestone Plateau is topped by stony *serir* (small round stone) and *hamada* (large angular stone) surfaces. Repeated animal movement along desert trails pushes these stones aside, leaving depressions in the desert surface, which fill with windblown sand that contrasts with the surrounding surface and appears as a single, winding linear feature in low-resolution imagery such as the Landsat 8.[47]

Fig. 4 shows how two features appeared in each band of the Landsat image. Both a historic/ancient trail (since identified as part of the Darb el-As'as from the Survey of Egypt 1:100,000 Normal

40 Bubenzer and Bolton 2013, 69–72.

41 De Laet et al 2015, 289–92.

42 Eichhorn et. al. 2005, 215.

43 Bubenzer and Bolton 2013, 71–72.

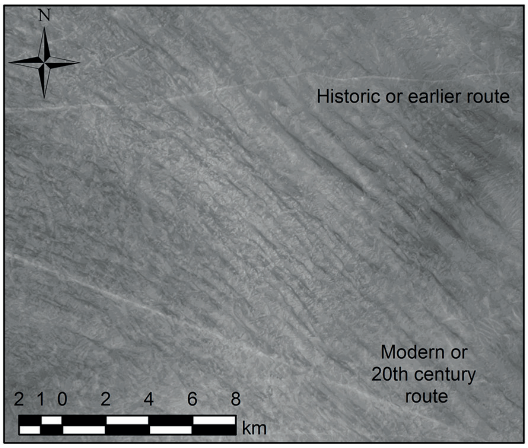
44 De Laet et. al. 2015, 289–92.

45 Pedersén 2010, 388.

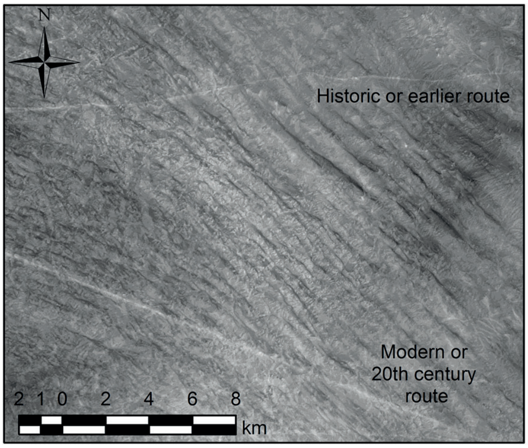
46 for these techniques see Lillesand et. al. 2004, 492–99.

47 Bubenzer and Bolton 2013, 62–63.

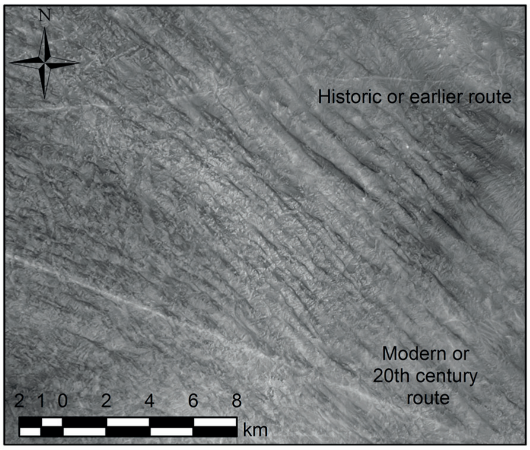
Desert Series sheet 62/42 Bahariya Approaches 1940) and a modern or 20th century route (subsequently identified as power line with pylons from the Tactical Pilotage Chart 1:500,000 scale World Series Sheet H-5 A, compiled 1972, revised 1999) appear across all the multi-spectral bands in Fig. 4, except for Band 9, which is not shown because it did not contain any usable data.



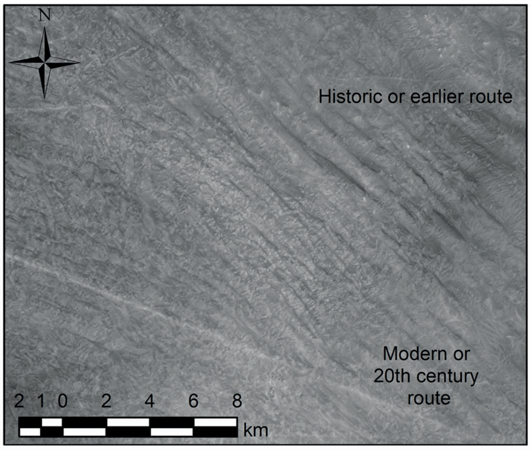
Band 1, ultra blue (0.43-0.45)



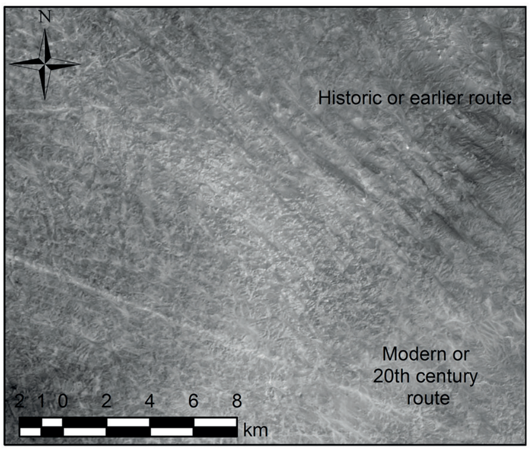
Band 2, blue (0.45-0.51)



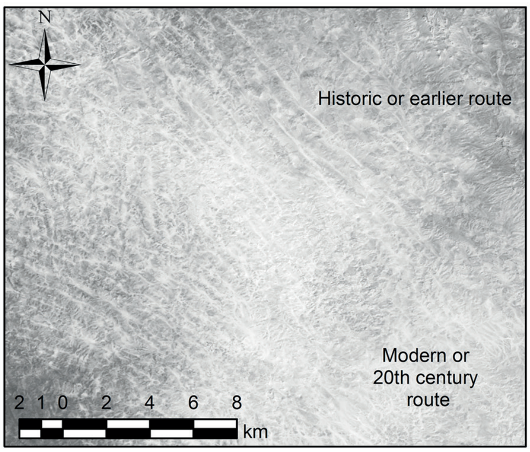
Band 3, green (0.53-0.59)



Band 4, red (0.64-0.67)



Band 5, Near Infra-Red (0.85-0.88)



Band 6, Short-Wave Infra-Red 1 (1.57-1.65)

