LANDSCAPES OF IRRIGATION IN THE PTOLEMAIC AND ROMAN FAYUM: INTERDISCIPLINARY ARCHAEOLOGICAL SURVEY AND EXCAVATION NEAR KOM AUSHIM (ANCIENT KARANIS), EGYPT

by

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ABSTRACT

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The ancient irrigation of the Fayum region of Egypt is known principally from the documentary evidence preserved on papyrus. This study examines one part of the Graeco-Roman (ca. 332 BCE – 400 CE) irrigation system of the Fayum from diachronic, comparative and interdisciplinary archaeological perspectives. The only previous detailed archaeological fieldwork on an irrigation system in the Fayum was the pioneering study undertaken by G. Caton-Thompson and E. Gardner in the 1920s.

Archaeological survey and excavation conducted by the author on the irrigation system near the ancient site of Karanis (modern Kom Aushim) uses innovative methodologies developed by archaeologists around the world and forms the basis for independent reassessment of their important contributions. In addition, newly-discovered segments of the irrigation system are presented and interpreted in the

context of the landscape. From an archaeological perspective, the hinterland to the north of Karanis emerges as a dynamic landscape occupied over a long period rather than a marginal and short-lived part of an agricultural expansion scheme undertaken by the Ptolemies. The result of this innovative fieldwork is to move beyond interpretation of the Graeco-Roman irrigation system of the Fayum based upon a single type of evidence.

Chapter One: Introduction

> The season for the building up of the dykes and the cleansing of the canals having arrived... Therefore let it be the care of you, the *strategoi* and *dekaprotoi*, both to urge all to devote themselves to this most necessary labour, and to see that the overseers usually elected for the purpose are chosen from magistrates or private persons, who will compel every one to perform his proper work by personal service... so that the dykes are raised to the ordained height and breadth and the breaches are filled up, in order that they may be able to withstand the flood of the most sacred Nile auspiciously approaching... If anyone dare to attempt exactions or neglect these orders, let him know that not only his property but his life will be at stake for injuring measures designed for the safety of the whole of Egypt.[1]

It has long been recognized that a massive, man-made irrigation system supplied water to the Fayum region during the period of Greek and Roman hegemony in Egypt (ca. 330 BCE – 400 CE). This irrigation system had a profound impact on the agricultural exploitation of the Fayum region and on its inhabitants. Most of our knowledge of this important landscape feature has, however, been derived from ancient Greek texts on papyrus, rather than from the physical remains of the irrigation system itself. This dissertation attempts to provide a more balanced study of one section of the ancient irrigation system near the site of Karanis (modern Kom Aushim) in the Fayum using both

[1] Circular from the *dioiketes*, Ulpius Aurelius, to the *strategoi* and *dekaprotoi* of the Heptanomia and Arisinoite Nome, 278 CE. Adapted and abridged from *Select Papyri* II.225 = *P.Oxy*. XII.1409.

archaeological and papyrological evidence. It also argues for a reinterpretation of these landscape features from alternative perspectives in order to formulate fresh conclusions concerning their role throughout the history of Egyptian society. Although ancient canals were major projects requiring significant resources and considerable effort to construct, they remain poorly understood and under-described in comparison with other monumental constructions, such as stone architecture. Ultimately, the goal is not only to describe the irrigation system(s) of one part of Graeco-Roman Egypt, but to use the ever-increasing archaeological literature on the study of canals from around the world to place these monumental Egyptian constructions in a broader context and to address social and economic questions concerning life in the ancient Fayum.

Before proceeding, however, it is necessary to acknowledge certain structural issues which have limited the study of irrigation systems in ancient Egypt.

A History without Archaeology

> For the Hellenistic age, a heavy reliance on textual evidence, and principally Greek textual evidence at that, long tilted scholarly perspectives on the Hellenistic *oikoumene*... We once perceived that world as fundamentally transformed by the arrival of Hellenic culture, as deeply divided from whatever had come before, as a newly created and somehow homogeneous entity... It is not news to announce that such perspectives are, to a great extent, misguided, and that (to present-day eyes) they appear the somewhat absurd product of a particular and limited reading of a particular and limited body of evidence.[2]

[2] Alcock, et al. 2003: 354.

Archaeology is providing an ever-increasing new body of information about all aspects of life in Graeco-Roman Egypt. However, the little archaeological work that has been done on the irrigation system of the Graeco-Roman Fayum has been virtually ignored in recent research on agriculture and canals in Egypt in favor of the data provided by the documentary record. This traditional emphasis on the textual evidence, and particularly the Greek evidence, has had a major impact on the study of canals in Egypt in several fundamental ways: by circumscribing the geographical areas and chronological periods worthy of study, by dividing those periods between different academic disciplines, and by limiting the types of questions that academic discourse brings to bear on the evidence.[3]

Greek Papyri from the Fayum

While some Egyptian papyri were recovered as early as the eighteenth century, the main period of discovery occurred in the late nineteenth and early twentieth centuries.[4] A number of treasure hunters and early Classical archaeologists dedicated their fieldwork to the recovery of these documents and quickly discovered that certain sites in certain regions were more easily harvested. For example, the peripheral villages of the Fayum had not been inhabited since late antiquity and were thus easily accessible, while the dry conditions along the desert fringe in that area maintained papyri in a remarkable state of preservation. They were also selected for excavation on the basis of

[3] Undoubtedly, these factors have additional, as yet unrecognized, implications for the study of ancient Egypt.
[4] Cuvigny 2009. A brief history of the emergence of papyrology as a discipline is given in Turner 1980: 17-41.

their “classical” status, which ensured the presence of Greek, rather than Egyptian texts.[5]

The uneven preservation of documents across Egypt has combined with the localised activity of early and modern researchers and resulted in a number of peculiar chronological, geographical, and cultural biases in the available evidence.[6] First, significant numbers of documentary papyri are preserved only from the early Ptolemaic period onwards — the record is much more scattered in earlier periods, for the most part. This fact has made it much more difficult for scholars to study the preceding period and to assess issues of continuity and change between the Dynastic and Graeco-Roman periods.[7] There is also considerable chronological variation in the quantity of evidence available within the Graeco-Roman period itself; the bulk of the Greek documents originate in the 2nd to 4th centuries CE.[8] This imbalance can sometimes give the superficial impression that what was common at one moment was indicative of the entire Graeco-Roman period. It can also suggest that individual features, such as the Fayum irrigation system, were Greek innovations because there is no earlier textual evidence for their existence, although scholars are becoming more and more aware of the difficulties inherent in these types of assumptions.[9]

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[5] Conversely, the first major European investigation of Egypt, under the direction of Napoleon Bonaparte, collected only Egyptian texts, see Cuvigny 2009: 30-1.
[6] Bagnall 1995: 26-9; Habermann 1998; Gagos and Potter 2006: 60-1.
[7] Hobson 1988; Bagnall 1995: 68-72.
[8] Habermann 1998.
[9] Hobson 1988; Keenan 1991; Bagnall 1995: 68-72.

Second, papyri have not been recovered evenly from across the landscape of Egypt.[10] Owing in part to differential preservation at various sites, the size and importance of particular sites in each period, and the choice of sites by the early excavators, some areas have yielded far more documents than others. Thus, the great volume of documents originating in the Fayum compared to other regions gives an exaggerated sense of its importance in antiquity, even though most of the documents derive from what are best termed villages, rather than cities.[11] As a result, the Fayum has been the primary focus of agricultural studies and conclusions based on this one, anomalous, region have been traditionally extrapolated to the Nile Valley.[12]

Third, the majority of papyri are written in Greek, the administrative language of Egypt in the Graeco-Roman period.[13] While Greek was commonly used in Egypt at that time, the reality is that, outside the major centers, far and away the majority of the ancient population spoke a late form of the Egyptian language, the written form of which is called Demotic.[14] Yet comparatively few Demotic papyri have been recovered and fewer published. The lower number of Demotic documents is primarily the result of an undeveloped "papyrological habit" among the Egyptian population which may reflect their lower social status during the period, but must have been exacerbated by preservation issues, the early archaeological focus on "classical" sites, and by the

[10] Habermann 1998.
[11] Keenan 1991: 161. For the village versus city controversy in the study of Egypt more broadly, see Eyre 1999 and Lehner 2010, *contra* Bagnall 1995: 69-70.
[12] Thompson 1999a; 1999b; Rathbone 2004; Manning 2005.
[13] Bagnall 1995: 17-22.
[14] For other languages in use in Egypt during the period between the New Kingdom and the Islamic Conquest, and for estimates of literacy rates in the Late Period, see Ray 1994.

privileged status afforded to Greek papyri by scholars with a cultural bias.[15] The relatively low number of published Demotic documentary texts reflects both the small number of Demotists, who occupy an often marginal space in their discipline, and the privileging of certain Demotic textual genres, particularly literature, over others.

While far fewer Demotic documents have survived, those that have survived and been studied have been relegated to a marginal role by scholars of Egypt until quite recently.[16] The exclusion of Demotic documents from discussions of ancient life has not only limited the available evidence for discussing ancient agriculture and irrigation[17], on a broader level it has also reinforced cultural biases concerning the relative importance of imported versus indigenous elements within Egypt.[18] There is now a growing consensus that the evidence concerning the indigenous Egyptian population should be integrated whenever possible into synthetic studies of ancient life in the Fayum and elsewhere.[19]

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[15] Hobson 1988: 356; Cuvigny 2009: 36-7.

[16] Hobson 1988. For an overview of the chronological and spatial distribution of the Demotic evidence, and some of its major interpretive problems, see Tait (1992).

[17] For preliminary attempts to examine the Demotic terminology for irrigation, see Andrews 1994; Bresciani 1994; Manning 1994; 1997.

[18] Ritner 1992. Although the impact of Egypt on Greek culture following the settlement of Greeks under the Pharaoh Amasis has been recognized. "Nonetheless, Greek culture was to be viewed as superior, with a distinctly patronizing attitude toward the locals. Thus, when Bevan briefly notes the presence of Demotic documents, he remarks that they furnish important data for *native* life; the possibility does not occur to him that they could be of importance for the country as a whole, and they play almost no role in his history of Ptolemaic Egypt" (Ritner 1992: 286). See also the comments of Bowersock quoted, *Ibid*.: 288.

[19] Hobson 1988; Heinen 1989; Geraci 1989; Keenan 1991: 163-4; Bagnall 1995: 19-20; Gagos, Gates and Wilburn 2005; Manning 2005. Note the explicit claim that combining Greek and Demotic evidence concerning irrigation would be fruitful, particularly in the Fayum (Vleeming 1998: 508).

The first papyrus to be published by modern scholars, the so-called *Charta Borgiana* (*SB* I 5124), was a Greek document from the Fayum.[20] Published in 1788, the papyrus concerned the maintenance of the Roman period canal system near Tebtynis and initiated the long debate concerning agriculture and irrigation in the Fayum while providing, "...a striking example of the centrality of the subject" of irrigation to the study of the ancient Fayum.[21] It should come as no surprise, then, that the entire history of interpretation of the Fayum irrigation system has become almost inextricably embedded in a series of meta-narratives among papryologists concerning the relative primacy of periods, regions, languages and cultures which date back to the founding of papyrology as a discipline.