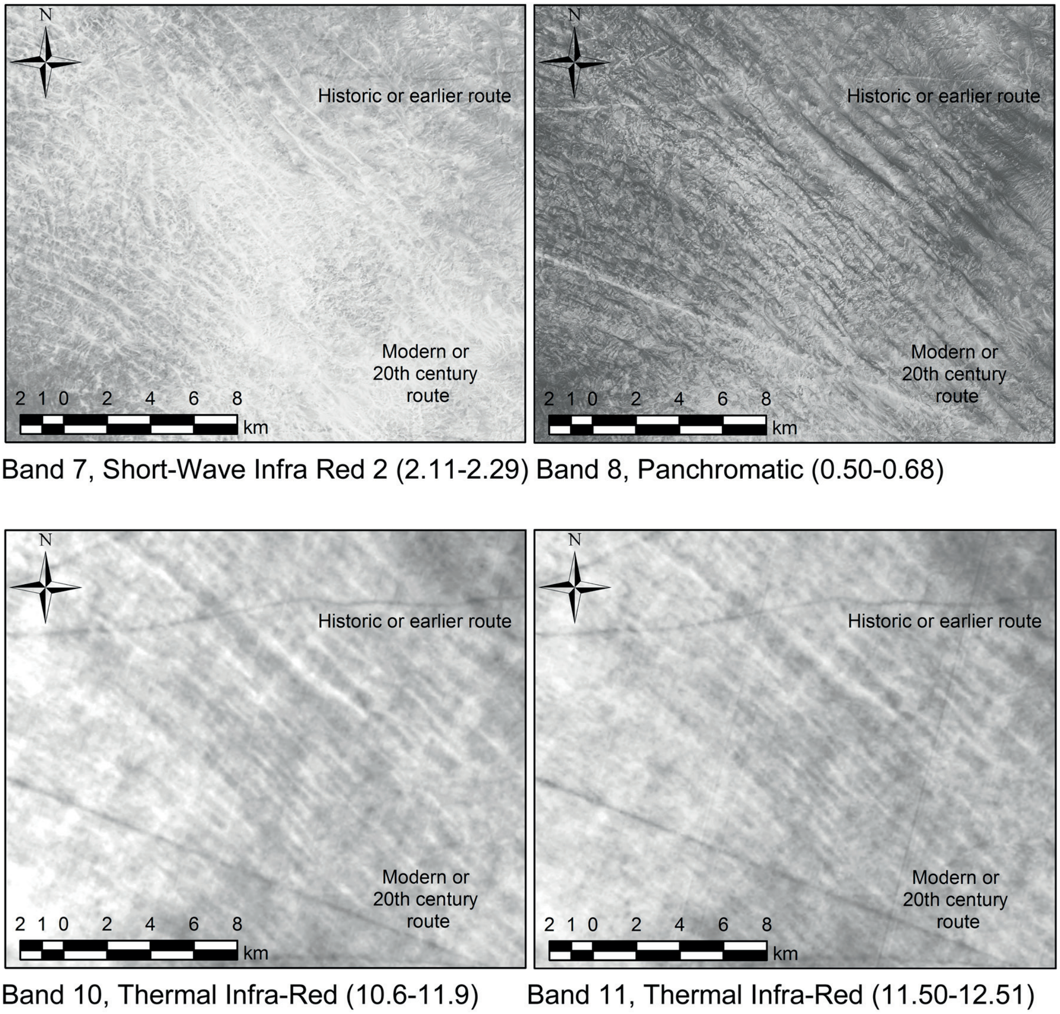


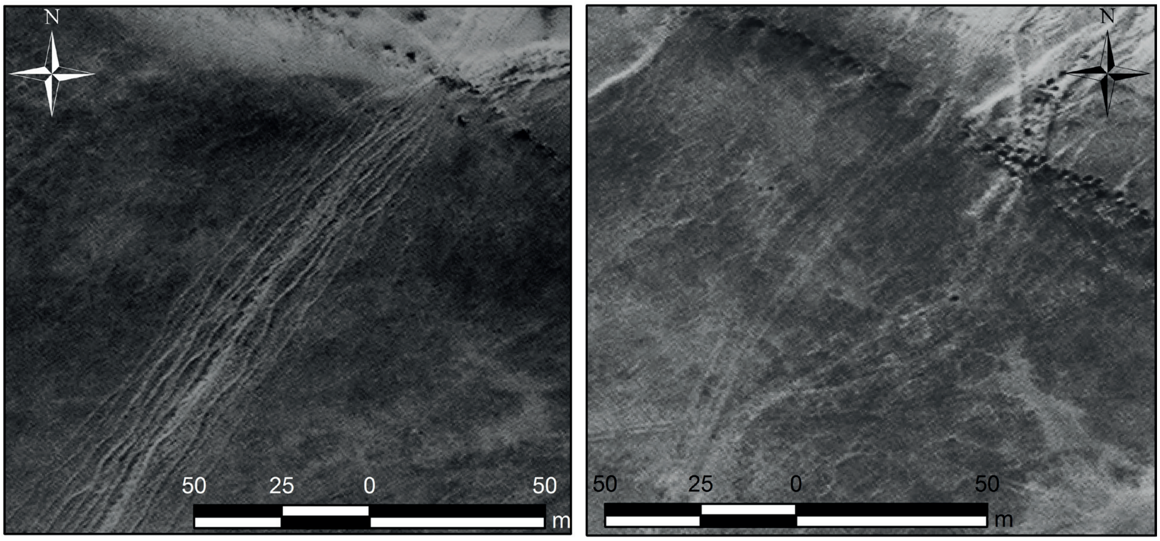
Fig. 4 The appearance of historic/ancient and modern routes in different bands of Landsat 8 image LC81770402013078LGN01 following enhancement appropriate to bring out the detail in each band. (Landsat data available from the U.S. Geological Survey).

Fig. 4 reveals that there are several differences in the spectral appearance of the historic/ancient trail and the modern/20th century route, which suggest that historic and ancient trails can appear differently to modern features in certain spectral bands. Because of this phenomenon, we present each band individually in Fig. 4 to provide a more detailed breakdown of the appearance of the trails across the Landsat bands. More research and fieldwork will be necessary to determine the precise spectral signatures of modern and historic or ancient trails, how consistently they occur and whether they can be used for dating.

Although they are lower resolution, Bands 10 and 11 (thermal infra-red) are amongst the best for the identification of possible historic or ancient trails and show a fine, faint route in the top north-western corner of the images, which was not visible in any other band but is a potentially ancient trail, that forms part of the historic Darb el-Rayyan, according to the Survey of Egypt 1:100,000 Normal Desert Series sheet 62/42 Bahariya Approaches (1940). While Bubenzer and Bolton[48] demonstrated that the multi-spectral component is particularly important at this low-resolution, our research shows that the thermal infra-red bands are particularly significant for the identification of historic trails.

Analysis of the low-resolution Landsat 8 imagery confirmed that potentially historic or

48 Bubenzer and Bolton 2013.



Braided trail leading up to a desert escarpment.

A section of the approach to the same escarpment showing the tracks made by modern wheeled vehicles.

Fig. 5 A comparison of a braided trail (left), like those from animal caravans, and the tracks of modern wheeled vehicles (right) in the 0.4m resolution panchromatic Worldview 2 image (Satellite image © European Space Imaging /Digitalglobe).

ancient routes are difficult to trace using low-resolution satellite imagery in more disturbed areas or those with sandy material.[49] To test methods for identifying trails in high-resolution satellite imagery across disturbed terrain, a 25 km^2 study area of Worldview 2 satellite image no. 1030010-037D58100 from 2014, was obtained, including multi-spectral and panchromatic data.

Identification of the trails in the Worldview imagery was focussed upon their morphology. Bubenzer and Bolton[50] demonstrated that in higher resolution imagery the wiggling linear features visible in the Landsat 8 imagery resolve into groups of individual braided trails that were created as animals spread out widthways along the route, bunching together where the trail crosses steeper or difficult terrain. These braided trails are clearly visible in the panchromatic band of the Worldview 2 imagery and appear quite distinct from the palimpsest parallel lines produced by vehicular trails (Fig. 5), or heavily used modern tracks.

It is possible that the braided appearance of some of these trails is due to motorcycles or repeated vehicular traffic randomly erasing wheel-ruts across a long period of time.[51] Further research will be necessary to confirm the nature of these routes in both the Worldview 2 and Landsat 8 imagery once it is possible to undertake fieldwork in this area.

The multi-spectral bands of the Worldview 2 image were analysed, but they did not provide any additional information beyond the higher resolution panchromatic band. This is consistent with past research, which revealed that at sub-1 m resolutions and on disturbed terrain the resolution of satellite imagery is of greater importance than its multi-spectral component in the identification of anthropogenic trails.[52]

Once trails had been identified in the Landsat 8 and Worldview imagery, these features were cross-referenced with CORONA high (1.8 m) resolution KH-4B satellite photography from 1968 (USGSb)[53] and relevant historic maps to identify

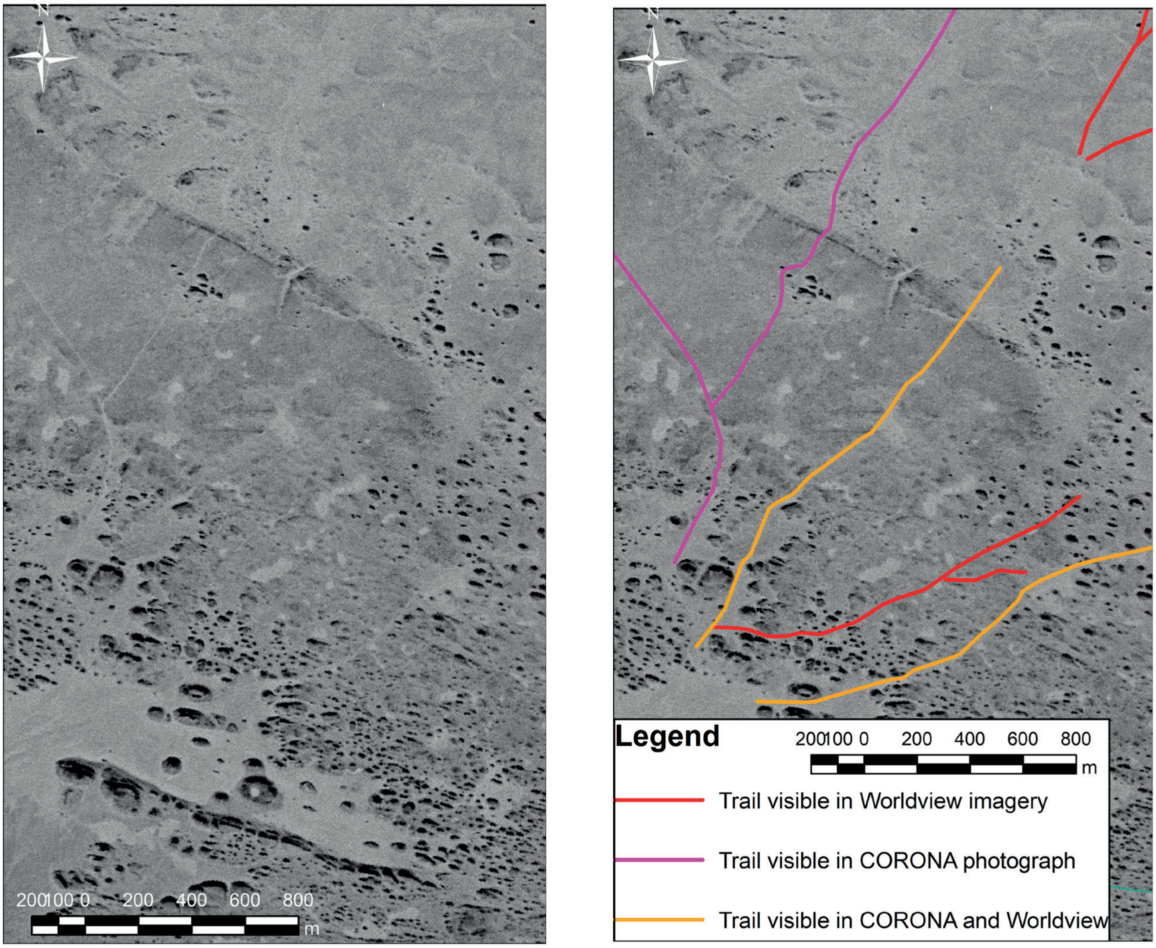
49 previously discovered by Bubenzer and Bolton 2013, 71–72.

50 Bubenzer and Bolton 2013, 65–68, and fig 4.

51 Salima Ikram pers comm.

52 Bubenzer and Bolton 2013, 66; De Laet et al. 2015, 289; Dore and McElroy 2011, 15.

53 Downloaded from the University of Arkansas Centre for Advanced Spatial Technologies CORONA Atlas of the Middle East (http://corona.cast.uark.edu, last accessed 25 September 2018).



CORONA 1968 KH-4B satellite photograph of the eastern part of the Worldview study area, showing the varied desert surface.

The same CORONA photograph overlaid with potentially historic or ancient trails identified in the Worldview and CORONA imagery.

Fig. 6 CORONA KH-4B satellite photograph ds1105-1090df028 showing the variable visibility of trails in the eastern part of the Worldview study area and the two additional historic trails identified in the western part of the study area from the CORONA photograph (CORONA data available from the U.S. Geological Survey).

which trails were modern and which had a longer history. This comparison was undertaken after the analysis of the satellite imagery had been completed to prevent confirmation bias.