Dynastic Egypt and Graeco-Roman Egypt

If disciplinary boundaries based on linguistic and cultural grounds have been difficult to bridge within the Graeco-Roman period, the gulf is much greater between Dynastic Egypt and the Graeco-Roman period.[22] Egyptologists tend to view the Late Period as a pale imitation of the *real* Egypt that came before, while Classicists view Egypt before the Greeks as a completely different and lesser entity and tend to exclude Dynastic evidence from their studies.[23] There seems to be little interaction between the scholars studying these two periods. For Classicists, "The presumption is, of course, that Ptolemaic history

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[20] Donadoni 1983; Capasso 1986-87; and Keenan 2009: 59-60, place the papyrus in its context at the head of the papyrological tradition. The latest edition is Litinas 2007.
[21] Thompson 1996: 43; see also 1999a: 107-8.
[22] Hobson 1988; Keenan 1991; Ritner 1998.
[23] Even a recent work with the stated goal of including the Late and Ptolemaic Periods in Egyptian history was titled *The Twilight of Ancient Egypt* (Myśliwiec 2000).

is *Greek* history; native Egyptian history was dead".[24] The limited communication between the two disciplines has been reinforced by the traditional linguistic and historical education of the respective groups of scholars and by the customary separation of the two in different academic departments.[25]

The remarkable result of these disciplinary boundaries becomes abundantly clear once a long-term approach to a problem is adopted. From a technological perspective, for example, there is a fundamental paradox in the study of ancient canals in ancient Egypt. On the one hand, Dynastic period canals have been considered as a static and underdeveloped technology. Only in exceptional circumstances, as when canals had ritual functions or contributed to monumental construction projects, have they been examined in detail by Egyptological archaeologists.[26] In this interpretation, canals are essentially seen as ditches dug by peasants, remaining unchanged in their design for almost 4000 years and yielding relatively little information.

On the other hand, the Graeco-Roman canals of the Fayum region have been hailed as a technological innovation which required the importation of Greek and Macedonian engineers trained in major lake draining projects in Boiotia and Macedon: "So far the picture has been one of success – an upbeat account of agricultural innovation, experimentation, and Graeco-Macedonian technical expertise transplanted

[24] Ritner 1992: 285.
[25] Bagnall 1995: 19-20.
[26] E.g. Goyon 1971.

to a new country".[27] In this interpretation, the canals of the Fayum are presented as part of a sophisticated and complicated system which could not have been undertaken using the existing Egyptian techniques. But how innovative was this "new" system?[28] This appears to be a conclusion based more upon *a priori* assumptions concerning the cultural role of the Greeks in Egypt than on a careful examination of Dynastic precedents.[29]

In a few cases, however, canal systems are known to have had much longer histories; for example, it is commonly accepted that major construction projects, including irrigation works, at the entrance to the Fayum may have been undertaken by the Pharaohs of the Middle Kingdom.[30] Even if direct evidence for continuity between Dynastic and Graeco-Roman agricultural practices in general remains elusive,[31] it is unlikely that the Ptolemies were the first rulers to undertake large-scale hydraulic schemes in the Fayum and their activities should be interpreted as only one part of a long development of the built landscape over time.

Differences between the types of documentary evidence available in the Dynastic and Graeco-Roman periods have also discouraged the formation of a long-term

[27] Thompson 1999a: 135. "When Alexander the Great of Macedon took Egypt from the Persians in 332 BC, he initiated a foreign regime which was to have an important effect on the landscape and the productive capacity of the country. With him, as later with Napoleon, there came an army of engineers," (Thompson 1996: 42).
[28] A point touched on by Thompson, but without seriously considering the possibility of continuity (1999a: 135), "But what of the other side, of what was old in the picture? How far in the Ptolemaic Fayyum did new and old coexist, or how far did they come into conflict?" See also, Thompson 1996: 45, n.9.
[29] See Chapter Three for a discussion of Ptolemaic "innovation" in the Fayum.
[30] Bell 1975; Garbrecht and Jaritz 1990. But see the discussion of the underlying evidence below, Chapter Three.
[31] Eyre 1994.

view of canal use in Egypt. Using scattered inscriptions and tomb reliefs, studies of Dynastic period canals generally interpret them at a high level of analysis, in terms of state formation, for example.[32] They also tend to stress the introduction of new systems by individual rulers. Studies of Graeco-Roman canals, on the other hand, tend to emphasize a mid-level interpretation in terms of regional and local administration and the maintenance of the irrigation schemes by elites in the *chora*,[33] the main subject matter of the surviving Greek documents.

Canals and Administration

> [Les préoccupations administratives des gouvernements qui se succédèrent à la tête de l'Égypte antique] présupposent une infrastructure, c'est-à-dire un réseau hydraulique, un organisme d'exécution des opérations et un système de contrôle. C'est ce que nous allons étudier; il n'a pas été possible de donner en même temps l'infrastructure géographique du réseau hydraulique de l'Égypte antique, bien que la documentation papyrologique, jointe à la géographie historique, offre de ce point de vue d'énormes moyens de recherche.[34]

The nature of the papyrological evidence has dictated to a great extent the types of questions posed by scholars studying the Graeco-Roman period. By far the majority of the surviving ancient texts record information of political, administrative, legal, or financial import – subjects which were of sufficient importance to individuals or corporate entities to be written down.[35] This, of course, leaves major gaps in the available evidence for certain aspects of ancient Egyptian society. It also conditions

[32] Butzer 1976; Schenkel 1994.
[33] E.g. Bonneau 1993; Thompson 1981; 1996; 1999a; 1999b; 2007.
[34] Bonneau 1993: 3.
[35] Bagnall 1995: 13-15.

scholars to examine each new text from a traditional viewpoint within the evidence and to focus on the questions which the papyri themselves raise – what has been called the "philological" aspect of the discipline.[36] Recently, there have been increasing calls for a broader approach which encompasses comparative and anthropological models as well as archaeological data in the formation of a holistic picture of ancient Egyptian society, but this approach remains the exception rather than the rule.[37]

A similar preoccupation with the papyrological evidence has affected the interpretation of the ancient irrigation system. As most of the relevant texts are administrative and legal documents, scholars have tended to focus on the organization, administration and maintenance of the irrigation system to the exclusion of other subjects.[38] However, this has not prevented scholars from using the irrigation system as evidence when engaging with additional topics. For example, canals have been deployed in debates concerning demography, taxation, land tenure, and the abandonment of the Fayum villages in late antiquity,[39] almost entirely on the basis of the papyrological record.

The fundamental problem is that canals in Egypt have been understudied archaeologically and virtually nothing is known about them that was not known 50 years

[36] Bagnall 1995: 71-2, 90-108.
[37] Hobson 1988; Keenan 1991: 162, 164; Gagos, Gates, and Wilburn 2005.
[38] E.g. Sijpesteijn 1964; Bonneau 1993; Thompson 1996.
[39] E.g. Boak 1955; van Minnen 1995; Pollard 1998; Keenan 2003; Manning 2003.

ago. Comparative approaches are lacking, and there has been little attempt to explore the irrigation systems of the Fayum, or of any other part of Egypt, archaeologically.[40]

Archaeological fieldwork on the Graeco-Roman period canals of the Fayum has the potential to provide an important complement to the rich textual record from the region. However, any study must consider the biased nature of the papyrological evidence and attempt to include both the Greek and the Demotic sources. Only a synthetic study combining documentary and artifactual evidence could expand beyond the traditional disciplinary and chronological boundaries to form a holistic, diachronic, and interdisciplinary study of canals in the Fayum.[41]

Egypt: An Archaeology of Temples and Tombs

> Egypt has fallen victim to its extraordinary archaeological riches and is undoubtedly one of the least well excavated of the ancient Mediterranean cultures.[42]

Archaeology offers an additional avenue through which to examine ancient irrigation agriculture, but this source has not been exploited to its potential in Egypt. There are several structural and historical reasons for this omission. First, there has been a general lack of communication between archaeologists, historians, and papyrologists. Second, the traditional disciplinary boundaries between Egyptologists and Classical scholars, well

[40] Despite a recognition by some scholars that papyri are only one type of evidence and don't tell the whole story: "...whereas there are some aspects which papyri can illuminate, the overall picture is not to be found in the scraps that survive" (Thompson 1999a: 109). Note also the suggestion that selective excavation of the canal system could supplement the picture in Rathbone 1996: 52-3.
[41] Keenan 1991: 162, 164; Gagos, Gates, and Wilburn 2005.
[42] Cuvigny 2009: 38.

known in textual studies (see above), exist also between Egyptological archaeologists and Classical archaeologists. Third, archaeologists who work in Egypt have remained relatively isolated from the broader archaeological community and many have not engaged with methodological and theoretical debates occurring elsewhere. These limitations have combined to restrict the impact of archaeology on the study of Graeco-Roman Egypt and, specifically, to hinder the study of irrigation systems in Egypt, particularly in the Fayum.

Historians, Papyrologists, and Archaeologists

> Subservience to the demands of history is even more evident in those cases where the practice of archaeology is explicitly directed at the recovery of ancient written materials. Here archaeology ceases to be a discipline in its own right and serves merely as a producer of texts to be consumed by historians and philologists. *They* then write history. This demonstration of abject subservience seems to be a feature of the early history of historical archaeologies in, for example, Mesopotamia, the Mediterranean and China, but is not just a relic of the past.[43]

Historians and archaeologists have had very different approaches to the study of the ancient world, in part due to the nature of the sources at their disposal. The (seemingly) contradictory and mutually exclusive discourses of the disciplines, reinforced by traditional academic boundaries and educational curricula, have been lamented frequently and have been the subject of numerous attempts at reconciliation.[44] However, the primacy of the written word as a source in western scholarship has often

[43] Moreland 2001: 18.
[44] E.g. Bintliff and Gaffney (eds.) 1986; Andrén 1998; Moreland 2001; Sauer (ed.) 2004.

made archaeology subservient to history in the interpretation of the past.[45] Despite significant progress in recent years,[46] the relationship between history and papyrology (the main historical discipline of the Graeco-Roman period in Egypt) on the one hand, and archaeology on the other, remains strained.

The lack of communication between history and archaeology in the study of ancient Egypt is evident at all levels of analysis.[47] Bemoaning the lack of cooperation between the two disciplines, one papyrologist has gone so far as to propose several reasons for the apparent indifference of archaeologists to the aims of text-centered scholars.[48] Most importantly, according to Cuvigny, archaeologists are uninterested in the towns of Graeco-Roman Egypt because:

> There is no prestige attached to these sites. Their monuments have been dismantled, Egypt is notoriously poor in Greek or Latin inscriptions, and what is left for the archaeologist are modest mud-brick structures, rubbish dumps with difficult and unrewarding stratigraphies, and overwhelming quantities of commonplace material, not the least of which is pottery.[49]

Furthermore, while papyrologists would be happy to accumulate more texts through excavation, Cuvigny claims that the quest is simply too demanding for the average archaeologist:

> The ungratifying work of analyzing a refuse heap is undoubtedly an important factor in influencing scrupulous archaeologists not to search

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[45] Moreland 2001.
[46] E.g. Gagos, Gates and Wilburn 2005.
[47] *Contra* e.g. Bard 2008: 17-18. "Excavations in Egypt today are multi-disciplinary, requiring the input of many specialists from different disciplines" (17). "Philologists and Egyptologists are needed on excavations of pharaonic sites, and classical scholars on excavations of Graeco-Roman sites" (18).
[48] Cuvigny 2009.
[49] Cuvigny 2009: 40.

> for texts. It is a great deal of work, and afterward one has little to write about it; moreover the descriptions are indigestible for the reader and, for the author, boring and academically unrewarding.[50]

Thus, despite the increasing professionalization of archaeology in Egypt, many excavations of the later periods of Egyptian history are conducted by papyrologists and historians: “And yet, although the papyrologists hardly dare touch a trowel nowadays, many Graeco-Roman sites in Egypt are still opened on their initiative”.[51] This state of affairs results, of course, from the continued desire to harvest papyri.[52] Interestingly, the archaeological foci of papyrologists have led to certain periods, such as the Byzantine and early Islamic, being ignored or avoided archaeologically,[53] just as texts of those periods have traditionally been relegated to a marginal status in textual studies because of a perceived hierarchy of value among particular languages, cultures, and periods.

If historians and papyrologists have seized the initiative in order to collect artifacts and to address issues of interest to them, they have also dictated in large part the agenda for archaeologists studying the Graeco-Roman Period in Egypt. For example, while there have been numerous studies of Egyptian agriculture and irrigation in recent years, archaeology has only very rarely played a role, despite the obvious benefits of

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[50] Cuvigny 2009: 53.
[51] Cuvigny 2009: 39.
[52] Cuvigny 2009: 40-1. For example, Cuvigny’s own project at the Roman period site of Mons Claudianus where, “...the team was strengthened by the participation of several archaeologists, who added some archaeological respectability...Our colleagues could but regard us as looters, while we tended to see them as killjoys,” (Cuvigny 2009: 41). Excavation by historians and papyrologists remains common in Egypt, particularly in the Fayum.
[53] Bagnall 2001: 234; Cuvigny 2009: 43.

such an approach.[54] Thus, archaeology remains a subordinate, technical discipline of minor interest to those who actually "write history".[55]

Archaeology in Egypt

Whether investigating the Dynastic Period or the Graeco-Roman Period, archaeology in Egypt has traditionally been obsessed with temples and tombs.[56] In great part this emphasis has been the result of the geomorphology of the Nile Valley.[57] Changes in the course of the Nile River have obliterated some valley sites, while others have been buried under metres of alluvial sediment.[58] The effects of these processes on archaeology have been compounded by the almost continuous habitation at many sites, which now lie beneath modern towns and villages, making excavation of ancient settlements difficult.[59] The ancient irrigation systems, well-known from the textual

[54] E.g. Bonneau 1993; Menu (ed.) 1994; Bowman and Rogan (eds.) 1999; Moreno García (ed.) 2006. But see Cappers 2006, for an important counter-example from the site of Berenike.

[55] It could be said that the archaeology of Graeco-Roman Egypt is the "hand-maiden" of papyrology - ironically, as papyrology has been considered by historians of Greece and Rome as a peculiar technical skill useful primarily in one idiosyncratic region. As recently as 1993, Peter van Minnen (1993: 12) found it necessary to write, "Papyrology is not an ancillary discipline, a view often erroneously held even by papyrologists. Papyrology is a primary discipline." For a discussion of Egypt's *Sonderstellung*, see Hickey 2009.

[56] O'Connor 2003. It should be noted that Egyptian temples and tombs are often heavily decorated with hieroglyphs and other writing, making the monuments themselves gigantic texts which can be read and privileged by the broader scholarly community.

[57] Bard 2007: 54-6.

[58] Bard 2007: 56. Butzer (1976) estimates an average deposition of ca. 0.10 m per century, or a total of ca. 5 m since the Predynastic Period and ca. 2 m since the Graeco-Roman Period.

[59] While some early excavators, such as Petrie, excavated settlements near the Fayum and elsewhere, their excavations lacked detailed recording, scientific analysis and comprehensive publication of the finds. Recently, archaeologists (e.g. Kemp) have begun more rigorous projects to investigate settlements, where they have survived, as at Amarna, Deir el-Medina, and now Giza. However, it is not clear how these, usually planned, workers' settlements of the Dynastic period in the low desert relate to the missing valley sites (Lehner 2010). For the Graeco-Roman period, note the work in the Delta (particularly at Athribis and Pelusium) and at Memphis, Oxyrhynchus, etc., as well as in the Fayum. See Bagnall 2001, for a recent survey of the discipline. For up-to-date field methodologies applied to settlements in Egypt, see Herbert and Berlin (eds.) 2003 and Wendrich and Sidebotham (eds.) 2007.

evidence, are even more deeply buried. Only those sites, primarily temples and tombs, which are situated in the low desert rather than the floodplain are easily accessible.

The high sedimentation rate before the advent of the Aswan High Dam has also discouraged the use of systematic and intensive field survey in Egypt. Most ancient settlements are now deeply buried and the mining for *sebbakh* at exposed sites has led to the spreading of ceramic sherds and other artifacts across the landscape of the valley during the modern period, although more peripheral areas remain viable.[60] Still, diachronic pedestrian survey of the type utilized in other Mediterranean countries has been largely ignored in Egypt and limited by disciplinary boundaries as well as by bureaucratic and administrative procedures which make it difficult to obtain a permit for a region rather than for a single ancient site.[61] The rapidly decreasing cost and greater availability of satellite imagery has provided an alternative to traditional pedestrian survey in Egypt and has to some extent mitigated the difficulties of obtaining permits for large geographical areas.[62] Nevertheless, satellite imagery must still be interpreted and requires ground-truthing to confirm tentative identifications, making it subject to the same permit difficulties.

A more fundamental problem lies in the lack of engagement by archaeologists working in Egypt with theoretical and methodological developments elsewhere. As Wendrich writes:

[60] Bailey 1999. Such as the eastern desert. See, for example, Wright 2003; Gates forthcoming; Wendrich and Sidebotham (eds.) 2007, and the summary in Bagnall 2001; 235-6.
[61] And compounding the difficulties of "off-site" archaeology, including the study of agriculture and irrigation.
[62] See Parcak 2009.

> Even today some Egyptologists question how archaeological theory would improve our understanding of the ancient Egyptian culture, while the question should of course be turned around: how flawed is our understanding *without* theory?.[63]

This poverty of theory has allowed archaeology in Egypt to continue using dated, "common-sense" approaches and backward methodologies, although the exceptions have been particularly inspiring and the situation is improving rapidly.[64] The unwillingness of researchers to utilize theoretical perspectives from archaeologies outside of Egypt can be ascribed, at least in part, to intransigence, and in part to the disciplinary boundaries affecting their training. The lack of methodological innovation on the other hand, particularly the use of new scientific analyses of artifacts, is due in great part to official restrictions on the exportation of scientific samples and the difficulty of bringing equipment into Egypt.

Archaeology in the Fayum

The focus of archaeological research in the Fayum region closely resembles that in the Nile Valley, with an emphasis on sites along the desert fringe, despite major differences in geomorphology and site preservation. Fieldwork has also remained focussed on the Graeco-Roman sites to the exclusion of other periods, although a much greater emphasis has been placed on settlement archaeology. This is, in part, the result of the objectives of the earliest excavation directors and their sponsors, who were motivated by the desire to collect papyri from the rubbish heaps near habitation sites.

[63] Wendrich 2010: 1. It is thus doubly ironic that Cuvigny (2009: 39) should write, "...Graeco-Roman sites in Egypt have not been very attractive to archaeologists unless they have a bearing on a larger *historical* problem like central power, commerce, or the environment" [emphasis mine].
[64] E.g. Bietak 1996; Meskell 1999; 2002; 2004; Wilfong 2002; Richards 2005; Kemp 2006; Lehner and Wetterstrom (eds.) 2007; O'Connor 2009.

Of five major recent and ongoing projects in the Fayum[65], three are directed or co-directed by papyrologists. Four of the projects have studied temples or their environs intensively; three have studied baths, while all five have studied houses. However, all five were located at major Graeco-Roman *kom* sites on the desert fringe, while the massive diachronic site of Kiman Faris (ancient Shedet/Crocodilopolis/Arsinoe) was allowed to succumb recently to construction in modern Medinet el-Fayum.[66] Remarkably, surveys have been conducted along the desert margin in the southern Fayum, both independently and as part of the Fayum Project, but they were neither intensive nor systematic and focussed on relocating and recording previously known sites primarily of Graeco-Roman date.[67] A few attempts have been made to examine the ancient landscape using satellite imagery,[68] but most studies still rely on the papyrological evidence to address basic issues of toponymy.[69]

Geoarchaeology, Hydrology and Ecology

> Every archaeological problem starts as a problem in geoarchaeology.[70]

> Irrigation systems are a direct interface between cultural systems and their environments.[71]

Although they have been studied only cursorily in Egypt, irrigation systems are a common feature of archaeological landscapes around the world and a wide variety of

[65] Bacchias, Dime, Dionysias, Karanis, Narmouthis (Medinet Mahdi), and Tebtynis.
[66] Davoli and Ahmed 2006.
[67] Arnold 1966; 1977; Rathbone 1997; 2001; Römer 2003; 2004.
[68] E.g. Bitelli 1997. See also, Chapter Three.
[69] Müller 2003a; 2003b; 2004; Müller and Lee 2005. Note the criticism of the computer-aided method in Hoffman and Klin 2006.
[70] Renfrew 1976.
[71] Howard 1993: 263.

theoretical frameworks and methodologies have been applied to their study.[72] These approaches have recognized the fundamental importance of irrigation, especially in arid environments; the need to consider irrigation *systems* within the broader landscape and its evolution;[73] and the importance of interpretation from a diachronic perspective in light of technological and cultural changes.[74] This vast body of scholarship – a veritable "world archaeology of irrigation" – forms an important resource which can be applied to the investigation of the Fayum irrigation system.

While archaeologists in Egypt were some of the pioneers of geoarchaeology and hydrological and ecological approaches to past landscapes,[75] the archaeology of the country has now fallen behind in the application of new techniques formulated elsewhere. While archaeologists working in Egypt have recognized the importance of the Nile as one of the primary physical factors in the ancient landscape and have taken major strides towards understanding changes in the Nile's physical position and flood regime over time, they have done so at the expense of other subjects.[76] Developments in the broader fields of geoarchaeology, particularly sedimentology, and hydrology are beginning to be applied in Egypt,[77] but these studies and their implications have not been integrated into a study of the canals which make up the Fayum irrigation system,

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[72] For recent general surveys of irrigation systems world-wide, see Ortloff 2009 and Scarborough 2003. Further detail is provided in Chapter Three.
[73] Howard 1993; Wilkinson 2003.
[74] Adams 1981; Doolittle 1990.
[75] Caton-Thompson and Gardner 1934; Butzer 1959 ; 1976; Hassan 1978; 1997.
[76] Butzer 1997, for a recent survey of geoarchaeological research on Egypt.
[77] For general surveys of geoarchaeology, see Rapp and Hill 2006 and Goldberg and Macphail 2006. For alluvial geoarchaeology specifically, see Brown 1997. Archaeological interpretation of sediments is covered in Stein and Farrand (eds.) 2001.

even though the physical remains of irrigation systems are best studied from these perspectives.

Why Karanis?