Comparison with CORONA (HP)

Comparison of the Landsat 8 and Worldview imagery with CORONA photographs, which do not have a multi-spectral component, further emphasised the importance of multi-spectral data in the identification of desert trails, particularly at low-resolutions. Although CORONA KH-4B photographs are of much higher resolution than the Landsat 8 imagery, it was only possible to locate the trails in the CORONA photographs after they had been initially identified in the Landsat 8 and Worldview imagery. The trails were often indistinct and ranged from very clear to almost invisible in the CORONA photographs (Fig. 6). The absence of a trail from the CORONA photographs when it is present in the Landsat 8 imagery is highly suggestive of modernity, although it cannot be taken as conclusive evidence, because of the different techniques used to record the landscape in the Landsat and CORONA imagery and variation in how clearly trails appear in the latter. The absence of a trail from the CORONA imagery that is present in the Worldview imagery is an even less reliable indicator of modernity since the

Worldview imagery is higher resolution than the CORONA imagery and covers a highly variable desert surface, where trails might easily be obscured from CORONA satellite photographs due to adverse environmental conditions.

Their variable appearance made the trails difficult to distinguish in the CORONA photographs, so CORONA was primarily used for dating known trails rather than discovering new ones. Two trails were identified in the CORONA photographs that had not been visible in the Worldview imagery because they were obscured by modern activity (Fig. 6). Their location and probable date will be discussed below, with the rest of the Worldview imagery.

Comparison with Historic Maps (HP)

To improve understanding of the trails visible in the Landsat 8 and Worldview imagery, they were compared with accessible historic maps of the area between Bahariya and the Nile, including: the Survey of Egypt 1:100,000 Normal Desert Series sheets 62/42 Bahariya Approaches (1940) and 62/49.5 Darb el-Bahnasawi (1941);[54] the British War Office World 1:500,000 Series 1404 Sheets El-Bawiti 448-C (1956) and Suez 447-D (1956); the US Army Map Service 1:250,000 Series P502 Sheets Bahariya Oasis NH 35–16 (1941) and El-Minya NH 36–13 (1960); and the Tactical Pilotage Chart 1:500,000 scale World Series Sheet H-5 A (Compiled 1972, revised 1999).[55]

These maps confirmed that the features identified in the Landsat 8 and Worldview imagery were a series of trails crossing the desert between Bahariya Oasis, the Faiyum and the Nile, which were present by the mid-20th century. The maps also provided additional information about modern features in the satellite imagery and confirmed the anticipated routes of the trails beyond the areas where they were visible in the satellite imagery.

Results (HP)

Eight features appear in the Landsat 8 imagery as fine lines wandering across the northern section of the Egyptian Limestone Plateau (Fig. 7). These were identified as potentially historic and/or ancient routes because their appearance is consistent with the historic and/or ancient routes recorded by Bubenzer and Bolton[56] in imagery of a similar resolution.

All eight of these features were subsequently identified as historic trails and are present in CORONA satellite photography from 1968 and historic maps dating from 1940–1941. The northernmost trail in the Landsat 8 imagery (Fig. 7), is the best candidate for the Roman route between Bahariya and Faiyum, attested in written sources, and a potential Pharaonic predecessor, suggested by archaeological evidence. In the satellite imagery the trail heads directly towards the Wadi Rayyan, a stopping place on the historic route between Bahariya and the Faiyum, and if projected northeastwards it would reach the Faiyum oasis around the Middle Kingdom town of Medinet Maadi. Westwards, this route would join up with the north-eastern extension of the Bahariya depression at Ayn el-Bahariya.

This northern trail in the Landsat 8 imagery aligns almost exactly with the Darb el-Rayyan as recorded running from Ayn el-Bahariya to the area of Medinet Maadi on the Survey of Egypt 1:100,000 Normal Desert Series sheets 62/42 Bahariya Approaches (1940) and 62/49.5 Darb el-Bahnasawi (1941), and the British War Office World 1:500,000 Series 1404 Sheet El-Bawiti 448-C (1956). The US Army Map Service 1:250,000 Series P502 Sheet El-Minya NH 36–13 (1960) shows a secondary trail (Darb el-Wahat) leaving the Darb el-Rayyan and following the southern edge of the Faiyum depression. It follows the same line as the proposed extension of the Darb el-Rayyan to Gurob (Fig. 7), strengthening the case for the inclusion of Gurob in these ancient trading routes.

To the south of the Darb el-Rayyan, the next four historic trails visible in the Landsat 8 imagery are also present on the Survey of Egypt 1:100,000 Normal Desert Series sheets 62/42 Bahariya Approaches (1940) and 62/49.5 Darb el-Bahnasawi (1941). They are named from north to south: the Darb As’as branching off the Darb el-Rayyan towards the Nile at Maghaga; the Darb el Masudi, from Ayn el-Bahariya and Ayn el-Harrah to El-Sheikh Masud north of El-Bahnasa in the Nile val-

[54] Survey of Egypt maps downloaded from the University of Chicago Centre for Ancient Middle Eastern Landscapes (CAMEL) integrated database.

[55] British War Office World 1:500,000 Series 1404, US Army Map Service and Tactical Pilotage Charts downloaded from the University of Texas Libraries map collection.

[56] Bubenzer and Bolton 2013.

ley; the Darb el-Bahnasawi from Ayn el-Harrah to El-Bahnasa in the Nile valley; and the Darb el-Rubi, from the south end of the Ayn el-Harrah depression to the Nile valley at El-Rubi (Kom el-Rahib). Running along the same approximate alignment as the Darb el-Rubi is a disused railway, that was already dismantled when recorded in 1940/1.

South of the Darb el-Rubi three further trails are visible in the Landsat 8 and are recorded but not named on the British War Office World 1:500,000 Series 1404 Sheet Suez 447-D (1956).

The Landsat 8 image was too low-resolution for these trails to be traced in the disturbed and sandy areas close to Bahariya and Faiyum, but a 25 km^2 study area of Worldview 2 high-resolution multi-spectral imagery revealed that trails can be identified in broken or disturbed terrain using high-resolution imagery. The 25 km^2 was located at the Bahariya end (Fig. 7) of the Bahariya-Bah-

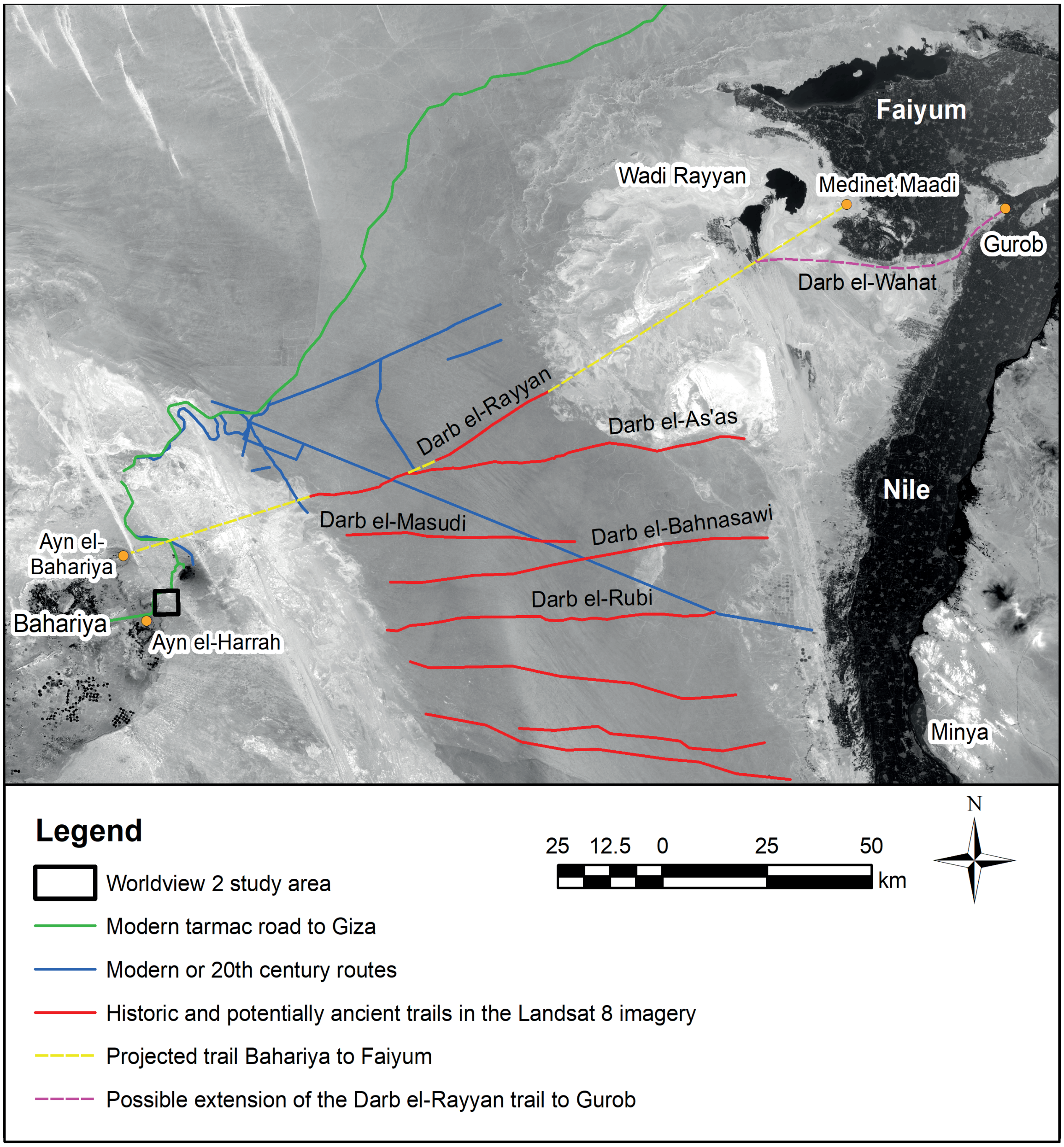


Fig. 7 Routes visible in the Landsat 8 image LC81770402013078LGN01 and the projected route of the Darb el-Rayyan Bahariya to Faiyum trail (Landsat data available from the U.S. Geological Survey).

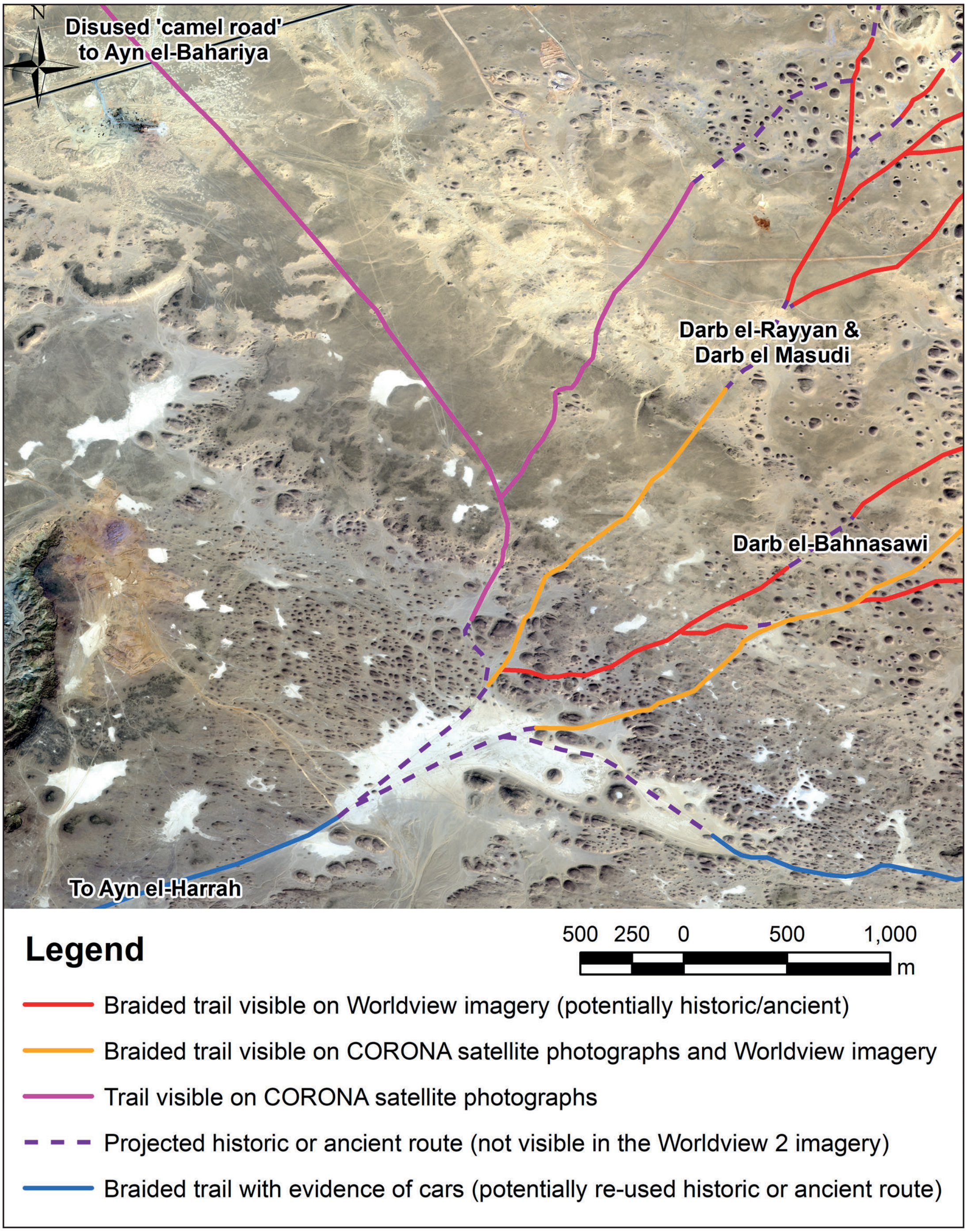


Fig. 8 Potentially historic and/or ancient trails identified in the high-resolution Worldview 2 image in the desert east of Bahariya. Ayn el-Harrah is located to the south-west of the image. The modern tarmac road is visible in the north-western corner of the image and various other modern trails are visible as lighter lines (Satellite image © European Space Imaging /Digitalglobe).

nasa (now Minya) route because the evidence suggested that this route was much more heavily travelled than the Bahariya-Faiyum route,[57] producing a greater impact upon the physical landscape and making the trail more likely to appear in the satellite image.