The ancient site of Karanis (modern Kom Aushim) is situated in the north-eastern Fayum, ca. 25 km from modern Medinet el-Fayum along the road to Cairo. Like other sites located along the desert fringe of the Fayum, such as Bakchias and Philadelphia, the foundation of Karanis is ascribed to Ptolemy II Philadelphos in the third century BCE as part of a plan to settle veterans in the region. A document from the contemporary Zenon Archive (*P.Cair.Zen*. 3, 38) first attests to the site in 242 BCE, by which time it was already an established village. The latest datable document which refers to the site (*P.Haun*. III 58) is a water dispute dated to 15 May, 439 CE. After that date there is virtual silence, apart from a single mention in a list of place names of 7th or 8th century CE date.[78] Archaeological evidence, however, attests to some level of occupation at the site until at least the mid 6th century CE.[79]

[78] Keenan 2003. Note also the undated, but possibly later fifth century CE, *P. Col.* VIII 242. See Rea 1993. The 7th/8th century document is *SPP* X 67, but requires a restoration in the text. See Keenan 2003: 129; 2007: 228-30; and *SB* I 5339.25. A coin hoard of 5th century date has been recovered, El-Nassery and Wagner 1975. For surface coins of 6th and 7th century CE date found at Karanis, including a coin of Heraclius, see Keenan 126, n.27. They are Kelsey Museum of Archaeology inventory numbers 66889 (539/40 CE) and 66890 (Heraclius). Contra Kraemer (2007; 2010, erroneously citing Keenan 2003), Karanis ("Washeem") is not mentioned as one of the abandoned villages mentioned by the 13th century Arab writer an-Nabulsi. The error arises from a misreading of the Arabic manuscript.
[79] Pollard 1998.

Karanis first gained scholarly attention after it was visited by W. M. F. Petrie in 1890.[80] He described Karanis as a major archaeological site, but ravaging by local looters had already begun. In 1895-96, the British archaeologists D. G. Hogarth and B. P. Grenfell undertook brief excavations at the site, revealing the southern temple among other structures, but departed when they were unable to harvest large numbers of papyri easily.[81] The site was then abandoned to looters and the *sebbakhīn*, or fertilizer miners.

While some important finds, such as the archive of Aurelius Isidorus discovered in 1923, made it to the market from Karanis, the site was not investigated again until an expedition from the University of Michigan excavated the site from 1924-35. Initiated by F. Kelsey, a professor of Latin, the project was directed by J. L. Starkey and later E. E. Peterson. With an attention to detail and archaeological provenance that was uncommon for its time, the project focussed primarily on domestic structures and recovered a vast number of artifacts which elucidate daily life in Karanis. The excavation was published in a series of volumes,[82] and in a number of detailed specialist studies and dissertations.[83] Following a long hiatus, Cairo University conducted limited excavations at the site between 1967/8 and 1975 in conjunction with IFAO,[84] along with

[80] Petrie, et al. 1891: 32, Pl. XXX. Referred to as "Kom Wezim" and "Kom 7". For the early excavation history of the site, see Davoli 1998: 73-94, figs. 23-46.
[81] Hogarth and Grenfell 1895-96; Grenfell, Hunt and Hogarth 1890: 27-35; Montserrat 1996.
[82] Kelsey 1927; Boak and Peterson 1931; Boak (ed.) 1933; Peterson n.d.; Husselman 1979.
[83] Wilson 1933; Harden 1936; Husselman 1952; 1953; Haatvedt and Peterson 1964; Shier 1978; Johnson 1981; Allen 1985; Higashi 1990; Thomas 2001.
[84] LeClant 1969; 1973 El-Nassery 1966 [1973]; 1975; 1976. Wagner and El-Nassery 1975.

some experimental remote sensing.[85] New archaeological investigation is now underway as part of the UCLA/RUG Fayum project in conjunction with the Supreme Council of Antiquities of Egypt (see Chapter Four).

Ancient Karanis has emerged, through excavation and the interpretation of the rich papyrological evidence from the site, as one of the best-known and best-understood of the Fayum villages. Its initial foundation as an agricultural community for Ptolemaic veterans was predicated upon the development of a major irrigation system which brought new lands under cultivation in the immediate vicinity. Throughout the Roman period, it remained a prosperous farming community and, interestingly, a popular residence for Roman veterans until its ultimate demise in late antiquity. As such, the community was closely tied to the irrigation system which supported the agricultural efforts of its inhabitants.

The Graeco-Roman site of Karanis is the ideal location to conduct fieldwork concerning irrigation canals in the Fayum for several reasons. First, the University of Michigan has a long-standing and well-known connection to the site, making most resources easily accessible. Second, the only portion of the Fayum canal system that has been explored archaeologically is located just north and west of the ancient site, ensuring the presence of sufficient data to formulate meaningful conclusions.[86] Third, there is a substantial body of ancient documentary evidence concerning irrigation from

[85] Hussain 1983.

[86] Caton-Thompson and Gardner 1934. For a purely hydrological, rather than archaeological, assessment of irrigation in the ancient Fayum, see also Garbrecht 1987a; 1987b; 1996; Garbrecht and Jaritz 1990; 1992. The pioneering work of Caton-Thompson and Gardner receives detailed treatment in Chapter Four.

Karanis and other nearby villages. Fourth, there is an ongoing interdisciplinary and diachronic field-project at the site – the UCLA/RUG Fayum Project – which, thanks to the generous permission of the permanent committee of the Supreme Council of Antiquities of Egypt, has a large permit area making field survey possible. Dr. Willeke Wendrich, Director of the project, kindly granted permission for me to examine the canals around Karanis under the aegis of her permit during fall 2007 and fall 2008. The results of that fieldwork form the basis of this dissertation.

Structure of the Dissertation

Chapter Two, "Canals in Ancient Egypt", summarizes the literature on canals in Egypt. It catalogues the existing evidence for canals and their interpretation from the Pre-Dynastic period to the fourth century CE and re-situates the Graeco-Roman irrigation systems of the Fayum in light of previous developments. It suggests that a long-term, cross-cultural perspective is more productive for the interpretation of Graeco-Roman period irrigation in the Fayum than more traditional approaches.

Chapter Three, "Hydrology, Geology and the Irrigation of the Fayum in Antiquity", places the Fayum irrigation system in the geological and hydrological context of the Nile and the Fayum Basin. It then discusses the evidence for Lake Moeris and its implications for the study of irrigation in the Fayum. A brief survey of the documentary evidence for canals and other irrigation features in the Fayum provides a basis for reconstructing the working of the system in the Graeco-Roman period and allows a reassessment of several well established perspectives on Fayum irrigation.

Chapter Four, “The Archaeology of Irrigation Systems in the Fayum and Around the World”, introduces previous archaeological research on the Fayum irrigation system. It summarizes and re-assesses the pioneering fieldwork of Caton-Thompson and Gardner, the only archaeologists to have examined part of the Fayum irrigation system in any detail. The reliability and limitations of their work is assessed in light of later developments in scholarship. The chapter also provides an overview of recent, innovative archaeological methodology and theory which has been applied to irrigation systems, particularly canals, outside of Egypt. These approaches, especially those derived from the arid environments of the New World, provide novel ways of locating, excavating, dating, and interpreting canals.

Chapter Five, “Preliminary Results of Survey and Excavation”, presents the results of two seasons of fieldwork conducted by the author on the irrigation system surrounding the ancient site of Karanis (modern Kom Aushim) in the Fayum. It records the re-location of a previously identified set of canal alignments to the north and west of the ancient site using pedestrian survey and satellite imagery, as well as the excavation of trenches across the canals using methodologies adapted from projects around the world. It goes on to discuss the tentative chronology, probable purpose, and physical features of the system. More detailed reports of the fieldwork and a catalogue of small rural sites re-identified during the research are presented in Appendices 1 and 2. Chapter Six, “Conclusions”, summarizes the results of the fieldwork and suggests possible avenues for future research.

Chapter Two:
Canals in Ancient Egypt

Canals were a fundamental part of the Egyptian agricultural landscape from the beginning of the Dynastic Period onwards and any attempt to assess Graeco-Roman period canals and their economic and social roles in ancient society must place them within this long context of development. However, canals have rarely been a focus of scholarly attention and, when they have been studied at all, it has been in the context of very specific scholarly discourse. Dynastic Period canals have traditionally been studied from the perspectives of state formation and central-versus-local control of the irrigation system. They are only rarely included among the monumental architectural features (palaces, fortifications, tombs, etc.) common to early complex societies despite the fact that they are present in most such states, are frequently mentioned by rulers in inscriptions and other media alongside more traditional architecture, and are sufficiently large to require labor and resources of a similar order of magnitude.[1]

Graeco-Roman period canals, on the other hand, have been studied from the perspective of local and regional administration and maintenance within a broader narrative of Greek innovation and Roman decline. These alternative perspectives reflect

[1] Irrigation systems are omitted, for example, by Trigger (1990) from one of the few serious discussions of "monumentality". The imbalance is redressed to a certain extent in Trigger 2003.

the differing nature and subject matter of the evidence available for each period as well as the particular preoccupations within the artificial disciplinary boundaries which exist between papyrologists, historians, and archaeologists studying ancient Egypt (see Chapter One). The following reviews the sometimes sparse evidence for canals in Egypt from the Predynastic Period to the Graeco-Roman period within their traditional scholarly contexts in an attempt to move beyond disciplinary boundaries and understand the role of canals in Egypt over the long-term.

Canals, Kings, and State Formation in Dynastic Egypt

> Yes, Wittfogel's method and his positions are dead, and they should be buried. But as in the case of Childe, we must acknowledge him as an innovative thinker in his day. He stimulated a suite of excellent studies on irrigation that eventually rendered his hypothesis obsolete. ... the underlying issues need reformulation, so that empirical research can be more sharply focused. If and when we can turn that corner, and stop rehashing Wittfogel, flowers will indeed be appropriate.[2]

The "hydraulic hypothesis" has been refuted convincingly by Egyptologists and by anthropologists studying other formative states around the world. Nevertheless, no publication concerning irrigation or agriculture in ancient Egypt would be complete without a peremptory disavowal of Wittfogel's causative link between the introduction of irrigation agriculture and the rise of a despotic state apparatus.[3] There has been a cost, however: in order to avoid even the appearance of "Wittfogelian" views, scholars refuse to accept all but the most indirect links between the Pharaoh and irrigation or

[2] Butzer 1996: 204.
[3] e.g. Schenkel 1994: 33-4; Rathbone 2000: 44-5; Manning 2002: 615-17.

agriculture in Egypt. As a result, a great deal of evidence for state involvement in the irrigation systems of both the Dynastic and Graeco-Roman periods has been minimized or ignored. A brief review of the evidence suggests that there was considerable royal initiative and administration in all periods. This fact need not, however, imply a deterministic relationship between the organizational demands of agriculture and a particular type of state.

Wittfogel and "Oriental Despotism"

Wittfogel's synthesis, *Oriental Despotism: a Comparative Study of Total Power* (1957), was something of a sensation in anthropological circles when it first appeared. His goal was to explain, from a Marxist perspective, why the great states of the cold war East had evolved differently from those of the West.[4] His conclusion, "...complicated by tangential arguments and his anguish with the terrors of totalitarianism",[5] was that the quasi-feudal eastern areas had developed from a similar origin as early hydraulic states sharing certain features:

> ...large-scale irrigation works and extensive road construction necessitating centralized government and a bureaucracy whose members due to their power accumulate wealth and thus become landlords.[6]

An elaborate hydraulic bureaucracy was a key element of the theory, as it provided a mechanism for despotic state control of society.

[4] Butzer 1996: 203.
[5] *Ibid.*
[6] Eberhard 1958: 446.