[57] Giddy 1987, 15–16; Fakhry 2003, 24–25.

Modern road construction and other activities have substantially altered the surface of the desert on the western side of the 25 km^2 study area, closest to the oasis, so most of the trails were identified in the better-preserved desert surface towards the eastern and southern parts.

Following visual examination of the Worldview 2 imagery, 12 potentially historic or ancient trails were identified. A further 2 trails showed evidence of both wheeled vehicles and the braided trails, suggesting they have potentially historic or ancient origins (Fig. 8) but have been re-used in recent times.

Comparison of the Worldview 2 imagery and CORONA satellite photography from 1968 revealed a further two trails on the west side of the Worldview study area (Fig. 6 and Fig. 8), which had been obscured by modern traffic in the Worldview image. The CORONA photograph demonstrated that these trails were older than the modern disturbance which obscured them. The more westerly of the two trails, heading north-west towards Ayn el-Bahariya, is marked on the British War Office World 1:500,000 Series 1404 Sheets El-Bawiti 448-C (1956) and may be the 'camel road' between Lyons Hills and Ayn el-Bahariya shown on the Survey of Egypt 1:100,000 Normal Desert Series sheets 62/42 Bahariya Approaches (1940).

The mid-20th century maps broadly confirm the historic nature of 13 of the 14 trails identified in the Worldview imagery. The maps all show trails rising up the escarpment from Ayn el-Harrah and heading in three directions. One trail heads eastwards to the Darb el-Bahnasawi, one goes north-east towards the Darb el-Rayyan and Darb el-Masudi and one turns north-west towards Ayn el-Bahariya. However, the historic maps show a single trail in each of these directions, rather than the branching trails identified in the Worldview 2 image. It is possible that some of the branches are more recent deviations from an original route, but it is more likely given the scale of the maps that the mid-20th century cartographers chose to show the general direction of the route, rather than the individual branching trails that are visible in the Worldview image.

Evidence from the CORONA satellite photography is somewhat ambivalent concerning the trails identified in the Worldview imagery. On the east side of the Worldview study area the terrain is broken. Combined with CORONA's resolution of 1.8 m, this makes it difficult to conclusively identify any but the three largest trails in the CORONA photograph. The apparent absence of the other trails from the CORONA photographs may indicate that they are more recent than 1968, but it is more likely to reflect a lower level of usage or environmental conditions that effectively obscured the faint traces from the satellite's cameras.

Only one of the trails identified in the Worldview imagery is completely absent from the historic maps. It may be a more modern feature, as it is one of the two with evidence of wheeled vehicles, but it might also be a less significant or local trail, that was not important enough to be included in the maps. Strangely, this feature is slightly clearer in the CORONA satellite photography than certain other trails in the Worldview study area, but this may reflect a differential contrast between the trails and the desert surface rather than differences in date.

It is clear from the historic maps (Fig. 9) that the trails identified in the Worldview imagery comprise the western end of those visible in the Landsat 8 data. Most of the 13 historic trails in the Worldview 2 imagery join up with those heading eastwards towards the Middle Egyptian Nile valley at Masudi or Bahnasa, although the historic maps indicate that the Darb el-Rayyan and Ayn el-Bahariya could also be reached from Ayn el-Harrah.

The successful identification of 13 trails and three historic routes despite the extensive disruption of the desert surface within the Worldview study area, demonstrates that the same techniques which enabled Bubenzer and Bolton[58] to identify trails across the Egyptian Limestone Plateau can be successfully applied to more disturbed and sandy areas, provided the remotely sensed imagery is of sufficiently high-resolution. The investigation of additional high-resolution satellite imagery along the Bahariya – Faiyum route, is a priority in the next stage of this research as it will enable us to map the trails in more detail and improve understanding of the termini, including the Ayn el-Bahariya end of the Darb el-Rayyan.

Both high and low-resolution elements of the satellite imagery will make a valuable contribution to future research. By using low-resolution free Landsat imagery to record routes where this is appropriate to the terrain, it will be possible for high-resolution satellite imagery to be concentrat-

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58 Bubenzer and Bolton 2013.