Wittfogel felt that the causative link between the form of government and the underlying mode of production was so strong that:

> No matter whether traditionally nonhydraulic leaders initiated or seized the incipient hydraulic "apparatus," or whether the masters of this apparatus became the motive force behind all important public functions, there can be no doubt that in all these cases the resulting regime was decisively shaped by the leadership and social control required by hydraulic agriculture.[7]

Attentive reviewers challenged the causal relationship between the type of agriculture and the type of state,[8] and questioned the legitimacy of ignoring cultural factors.[9] But, although a clear case of ecological determinism, the hypothesis provided an appealing explanatory theory of state formation for the anthropological community to test in the field.[10]

It took decades of anthropological research to conclusively disprove Wittfogel's hypothesis.[11] In Egypt, the task was accomplished primarily by Karl Butzer in a series of geological and climatological studies which documented the unique circumstances of Egyptian basin agriculture.[12] His conclusion was that large-scale, perennial irrigation agriculture was extremely limited or non-existent in ancient Egypt because of the shallow slope of the Nile and a lack of an effective water-lifting device before the

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[7] Wittfogel 1957: 27.
[8] Sherman 1959: 84.
[9] Eberhard 1958: 447, "Can such different forms all result in the same type of society? Are the Egyptian Pharaoh, the Russian Tzar, and the Chinese emperor really the same type of despot?"
[10] Butzer 1996: 203.
[11] Hunt 1988.
[12] Synthesized and elaborated in Butzer 1976. Flood recession agriculture is, of course, practiced elsewhere, although local ecological and cultural factors can have a major impact on its form, as demonstrated in the classic study of Mali by Harlan and Pasquerau (1969). See also, Park 1992.

introduction of the *shaduf* in the 18th Dynasty.[13] Further, Butzer argued that hydraulic schemes in Egypt were the product of local notables[14] working in a decentralized administration[15] contrary to the premises of Wittfogel's hypothesis.[16]

The State in Egyptian Agriculture

One troubling result of the demise of Wittfogel's hypothesis has been a reticence for scholars to admit to any royal agency in the creation or elaboration of hydraulic schemes in Egypt. Evidently, attempts to avoid a causal argument by denying the existence of a central administrative apparatus have led to a disproportionate response in the other direction, brought about, ironically, by universal theories which privilege the role of local and communal groups over central authorities.[17] This is a striking reversal, particularly as Butzer, while stressing local initiative in the development of agriculture, especially in the period of Egyptian state formation, never denied a role for the central state during the long course of Egyptian history. He did, however, relegate it to a marginal role:

> ...no form of centralized canal network was ever achieved in Dynastic times. In this same light the development of the Delta during and after the Old Kingdom, or the Faiyum projects undertaken by Amenemhat III and Ptolemy II, ***should only be viewed*** as examples of state efforts to

[13] Butzer 1976: 43-7; 1984b. Although "artificial irrigation," the use of small scale drainage and feeder canals to assist the basin agriculture system, is attested from the very beginning of the Egyptian state, as demonstrated by the scene on the Scorpion Macehead (*Ibid*.: 20-1; and below).
[14] *Ibid*.: 41-3.
[15] *Ibid*.: 51.
[16] *Ibid*.: 110-12. Even in modern Egypt, there has been considerable local agency in the maintenance and administration of hydraulic systems (Hunt 1986).
[17] e.g. Hunt 1988; Park 1992. Payne (1989) summarizes the scholarly rejection of the neo-evolutionary stance. See also, Manning 2002: 612-13 and n.6. It is possible that the trend also derives from certain aspects of the "New Historicism", which began in the 1980s. See, Bagnall 1995: 96-7 and n.14.

> develop unproductive, marginal lands for purposes of revenue, to support or reward civil and military officials, or to settle veterans and mercenaries [emphasis mine].[18]

This dismissal of major, state-initiated projects has been echoed frequently in the literature.[19]

Most troubling, however, is a new tendency to charazterize any royal claim to agency in the agricultural realm as mere posturing. This clearly develops from an attempt to avoid the slightest nuance of Wittfogel's hydraulic state bureaucracy.[20] For example, the 18th Dynasty *Duties of the Vizier* (24-5) states that, "It is he who dispatches the district councillors to deal with [or "make"] the ᶜ-channels."[21] Concerning this text, which seems to mention a state official responsible for some aspect of canal management, C. Eyre writes:

> These claims are idealizing, and should not be taken as evidence for an interventionist central bureaucracy, actively controlling the detail of water distribution. The context is a political assertion of central authority.[22]

Could such assertions be mere propaganda, without any basis in reality? Does that mean that there were no such officials, that they did not really have any authority or power, or that they were not really appointed by the Vizier? As an alternative to state and local interests, Eyre suggests that the principal agents of perennial irrigation

[18] Butzer 1976: 50-1.
[19] Eyre 1994: 80 and Manning 2002: 622.
[20] Rathbone 2000: 44-5, notes increasing, and misleading, attacks on the concept of the Ptolemaic 'Royal Economy', but does not link them to opponents of Wittfogel.
[21] Modified from Eyre 1994: 74. See also Crawford 1971: 108, and below.
[22] Eyre 1994: 74-5. Schenkel implies that this is evidence only for the bestowal of the office and that the state is not really involved (1994: 34).

development in Egypt were plantation owners, who needed very specific, year-round watering schedules for their crops. These great estates were fundamental because:

> ..neither the state bureaucracy nor the communal interest of the peasant farming communities was ever sufficiently sensitive, efficient, or rational to maintain the stability of the water regime in the long term.[23]

The argument avoids the challenges of assigning the major organizational and maintenance tasks of Egypt's massive infrastructure to the initiative of local farmers, but would be more convincing if the majority of vineyards, for example, were not owned by royalty and by state institutions.[24]

J. Manning has gone so far as to characterize claims to irrigation management and control by the Pharaoh as, "...le «théatre», pour reprendre l'expression de Clifford Geertz, du contrôle royal central."[25] Apparently, the power of the Pharaoh rested on a fiction by which he remitted hypothetical rents to local elites in exchange for loyalty and the obligation to raise local manpower. Certainly, this type of accommodation has been well documented by anthropologists, but the case is less convincing for Egypt when we hear the purposes for which the manpower might be used: "...pour les campagnes militaires..., ***le dragage des canaux*** ou les expéditions d'exploitation de carrières" [emphasis mine].[26] Dredging of canals using requisitioned labor seems less like "political theatre" than hydraulic maintenance and administration by the state.

[23] Eyre 1994: 73. Extrapolated from conditions in the Graeco-Roman Fayum.
[24] As admitted by Eyre 1994: n.114, for the Graeco-Roman period, at least.
[25] Manning 2002: 618.
[26] *Ibid*.

Evidence for Royal Administration

Some of the arguments against royal involvement in the administration of irrigation are undoubtedly special pleading to avoid Wittfogel's conclusions and to conform to the new universal hypothesis, which proposes that irrigation systems are locally managed. However, the conclusion that Wittfogel was mistaken does not necessarily prove that the opposite point of view must be true; in fact, what anthropological research has proven above all is that the specific cultural and ecological factors of a society must be taken into consideration.[27] This realization opens the door to the possibility that there may have been significant royal involvement in irrigation in ancient Egypt, but that it would not have determined or defined the nature of the state. But how much evidence is there for state involvement in Egyptian irrigation? A survey of the sources indicates that there is considerably more evidence than is usually admitted.

The earliest evidence for royal concern with irrigation appears on the Scorpion Macehead of the Early Dynastic Period (Figure 1).[29] The scene depicts a king, clearly identified by the crown of Upper Egypt, brandishing a hoe while lesser figures offer a basket and a broom. Beneath his feet is a water channel which branches in two and, according to some authorities, feeds two rectangular field systems.[30] Even the most vociferous opponents of royal administration admit that the image depicts the opening of a canal and, thus, the presence of artificial irrigation from the very beginning of the

[27] Butzer 1996: 204.
[29] Butzer 1976: 20-1, fig. 2; Shaw (ed.) 2000: 65.
[30] *Ibid*.: 20.

Egyptian state.[31] But it is immaterial whether or not the act is only "ceremonial."[32] The close association of king and irrigation was materialized from an early date – such an early date, in fact, that the king himself may only have been a local ruler.[33]

During the Old Kingdom, officials in Lower Egypt held the title ^{c}*ḏ-mr*, "he who cuts the canals".[34] Another reference attests to the office of "commander of the inundation" under the 1st Dynasty pharaoh Djer.[35] As is generally the case with Old Kingdom titles, it is unclear whether the office is a purely ceremonial one as no further details exist to explain the precise function, if any, of such an officer of the royal court. Nevertheless, the title itself is further evidence of the perceived importance of the inundation and irrigation in early times.

On the basis of scattered textual references and the layout of the Giza pyramid complex, Goyon has hypothesized that a navigation canal was constructed from Lahun

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[31] Manning 2002: 614. Schenkel (1978: 28; 1994: 31), however, disagrees and places the introduction of artificial irrigation in the First Intermediate Period (see below).

[32] Butzer 1976: 20. See Bell (1971: 20) for the long connection between flood and king, citing the earliest Pyramid Texts from the tomb chamber of Unis: "It is Unis who inudates the land and who has come forth from the lake...Unis came today from the fullness of the flood, he is Subek...," etc. Further corroboration is provided by the importance of "fecundity figures" in royal art, see Baines 1985.

[33] Indeed, it has been suggested that Upper Egypt was the location of the earliest Egyptian state precisely because the numerous small basins created by narrowing of the Nile Valley permitted artificial irrigation (Wenke 1989: 140). See Bell (1971: 20) and Lembke (1994) for brief summaries of earlier, and somewhat dated, literature on the Egyptian god-king evolving from a prehistoric "rainmaker".

[34] *'ḏ-mr dw3-ḥr-ẖnty-pt*. Crawford 1971: 108; Butzer 1976: 103. For a brief discussion with further references, see Strudwick 1985: 312. Strudwick suggests that the title had become honorary by the fourth or fifth dynasty, but was one of several titles, "which were originally doubtless associated with the personal service of the king and his lands."

[35] Westermann 1919: 159, erroneously cites Baikie *Egypt under the Pharaohs* 21. In fact, the reference occurs in Baikie 1908: 21, where no source is given. It seems likely that the evidence is from an inscription found at the royal or subsidiary tombs at Umm el-Ga'ab, Abydos, by Amélineau in 1895 (1905) or by Petrie in 1900. See also, Bellucio 1994.

to Giza in 4th Dynasty.[36] This "Giza Canal" (or "Memphis Canal") would have provided an inexpensive way of shipping construction materials, particularly stone, to the pyramids from upriver. If Goyon's analysis is correct, this canal would have been one of the earliest and largest hydraulic projects of the Dynastic Period and, like other navigation canals, could also have been used to bring large areas under cultivation along its course. While there is as yet no concrete textual or archaeological confirmation for the existence of this canal in the 4th Dynasty, it is interesting to note that a canal is known to have existed in this general position in the early Ptolemaic period.[37] Running parallel to the Nile along the west bank, this Ptolemaic canal seems to have connected in the south with the Bahr Yusuf at Lahun and to have continued north towards Memphis, if not Naukratis and Alexandria.

Further evidence for royal interest in agriculture and irrigation is provided by the Palermo Stone.[38] Erected in the 5th Dynasty, the inscription records the height of the Nile flood by regnal year and covers a period spanning most of the 1st to 5th Dynasties. The recording of flood levels seems to have been something of a preoccupation for the rest of Egyptian history, although they are preserved only sporadically. For example, another large group of inscriptions from Semna in Nubia records flood heights during the 12th Dynasty.[39] These epigraphic attestations of Nile levels indicate considerable interest in the productivity of the flood by some form of central authority. Official concern is also expressed by reliefs from the Pavillion of Sesostris I at Karnak, which

[36] Goyon 1971. The associated harbors have now been located, see Hawass 1997.
[37] Derda 2006.
[38] Bell 1970; Wilkinson 2000.
[39] Bell 1975.

record the precise area of each nome and the length of the Nile within the nome boundaries, and by a text from the Temple at Edfu, which registers the total amount of land in Egypt.[40] The latter examples indicate a more practical concern with the flood and its productivity than can be explained by "ideological" associations between the king and the maintenance of order (*ma'at*).[41] Additionally, the recorded flood heights on the Palermo Stone presuppose the existence of a device, a Nilometer, designed to carry out such a function.[42] While Old Kingdom nilometers have not been attested archaeologically, they are well known from later times and indicate a further official recognition of the importance of variations in the Nile flood for the well-being and agricultural productivity of Egypt.