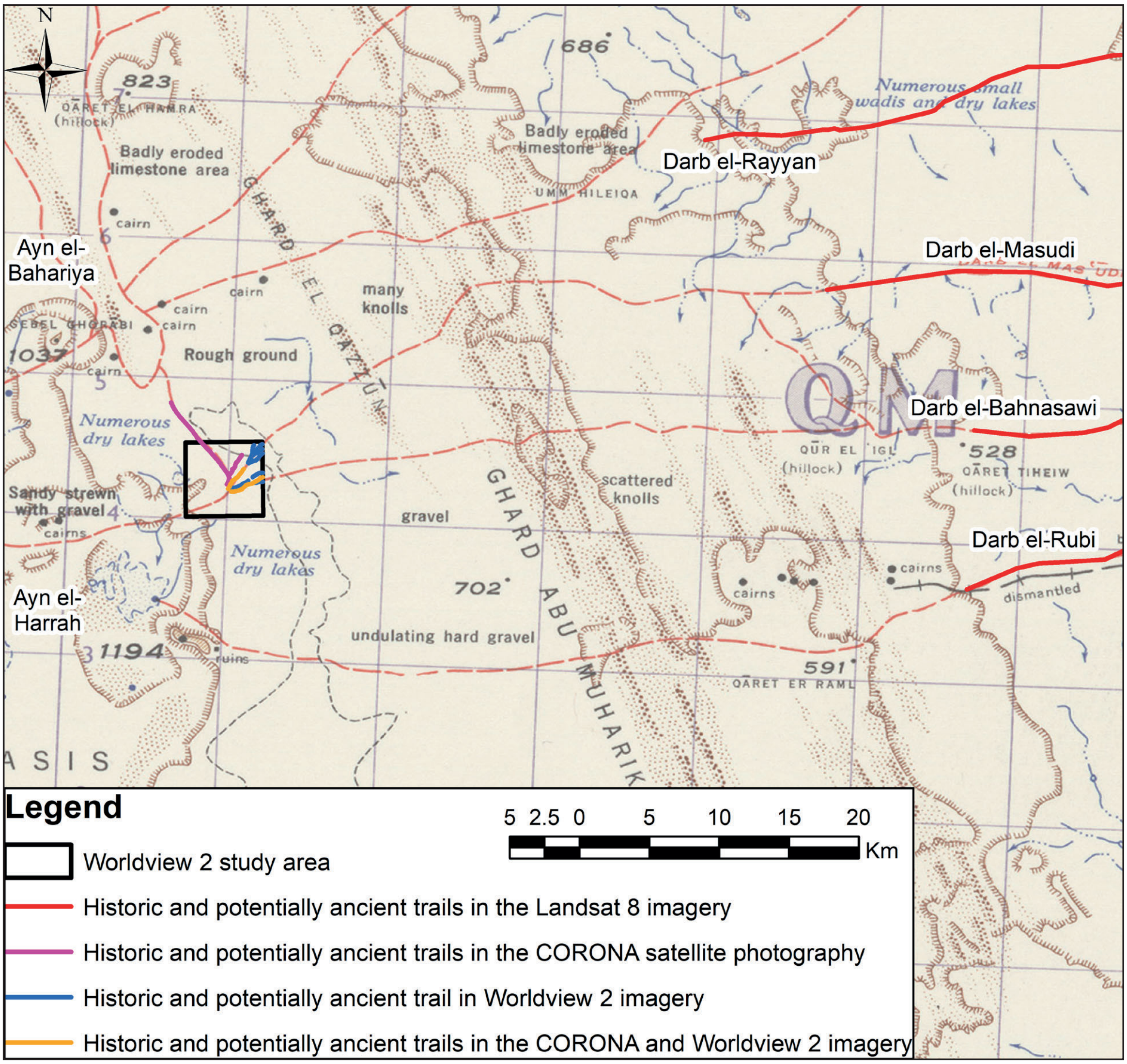

Fig. 9 Historic and potentially ancient routes between Bahariya and the Nile valley from the satellite imagery overlaid on the British War Office World 1:500,000 Series 1404 Sheet El-Bawiti 448-C (1956) (Landsat data available from the U.S. Geological Survey. Historic map downloaded from the University of Texas Libraries).

ed upon areas where trails are difficult to identify, or routes are in doubt.

All the trails identified in the Landsat 8 and Worldview 2 imagery will require ‘ground-truthing’ to confirm their nature and provide dating evidence, but this will be considerably easier with the information from the satellite imagery to guide the fieldwork. Furthermore, as much more of each route can be located in the satellite imagery than could be surveyed in a single field season, during the fieldwork it will be possible to concentrate upon dating the trails and investigating particularly interesting or significant archaeological remains along them.

Conclusion (VG and HP)

A late antique route between Bahariya and the Faiyum is described in written sources and confirmed by archaeological evidence. Ceramic and other archaeological evidence suggest that this route may be a much earlier Pharaonic creation, prior to the New Kingdom, with Faiyumi termini at Medinet Maadi, and possibly Gurob.

By combining low and high-resolution satellite imagery, validated by comparison with CORONA photography and historic maps, this research has identified a series of historic and potentially ancient routes running across the desert between

Bahariya and the Nile valley. The northernmost of these routes is identifiable as the historic Darb el-Rayyan shown on historic maps heading north-east from Ayn el-Bahariya towards Wadi Rayyan and arriving in the Faiyum close to the Middle Kingdom and later town of Medinet Maadi. This route is very likely to have been used as early as the Greco-Roman period and its trajectory and terminus close to Medinet Maadi might imply that it has 18th Dynasty, or earlier, antecedents.

Confirmation of the precise route of the Ayn el-Bahariya – Faiyum trail on the ground, its termini and date must await further study of additional satellite imagery and fieldwork, but the archaeological and historical evidence and the results from two different types of satellite imagery are remarkably consistent. The satellite imagery also provides a valuable starting point for further remote-sensing research and fieldwork that will hopefully confirm these conclusions.

This research has also demonstrated that the techniques pioneered by previous studies[59] for both low and high-resolution satellite imagery are applicable beyond the areas in which they were first tested and can be successfully combined to address differences in terrain along a route: low-resolution multi-spectral imagery in areas of open, consistent desert surfaces (such as the Egyptian Limestone Plateau) with minimal disturbance, combined with very high-resolution imagery in disturbed areas or with highly variable natural surfaces. In addition to confirming past discoveries regarding the importance of resolution in the identification of desert trails in disturbed areas, and of multi-spectral data at lower resolutions, we discovered that the thermal infra-red multi-spectral bands are particularly useful in identifying trails at low-resolutions.

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59 Bubenzer and Bolton 2013, 65–68; De Laet et al. 2015, 289.

Bibliography

Barich, B.E., Lucarini, G., Hamdan, M.A. and Hassan, F.A. (eds.)

2014 *From Lake to Sand: The Archaeology of Farafra Oasis Western Desert, Egypt*. Rome.

Bubenzer, O., and Bolton A.

2013 'Top down: New satellite data and ground-truth data as base for a reconstruction of ancient caravan routes. Examples from the Western Desert of Egypt', in: F. Förster and H. Riemer (eds.), *Desert Road Archaeology in Ancient Egypt and Beyond* (Africa Praehistorica 27), 61–76. Köln.

Cestari, I.

2010. *Villaggi dell'Antico Egitto III*. Imola.

Chadefaud, C.

1982 *Les statues porte-enseignes de l'Égypte ancienne (1580–1085 avant J.C.). Signification et insertion dans le culte du Ka royal*. Paris.

Colin, F.

2011 'Le «Domaine d'Amon» à Bahariya de la XVIIIe à la XXVIe dynastie: l'apport des fouilles de Qasr 'Allam', in: D. Devauchelle, (ed.) *La XXVIe dynastie continuités et ruptures. Promenade saïte avec Jean Yoyotte. Actes du Colloque international organisé les 26 et 27 novembre 2004 à l'Université Charles-de-Gaulle – Lille 3*. 49–50. Lille.

2012 *Bahariya I. Le fort romain de Qaret el-Toub I* (Fouilles de l'Institut Français d'Archéologie Orientale 62). Paris and Cairo.

Darnell, J. and Darnell, D.

2013 'The archaeology of Kurkur Oasis, Nuq' Maneih, Bir Nakheila and Sinn el-Kiddab', in: D. Raue, S. J. Seidlmeyer, P. Speiser (eds.), *The First Cataract: One Region, Various Perspectives,* SDAIK 36, 35–52. Cairo.