The *Pyramid Texts* of the 5th-8th Dynasties at Saqqara provide an additional early attestation of the relationship between canals, irrigation agriculture, and Egyptian kingship.[43] Situated in the interior of royal tombs, these un-illustrated texts are the earliest collections of Egyptian religious rituals and provide important insights into Egyptian thought. One of the earliest texts, from the pyramid of Unis (Dynasty 5, ca. 2353-2323 BCE) describes the king in these terms: "Unis is a trampler, who chops the

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[40] Cited by Manning 2002: 620-1, who views the inscriptions as, "...une affirmation d'ordre théologique du control politique." While they may be said to derive from a "religious" context, they also derive from a "royal" context. Rathbone (2000: 46) mentions evidence for population censuses and land surveys dating the 2nd Dynasty, but does not provide a reference – although, he may refer to the Pavilion of Sesostris.
[41] For the role of the king as intermediary between gods and men and as guarantor of the flood, see above n. 32-3. Note also that the High Priest of Memphis was the "right hand of Pharaoh".
[42] Bonneau 1976; 1986, with earlier references.
[43] The *Pyramid Texts* have not previously been used as evidence in the debates concerning the role of the king in irrigation nor concerning the date of the widespread introduction of irrigation agriculture in Egypt. They were, however, briefly discussed in a summary of evidence concerning irrigation in Egypt by Westermann 1919: 159. The *Pyramid Texts* survived in modified form in later times when they were incorporated into the *Coffin Texts* and the *Book of the Dead*. Allen 2005 is the most recent translation, but his numbering of the text differs from earlier systems.

canals' mud."[44] While the context is somewhat arcane, it is difficult not to envision some sort of cultic practice reminiscent of the scene on the Scorpion Macehead (above). In any case, canals are attested in direct association with the king as he acts to maintain them.

A *Pyramid Text* of Pepi I (Dynasty 6, ca. 2289-2255 BCE) provides further direct evidence for the association of canals with kingship in a royal context: "The $p3^{c}t$-canal has been opened up, the $p3^{c}t$-canal has filled with water. So the Marsh of Reeds has flooded and the Marsh of Rest has filled with water..."[45] Most interesting, however, is the emphasis on the antiquity of canals and the ancient Egyptians' association of canals with their own early development later in the same text:

> ...when the sky had [not] yet come into being, when the earth had not yet come into being, when canals had not yet been dug, when towns had not yet been founded.[46]

A number of inscriptions set up by provincial officials in Upper Egypt during the First Intermediate Period have been cited as evidence of local, rather than state, execution of irrigation projects.[47] The inscriptions were erected by nomarchs to commemorate their actions during what appears to have been a period of unusually low flood levels leading to widespread famine and include several references to canals. For example, the Stele of Khety from Assiut reads:

[44] Allen 2005: 53 (W185).
[45] Allen 2005: 160 (P467).
[46] Allen 2005: 196 (P557).
[47] Bell 1971; Butzer 1976: 28; Schenkel 1978; 1994: 30-2. Schenkel feels that the texts indicate the origins of artificial irrigation in the First Intermediate Period.

> ... I made a monument [probably a canal] in - - a substitute for the river, of 10 cubits; I excavated for it upon the ploughlands; I provided a gate...in brick...in one (act of) building, without dispossessing anyone of any house/property...I nourished my town, I acted as (my own) accountant in regard to food (?) and as giver of water in the middle of the day, in order to be very wary of ??? in the island (?) I made a dam for this town, when Upper Egypt was a desert (?), when no water could be seen. I closed my (?) frontiers...(to outsiders)...I made (agricultural) highlands out of swamp and caused the inundation to flood over old ruined sites...[48]

First, it is worth pointing out that these texts date to a time of crisis and weakened central authority during the First Intermediate Period, when the king may not have been able or willing to act. Secondly, it could be argued that a local nomarch would not have chosen to commemorate an event if it were common practice. Thus, it may not be a coincidence that the first attestation of canal and dam construction by local officials occurs at this unsettled time.[49]

The most frequently cited act of Pharaonic intervention in irrigation dates to the early part of the Middle Kingdom.[50] Although the precise chronology is somewhat uncertain, it has long been supposed that 12th Dynasty Pharaohs, perhaps Sesostris II and Amenemhat III, undertook a massive project of hydraulic management in the Fayum (see Chapter Three). While some scholars have been keen to dismiss the project (above,

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[48] Bell 1971: 10, citing also the Stele of Merer in the Krakow Museum: "...I shut off all their fields and their mounds in the town and in the country. I did not allow their water to inundate for someone else..."

[49] An earlier navigation canal may have been constructed by Weni during the reign of Merenre in the 6th Dynasty, see Bell (1975: 245-6). Weni also held the title of "superintendent of the irrigated lands of the Pharaoh" (Westermann 1919: 159). Note also the enigmatic reference preserved in a papyrus of ca. 2000 BCE: "Those who build of granite…who erect pyramids…their offering tables are as empty as those of the weary ones who die upon the dikes." Quoted in Westermann 1919: 160. The text is known as „The Suicide and his Ba," lines 61-4. A recent translation is given in Simpson (ed.) 2003: 178-87, where "dikes" are rendered as "riverbanks".

[50] E.g. Luft 1994; Callender 2000; Grajetski 2006. No direct ancient evidence for irrigation is cited – irrigation development is inferred from contemporary building projects, see further Chapter Three.

pp. 28-9), recent archaeological work in the Fayum has suggested that it may have been an immense undertaking involving the canalization of the Bahr Yusef, a diversion dam at Lahun, and a separate storage dam within the Fayum to retain the water in an artificial lake of up to 100 km^2.[51] The result was essentially a man-made basin similar to those occurring naturally in the Nile Valley, which could have been exploited using familiar artificial irrigation practices.[52] Eyre has gone so far as to suggest that this Middle Kingdom program may have led to the development of perennial irrigation agriculture when supplemented by the introduction of the *shadouf* in the 18th Dynasty and the *saqiya* in the Ptolemaic period.[53]

The New Kingdom may have seen supervision of the entire water supply of Egypt entrusted to the vizier.[54] Ultimate responsibility, and credit, for administration remained the prerogative of the Pharaoh, however. Ramses III claims: "I made slaves as watchmen of the canal-administration."[55] Additional canal projects were undertaken in the Wadi Tumilat and across the Isthmus of Suez at some time between the later New Kingdom and the reign of Neko II, but there is considerable dispute concerning their potential roles in agriculture as opposed to trade or defence, although irrigation would have been

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[51] Jaritz 2004, for a brief English summary.
[52] For a more detailed discussion of hydraulic projects in the Fayum, see Chapter Three.
[53] Eyre 1994: 72, *contra* Thompson 1999a. The latter believes that the Ptolemaic project was inspired by the draining of Lake Copais in Macedonia.
[54] Under Thutmosis III, see Westermann 1919: 161, citing Breasted *Ancient Records* II, sec. 698. The 18th Dynasty Tomb of Rekhmire, quoted above, p.29.
[55] In *Papyrus Harris,* Dynasty 20. Westermann 1919: 161, citing Breasted *Ancient Records* IV, sec. 266. Breasted, note g, suggests that the canal mentioned here was probably close to a temple and, therefore, had a ceremonial/ritual function. For a more recent translation, see Grandet 1994.

a secondary use in any case.[56] The traditional, official titles concerning irrigation continue in the Late Period as well, with a "chief of irrigation" attested under Sheshonq.[57]

In short, while the sources for canals in Dynastic Period Egypt are sparse considering the ca. 3000 year span involved, there is significant data attesting to their presence and importance in agriculture and ideology from the earliest times. The fundamental problem is that most of the evidence derives from elite, if not exclusively royal, contexts and scholars differ in their interpretation of the motives and accuracy of these sources. This has resulted in the interpretation of canals based on *a priori* assumptions about the "reality" of royal control of the irrigation system of Dynastic Egypt.

Although Wittfogel's theory of "Oriental Despotism" is dead and buried, its ghost walks the fields of Egyptian agriculture. Attempts to avoid Wittfogel's particular brand of theory-driven ecological determinism and "Oriental Despotism" linked to irrigation have led scholars to adopt an opposing, but equally theory-driven, position. However, their claim that the state did not play a significant role in the creation and maintenance of irrigation systems is not tenable in the face of the evidence, particularly when the

[56] Aubert 2004; Poesner 1936: 48-87; Redmount 1995; Shea 1977; Sneh, et al. 1973. The Red Sea-Nile project seems to have had a complicated history with known major phases in the Dynastic, Late, Persian, Ptolemaic, and Roman Periods.
[57] Perhaps Sheshonq I. Westermann 1919: 161, citing Breasted *Ancient Records* IV, sec. 726. The Dakhla Stela: "On this day (went up) the son of the chief (*ms*) of the Me; chief (ᶜꜣ) of a district (*ḳꜣḥ*); prophet of Hathor of Diospolis Parva; prophet of Horus (of the South), lord of Perzoz (*Pr-ḏꜣḏꜣ*), prophet of Sutekh, lord of the oasis; chief of irrigation, overseer of (...), the chief of the two lands of the oasis, and the two towns of the oasis, Wayeheset (*Wꜣ -yw -hꜣ -sꜣ -tꜣ*). See also, Gardiner 1933 and Ritner 2009: 173-8. In the latter, the title is translated as "overseer of inundated lands".

sources from the comparatively document-rich Graeco-Roman periods are considered as well.

Evidence for Graeco-Roman Period Canals

The literary and documentary evidence for Egyptian canals becomes much more plentiful in the Graeco-Roman Period, but it is also of a markedly different type. While some classical authors commented briefly on the irrigation system of Egypt, most of our evidence comes from documentary texts preserved on papyri and ostraka. Whereas the Dynastic Period evidence derives primarily from a royal context and concerns issues beyond mid- to lower-level maintenance and administration, the Graeco-Roman evidence concerns precisely these latter issues.

A variety of documents emanating from administrative officials at the level of the nome and village record the construction, maintenance and management of canals, while private documents attest to individual labor on the canals or mention them as geographical features. Only rarely, as in the case of circulars sent to nome officials by the *dioiketes* (see below), do the documents provide insights into the irrigation system from the perspective of the central administration. The chronological and geographical distribution of the documents mirrors that for Graeco-Roman documents in general, as does the legal and administrative character of the texts (see Chapter One). To a great extent, the subject matter of the documentary evidence has also determined the scholarly research agenda concerning Graeco-Roman canals. Most studies have been directed towards continuity and change in administrative processes in the light of perceived Greek innovation and Roman mismanagement of the system as a whole.[58]

Ancient Authors, General and Fayum

A number of ancient authors described the Nile, the Fayum, or the irrigation system of Egypt in varying degrees of detail and with varying accuracy. The fifth-century BCE historian Herodotos is perhaps the most famous of these, but is also the most controversial.[59] He describes the geography and customs of Egypt in considerable detail in Book II of his history, but displays a fascination with the marvellous which often overshadows his more mundane material. He claimed to have visited the Fayum and to have seen a man-made, high-level Lake Moeris of incredible size and depth near the site of the famous Labyrinth (II.148-50), but attempts to reconcile the description with the reality on the ground have met with limited success and have required considerable re-interpretation (see Chapter Three). The first century BCE historian Diodoros Siculus devoted an entire book (Book I) of his universal history to Egypt. Like Herodotos, he marvelled at Lake Moeris and the Labyrinth (I.51.5-I.52.6), but his account appears to be derived from that of Herodotos and adds little to the description.[60]

[58] The perception of Greek culture as inventive and creative while Roman culture is stagnant and derivative has long been recognized as an simplistic and old-fashioned meta-narrative in studies of ancient literature and art (e.g. Gazda (ed.) 2002). See also Chapter Three.
[59] Interpretation of the passage depends in great part on one's general approach to the reliability of Herodotos and his source, perhaps Hecataeus. For a negative view of Herodotos' description of the Fayum specifically, see Armayor 1985, with the reviews by West 1987 and Evans 1987.
[60] The relevant passages of Herodotos, Diodoros, and Strabo concerning the Fayum Lake are quoted in Chapter Three.

The geographer Strabo visited Egypt ca. 25 BCE and described the Nile and its agricultural function in considerable detail (xvii.1.1-5). He explicitly mentions numerous canals in the Delta and elsewhere, and describes briefly Lake Moeris in the Fayum (xvii.1.4).[61] Like Diodoros, however, he seems to follow Herodotos in the details of the lake.[62] Strabo's understanding of the irrigation system of Egypt, while brief, is the clearest found in any ancient author:

> The activity of the people in connection with the river goes so far as to conquer nature through diligence. For by nature the land produces more fruit than do other lands, and still more when watered; and by nature a greater rise of the river waters more land; but diligence has oftentimes, even when nature has failed, availed to bring about the watering of as much land even at the time of the smaller rises of the river as at the greater rises, that is, through the means of canals and embankments. At any rate, in the times before Petronius the crop was the largest and the rise the highest when the Nile would rise to fourteen cubits and when it would rise to only eight a famine would ensue; but in the time of his reign over the country, and when the Nilometer registered only twelve cubits, the crop was the largest, and once, when it registered only eight cubits, no one felt hunger (Strabo xvii.1.3, Trans. Loeb).[63]

[61] The Delta is said to have so many canals that the place is easily navigable: ὥσθ' ὅλην γενέσθαι πλωτὴν διωρύγων ἐπὶ διώρυξι τμηθεισῶν, αἳ κατὰ ῥᾳστώνην πλέονται τοσαύτην, ὥστε καὶ ὀστράκινα ἐνίοις εἶναι πορθμεῖα.

[62] It is sometimes claimed that Strabo's remarkably insightful description of canal irrigation in Mesopotamia (xvi.1.9-10), which mentions only one river, is actually based on his autopsy of irrigation practices in Egypt while travelling with his friend, Aelius Gallus (Prefect of Egypt ca. 25-24 BCE). See Westermann 1917a: 240-2; Armayor 1985. In any case, the insights provided in the passage are true of all earthen irrigation systems and prove that such knowledge was available to Strabo and was not confined to Egypt.

[63] Thus, also the importance of maintenance is stressed. P. Petronius was Prefect of Egypt ca. 24-22 BCE. ἡ δὲ περὶ τὸν ποταμὸν πραγματεία διαφέρει τοσοῦτον, ὅσον τῇ ἐπιμέλειᾳ νικᾶν τὴν φύσιν. φύσει γὰρ πλείονα φέρει καρπὸν καὶ ποτισθεῖσα μᾶλλον, φύσει καὶ ἡμείζων ἀνάβασις τοῦ ποταμοῦ πλείω ποτίζει γῆν, ἀλλ' ἡ ἐπιμέλεια πολλάκις καὶ τῆς φύσεως ἐξίσχυσεν ἐιλιπούσης, ὥστε καὶ κατὰ τὰς ἐλάττους ἀνάβασεις τοσαύτην ποτισθῆναι γῆν, ὅσην ἐν ταῖς μείζοσι, διά τε τῶν διωρύγων καὶ τῶν παραχωμάτων· ἐπὶ γοῦν τῶν πρὸ Πετρωνίου χρόνων ἡ μεγίστη μὲν ἦν φορὰ καὶ ἀνάβασις, ἡνίκα δ' ἐπ' ὀκτώ, συνέβαινε λιμός· ἐπ' ἐκείνου δὲ ἄρξαντος τῆς χώρας καὶ δώδεκα μόνον πληρώσαντος πήχεις τοῦ Νείλου μέτρου, μεγίστη ἦν ἡ φορά, καὶ ὀκτώ ποτε μόνον πληρώσαντος, λιμοῦ οὐδεὶς ᾔσθετο.

The first century CE polymath Pliny provided an abridged account of the Lake found in Herodotos (*HN* V.ix.50) before providing a longer description of the Nile (*HN* V.x.51-9) and its sources.[64] The mid-first century CE geographer Pomponius Mela (*De situ orbis* 1.9.55) only mentions Lake Moeris in passing.[65] The fragmentary Latin author Nigidius Figulus (ca. 98-45 BCE) purports to preserve the coronation oath of the Ptolemies, which includes the obligation of the king to uphold the calendar, the land, and the water.[66]

Other authors attest to governmental concern with the irrigation system during the Roman period. The biographer Suetonius (*Augustus* 18) records the use of soldiers by the young Octavian to clean out canals in Egypt following his victory over Antony and Cleopatra.[67] The same acts of ca. 30 BCE are also preserved in the early third century CE historian Dio Cassius (li.18.1).[68] According to the Scriptores Historiae Augustae (*Vita*

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[64] It is uncertain what, if any, significance should be given to the fact that Pliny uses the phrase "*lacus fuit*". See Van Beek 2006: 23.

[65] Also following Herodotos, but very abbreviated. *Moeris, aliquando campus nunc lacus uiginti milia passuum in circuitum patens, altior quam ad nauigandum magnis onustisque nauibus satis est*. See Silberman 2003. Mela goes on to attribute the nearby Labyrinth to Psammetichos, rather than Moeris.

[66] *De sphaera graecanica et barbarica* (ed. Schanze), 421. See also Thompson 1996: 50 and n. 43; Thompson 1988: 146-7. Thompson views the oath as a perpetuation of pre-Ptolemaic practices involving the flood and irrigation. She also compares it to the oath of office of an *antigrapheus* preserved in *P.Petrie* III 56 (b).9-10. It was still an important duty of rulers to ensure the flood under the Ayyubids and Mamlukes, see Rabie 1981.

[67] *Aegyptum in provinicae formam redactam ut feraciorem habilioremque annonae urbicae redderet, fossas omnis, in quas Nilus exaestuat, oblimatas longa vetustate militari opere detersit*. As Westermann (1917a: 242) points out, the project involved soldiers but must have relied primarily on Egyptian corvée labor. A parallel for using the army for canal maintenance is recorded by Strabo (xvi.1.9-10) for Babylonia.

[68] Τάς τε διώρυχας τὰς μὲν ἐξεκάθηρε τὰς δὲ ἐκ καινῆς διώρυξε.

Probi 9.3), the emperor Probus similarly used soldiers to "open up river mouths and dry out swamps" as well as for construction projects in Egypt ca. 270-80 CE.[69]

The Archive of Kleon and Theodoros

The best documented evidence for state intervention in irrigation dates to the Ptolemaic period. By remarkable chance, an archive of documents from the Fayum has been preserved which details the activities of Kleon and Theodoros, during their tenures as *architekton*, or "chief engineer in charge of the protection of the dykes and sluices,"[70] in the Fayum during the expansion of the canal system at the personal command of Ptolemy II Philadelphos.[71] The earliest datable document in the archive dates to 260 BCE and the latest to 238/7 BCE.[72] It is possible that the major acts of canal construction had already taken place by that time, perhaps during the reign of Ptolemy I Soter, and that

[69] *In Nilo autem tam multa fecit ut vecitgal frumentarium solus adiuverit. Pontes, templa, porticus, basilicas labore militum struxit, ora fluminum multa patefecit, paludes plerasque siccavit*... See Westermann 1919: 163-4.

[70] Thompson 1996: 46, citing *P.Petrie* II 42(a) = *P.Petrie* III 43(1). Theodoros was a *hyparchitekton*, or deputy, to Kleon until ca. 245 BCE, when he became *architekton* himself according to *P.Petrie* II 42a = *P.Petrie* III 43 (1) (Van Beek 2006: #79, 25 October, 250 – 24 October 249) and *P.Lond.* VII 2074. See Westermann 1917b: 427. An earlier deputy was named Petechonsis and it is worthy of note that he is Egyptian. See Westermann 1919: 162. The administrative position of *architekton* seems to have been dissolved after 237 BCE, probably ca. 230 BCE. See Westermann 1917b: 427 and Van Beek 2006: 15. The titles of *nomarchai* and *myriarouri* also disappear ca. 240-230 BCE and this has been taken to indicate their direct involvement in the early land development project of the Fayum. See Clarysse 1997: 73-6 and Van Beek 2006: 15, n.46.

[71] Lewis 1986: 37-45; Rathbone 2000: 46-7. Some documents from the contemporary Zenon archive also involve irrigation and include correspondence between Kleon and Zenon. See Rostovtzeff 1922; Préaux 1947; Orrieux 1985; Clarysse and Vandorpe 1995. An overview of the Zenon Archive is provided in *P.L. Bat*. 21. See now Van Beek 2006, a recent dissertation on the archive which is scheduled to be published as part of the re-edition of *P.Petrie* II^2, and which includes two such documents (Van Beek 2006: #17, 19). Also important are the papers of the *nomarchs* Aristarchos and Diogenes from Ghoran, esp. *SB* XII 10844 (19 October, 247 BCE). See Héral 1992. Additional documents are listed in Van Beek 2006: 3 n.10.

[72] Outgoing correspondence from Kleon and Theodoros are not customarily included in the archive by commentators (e.g. *SB* XII 10844 and *P.Lond*. VII 2074). See Van Beek 2006: 8. The earliest document is *P.Petrie* II 3 = *P.Petrie* III 146 (Van Beek 2006: #15, 28 January, 260 BCE); the latest *in the archive* are *P.Petrie* II 15 (2a) = *P.Petrie* III 43 (7) and *P.Petrie* II 15 (2b) = *P.Petrie* III 43 (7) (Van Beek 2006: #80-81, both 238-237 BCE. There are, however, later attestations outside of the archive, the latest of which is *P.Köln* VIII, 342 (232 BCE).

only the completion of the project is preserved in the archive.[73] Nevertheless, the fact that one of the new canals is named for the *architekton* Kleon (the *Dioryx Kleonos*), suggests that he was responsible for the largest and final stages of construction and that he probably also designed it (see Chapter Three).[74]

Originally excavated by Petrie at Gurob, the texts were official documents which were recycled as mummy *cartonnage* and clearly emanate from the administrative archive of Kleon and Theodoros, despite the presence of some private documents.[75] While the archive is composed primarily of Greek documents published in *P.Petrie* I-III, hundreds of fragmentary Demotic texts were also recovered, but the latter have not been published systematically.[76] Following initial publication, the documents were divided among various European institutions.