Darnell, J. and Manassa-Darnell, C.

2016. 'Umm Mawagir in Kharga Oasis: An industrial landscape of the late Middle Kingdom/ Second Intermediate Period', in: G. Miniaci, W. Grajetski, (eds.), *The World of Middle Kingdom Egypt (2000–1500 BC) Volume II*. 27–70. London.

De Laet, V.; van Loon, G; Van de Perre, A.; Deliever I. and Willems H.

2015 'Integrated remote sensing investigations of ancient quarries and road systems in the Greater Dayr al-Barsha Region, Middle Egypt: a study of logistics', *Journal of Archaeological Science* 55, 286–300.

Donadoni, S.

1952 'Nuovi testi da Medinet Madi', *Prolegomena* 1, 9–10.

Dore, C.D. and McElroy, S.A.

2011 'Automated trail identification and mapping: an experiment in archaeological spectral-image analysis using commercial high-resolution satellite remote-sensing data', *Archaeological Practice: A Journal of the Society for American Archaeology,* 12–18.

Dospel, M. and Sukova L. (eds)

2013 *Bahariya Oasis. Recent Research into the Past of an Egyptian Oasis*. Prague.

Eichhorn, B.; Hendrickx, S.; Riemer, H.; and Stern B.

2005 'Desert roads and transport vessels from late Roman – Coptic times in the Eastern Sahara', *Journal of African Archaeology* 3(2), 213–229.

Fakhry, A.

1974 *The Oasis of Egypt: Volume 2: Bahriyah and Farafra Oasis*. Cairo.

2003 *Bahriyah and Farafra*. 2nd Edition. Cairo and New York.

Förster F. and Riemer, H. (eds.)

2013 *Desert Road Archaeology in Ancient Egypt and Beyond* (Africa Praehistorica 27). Köln.

Förster, F., Riemer, H., Mahir, M. and Darius F.

2013 'Donkeys to El-Fasher or how the present informs the past' in: F. Förster and H. Riemer (eds.), *Desert Road Archaeology in Ancient Egypt and Beyond* (Africa Praehistorica 27). 193–220. Köln.

Friedman R. (ed.)

2002 *Egypt and Nubia. Gifts of the Desert*. London.

Gasperini, V.

2014 Mycenaean and Cypriot Pottery from Gurob in the Manchester Museum Collection: a test of trade network theories for the New Kingdom Fayum, *Journal of Ancient Egyptian Interconnections* 6:2.

Giddy, L.

1987 *Egyptian Oasis: Bahariya, Dakhla, Farafra and Kharga during Pharaonic times*. London.

Gomaà, F.

1973 *Chaemwese, Sohn Ramses' II und Hoherpriester von Memphis*. Wiesbaden.

Köpp, H.

2013 Desert travel and transport in Ancient Egypt: An overview based on epigraphic, pictorial and archaeological evidence, in: F. Förster, and H. Riemer, (eds.), *Desert Road Archaeology in Ancient Egypt and Beyond* (Africa Praehistorica 27) 107–132. Köln.

Lacovara, P.

1997 *The New Kingdom Royal City*, London and New York.

Lillesand, R., Kiefer, R. and Chipman, J.

2004 *Remote Sensing and Image Interpretation*. New York.

Loat, L.

1904 *Gurob*. London.

Marangou, A., and Marchand S.

2007 Conteneurs importés et égyptiens de Tebtynis (Fayoum) de la deuxième moitié du IVe siècle av. J.-C. au Xe siècle apr.J.-C. (1994–2002), *Cahiers de la Céramique Égyptienne* 8, 239–275.

Marchand, S.

2012 Prospection céramique de 2010 des environs du site de Dimeh (Fayoum). *Bulletin de Liaison de la Céramique Égyptienne* 23, 63–76.

Marchand, S. (ed.)

In press La céramique du désert Occidental égyptien de la fin du Néolithique à l'époque médiévale. La Marmarique, et les oasis de Bahariya, Dakhla et Kharga, *Cahiers de la Céramique Égyptienne* 11. Cairo.

Marchand, S., and Tallet P.

1999 Ayn Asil et l'oasis de Dakhla au Nouvel Empire. *Bulletin de l'Institut Français d'Archéologie Orientale* 99, 307–8.

Moeller, N.

2016 *The Archeaology of Urbanism in Ancient Egypt: From the Predynastic period to the end of the Middle Kingdom*. Cambridge.

Parcak, S.

2009 *Satellite Remote Sensing for Archaeology*, Abingdon and New York.

Petrie, W.M.F.

1890 Kahun, Gurob and Hawara. London.

Rose, P. J.

2007 *The Eighteenth Dynasty Pottery Corpus from Amarna (*Egypt Exploration Society Memoirs 83). London.

Serpico, M.

2008 'Gurob' in J. Picton – I. Pridden (eds.), *Unseen Images: Archive Photographs in the Petrie Museum: Gurob, Sedment and Tarkhan: 1*, London.

Shaw, I.

2011 Seeking the Ramesside royal harem: new fieldwork at Medinet el-Gurob, in: M. Collier and S. Snape (eds.), *Ramessid Studies presented to Prof. Kenneth Kitchen*, Bolton 2011, 453–63.

Sourouzian, H.

1989 *Les monuments du roi Merenptah*. Cairo.

1991 The Statues of King Merenptah, in: B. Bleiberg and R. Freed (eds.) *Fragments of a Shattered Visage. The Proceedings of the International Symposium on Ramesses the Great, Memphis, Tennesse*, 226–35. Tennessee.

Thomas, A.P.

1981 *Gurob: A New Kingdom Town*, Egyptology Today 5, 2. Warminster.

USGSa *Landsat Eight*. Available at http://landsat.usgs.gov/landsat8.php (accessed 21 November 2016).

USGSb *Declassified Satellite Imagery – 1*. Available at https://lta.cr.usgs.gov/declass_1 (accessed 30 August 2018).

Van Siclen, C.

1981 *Wall Scenes from the Tomb of Amenhotep (Huy), Governor of Bahria Oasis.* San Antonio.

Vogliano, A.

1937 *Secondo rapporto degli scavi condotti dalla Missione Archeologica d'Egitto della R. Università di Milano nella zona di Medinet Madi*. Milano.

Wagner, G.

1987 *Les Oasis d'Égypte à l'Époque Grecque, Romaine et Byzantine d'après les Documents Grecs*. Cairo.

Yoyotte, M.

2012 *Le "Harem" dans l'Égypte Ancienne. Enquête Philologique, Archéologique et Prosopographique*, PhD diss., La Sorbonne University, Paris.

Zecchi, M.

2001 *Geografia Religiosa del Fayyum. Dalle origini al IV secolo a.C.* Imola.