Recently, Manning has claimed that Ptolemaic activity in the Fayum irrigation system was limited in scope and ambition and had minimal state involvement.[77] However, it is abundantly clear from the surviving documents of the Archive of Kleon and Theodoros that the entire hydraulic undertaking was not only a state project, but

[73] Van Beek 2006: 18. Arguing for a late 4th century beginning of the works, Thompson (1996: 44 and n.5) points to the dynastic naming of Berenikis and the development of the Gharaq Basin in the southern Fayum. Westermann 1917b: 429 and n. 5 cites *P.Petrie* III 37 (257 BCE) to show that Philoteris was already inhabited by that time.
[74] Van Beek 2006: 25, citing *P.Petrie* II 6 = *P.Petrie* III 42 C (7) (Van Beek 2006 #20, 28 December, 256 BCE).
[75] The Ptolemaic state seems to have established the practice of selling out-dated archival material to embalmers for use in mummy cartonnage towards the end of the 3rd century BCE.
[76] Some were published in *P.Count*. 11-21. See Van Beek 2006: 2 and n.9. Even some of the Greek documents in Dublin remain unpublished.
[77] Manning 2002: 622 and *passim*.

that it was managed by state officials under close scrutiny from above.[78] In fact, the state was so concerned with improvement of the irrigation system and the resultant increase in agricultural productivity that it was willing to rent out state-owned tools to those undertaking projects.[79] What is more, contracts for the maintenance of the Fayum system were let by the royal treasury, proving that state involvement in maintenance of the canals was ongoing.[80] Continued royal concern for the success of agriculture at that time is also evident in an order to survey the entire irrigation system of Egypt preserved on an ostrakon from Thebes, dating to 258 BCE.[81] Even if aspects of administration were later delegated to regional and local officials, it cannot be said that the Ptolemaic state was uninvolved in irrigation and agriculture.[82]

Legal and Financial Documents

> 1st cleruchy. Ptolemais Nea (?): the southern division of the whole area in one plot, consisting of as many *arourai* as it may have and extending west to east. From this plot the northern division will be irrigated; the irrigation canal is on the western side of the aforesaid plot of the

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[78] Note the personal visit by Ptolemy II to the Fayum to inspect the progress of the engineers in 253 BCE mentioned in *P.Petrie* III 42 H (8f), ll. 1-18 (Van Beek 2006: #3, second half of 253/2 BCE) and *P.Petrie* II 13 (19) = *P.Petrie* III 42 H (5) (Van Beek 2006: #11, ca. 260-249 BCE). There is no reason to believe that the visit was ominous and brought about the downfall of Kleon, as Bouché-Leclercq 1908 and Lewis 1986. See Van Beek 2006: 6.

[79] Van Beek 2006: 34, citing (for stone cutting operations) #55, *P.Petrie* II 13 (1) = *P.Petrie* III 42 C (12); #57, *P.Petrie* II 4 (2) = *P.Petrie* III 42 C (4); #60, *P.Petrie* II 4 (3) = *P.Petrie* III 42 C (5); #62, *P.Petrie* II 4 (5) = *P. Petrie* III 42 G (1); and (for irrigation works) # 91, *P.Petrie* III 43 (2); #38, *P.Petrie* II 13 (10) = *P.Petrie* III 42 B (4); #53, *P.Petrie* II 5 (a) = *P.Petrie* III 42 B (5). Iron tools seem to have been in short supply in the early Ptolemaic period and they were carefully inventoried when returned at the completion of projects.

[80] *P.Petrie* III 43(2). Quoted in Lewis 1986: 41.

[81] Rathbone 2000: 46. Original publication in Bresciani 1978; 1983; corrections in Zauzich 1984 and Winnicki 1991: 2.

[82] *Ibid*.: 49-50. Note also that crop schedules (*diagraphe tou sporou*) were established by central authorities. See Vidal-Naquet 1967 on *PSI* V 502.19 (257 BCE); Bingen 1970.

southern division. All taxes in kind and in money to the extent of a half share . . .[83]

A large number of land registers, tax lists, sales documents, leases, and contracts contain references to the irrigation system. Most of the references to canals are made in passing and are included solely to delimit property boundaries.[84] While these documents have helped to establish the precise meaning of specific Greek terminology and occasionally provide names for the canals, their overall use in analyzing the irrigation system is limited.[85] Without a large number of contemporary documents discussing the same geographical area, precise positioning of most of the known canals in the landscape is impossible.[86] The difficulty of using land-holding documents as topographical evidence is compounded by the fact that canals and other features seem to have changed their names relatively frequently over space and time. While similar documents exist in Demotic, they have been less well studied and have not been subjected to systematic investigation from an irrigation perspective.[87]

Penthemeros Certificates

> The 2nd year of the Emperor Caesar Marcus Aurelius Antoninus Augustus and the Emperor Caesar Lucius Aurelius Verus Augustus. Has worked in fulfillment of his obligation of the same 2nd year with respect to the

[83] *P. Mich.* inv. 2898 + 2890 (= *SB* 6.9242). Second century CE. The document was excavated at Karanis and refers to land in the vicinity. Trans. P. Heilporn, APIS accessed 30/3/2010: α κλῆρος. Πτ̣ο̣(λεμαίδος) Ν̣έ̣ας τὴν ἐκ τοῦ πρὸς νότον μέρους τῶν ὅλων ἀρουρῶν μερίδα οὔσης ἐν ἑνὶ ὄγμῳ̣ ὅσου ἐὰν ἦ̣ ἀρουρηδοῦ διατείνον<τι> λίβα ἐπ’ ἀπ<η>λιώτη<ν> ἐξ οὗ ποτισθήσεται ἡ ἐκ βορρᾶ μερίς, ἔστι δὲ ἡ ποτίστρα ἐκ τοῦ πρὸς λίβα μέρους τοῦ προκειμένου ὄγμου τῆς ἐκ νότου μερίδος, τῶν δημοσίω[ν] πάντων σιτικῶν τε καὶ ἀργυρικῶν κατὰ τὸ ἥμισυ μέρος.
[84] One particularly interesting document of this type is *P. Lond*. III 1177. Dating to 113 CE, the document is a list of accounts for commissioners of the waterworks of a metropolis, probably Arsinoë — the nome capital of the Fayum.
[85] For an explanation of the Greek terminology, see Bonneau 1993 and below, Chapter Three.
[86] But see attempts by Calderini 1920a; 1920b; Pearl 1951; 1954; Vandorpe 2004.
[87] Thompson 1999b: 135; Bresciani 1994.

> embankments from Mesore 24 to 28 in the desert canal of Patsontis at Karanis... (*P.Mich* VI 419, 162 CE. Transl. APIS.)

An administrative change enacted shortly after the Roman annexation of Egypt brought a new type of evidence, the so-called penthemeros certificates, into existence. Beginning as early as the Augustan period, official receipts were issued on papyri and ostraka as proof that each inhabitant of the Fayum had undertaken his mandatory five days of labor on the canal system.[88] It appears that the practice of issuing receipts, which was almost exclusively confined to the Fayum, died out in the late 2nd century CE.[89] While it is tempting to see a major innovation in the introduction of *corvée* labor into the maintenance of the Fayum irrigation system, it is likely that the penthemeros certificates attest to a formalization of a much earlier practice based on Egyptian methods of dividing work.[90]

Administrative Circulars

The main evidence for high-level administrative concern for the irrigation system during the Roman period comes from a number of third century CE circulars sent by the *dioiketes* to nome officials.[91] The fact that all known documents of this type date to the same period has caused scholars to speculate that there was a problem with the

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[88] Sijpesteijn 1964; Bonneau 1993: 152-3. It seems possible that the new administrative documents were linked to the introduction of imperial estates. In the Ptolemaic period, maintenance was leased to the *ergolaboi*.

[89] For the few documents found outside the Fayum, see Sijpesteijn 1964: 1-2 and below, Chapter Three. It was equally possible to specify volume of earth moved (Gk. *Naubia* or *Aoilion* = 2 x 2 x 2 cubits = ca. 1.34m^3) instead of number of days, and a formal equivalency was established. See Martin 2000.

[90] Brashear 1979; Bonneau 1993: 153.

[91] One such circular is quoted at the head of Chapter One. See *P.Oxy*. 1409, 278 CE; *P.Yale* inv. 1529 = *SB* 14.11647, AD 280/1; and *P.Mich*. inv. 6660, which joins with *P.Yale* inv. 447 = *SB* 14.11349, AD III. The *dioiketes* was the chief financial officer of the state and reported to the Prefect. He had the principal responsibility for the efficient exploitation of the land and the collection of taxes. For the role of the Prefect in major construction projects involving water, see Jördens 2009: 399-439.

irrigation system of the Fayum at that time.[92] However, the documents are addressed to the *strategoi* and other officials of both the Heptanomia and the Arsinoite nome, suggesting at the very least a more wide-spread problem.[93] Also inferred from these documents is a supposed Roman mismanagement of the irrigation system which came to a head in the third century. However, this presumption is based primarily on the lack of evidence from other periods, when administrative concern may have been expressed in another form (See also Chapter Three).

Water Disputes

> Nobody from the village shall have the authority to draw water at Thanesamen, nor shall any from the same village have authority over the allotments in front of the same Thanesamen. For this reason we have made this *cheirograph*, swearing ... that if we find any basin of the same village of Caranis drawing any water at Thanesamen, and we smash them, we incur no blame... [94]

A few documents from Graeco-Roman Egypt provide evidence for disputes over the provision and usage of water. While such disputes over water rights are a common feature of irrigation systems around the world, the documentary record of Egypt is remarkable for their rarity. One possible explanation lies in a perceived difference between the provision of water, which was governed by public law, and the usage of water, which was governed by private law.[95] In Egypt, the latter was mostly concerned with local customs, which likely predated the coming of the Greeks and may not have

[92] Boak 1926: 362-3; Rostovtzeff 1926: 480-1; Van Minnen 1995: 54; Rathbone 1997: 18.
[93] Parássoglou 1974; Hagedorn 1976; Thomas 1976.
[94] *P.Haun*. III 58, 15 May 439 CE. Abridged from Rea 1993. See also Bonneau 1979. This is the latest securely datable text from the site of Karanis.
[95] Bonneau 1990: 56-58 and n.6. See also *P.Sakaon* 33.9 and 24 and *P.Oxy.* 2341.9.

been codified in any written form.[96] Nevertheless, some Egyptian water laws were ultimately recorded in the Digest and the Theodosian Code, suggesting that they had obtained a broader application in the Roman Empire.[97]

Conclusion

The differing quality and quantity of evidence for the ancient irrigation system of Egypt makes a long-term view of the subject difficult – a situation exacerbated by rigid disciplinary boundaries and the embedded position of the evidence within particular scholarly discourse. Nonetheless, a great deal of continuity in the irrigation system is suggested by the ongoing concern of the Egyptian state for the construction and maintenance of irrigation projects throughout the course of ancient history. While there is little mid-level administrative evidence from the Dynastic Period, the potential for continuity of practice is implied in the "Egyptian" nature of the penthemeros certificates and customary nature of irrigation rights, for example. From this perspective, there is much more evidence for continuity in traditions within Egyptian irrigation agriculture than for change over the long term.

[96] See Bonneau 1990. Irrigation is one of the few areas in which custom is regularly discussed in the ancient documents (others are religion and finance). It amounts to a legal right rather than just a guide, although the term *nomos* is never used with respect to irrigation. See *P.Tebt*. 50.25. According to Bonneau, the pre-Greek origin of these customs is proven by mention of them in the *Book of the Dead* ch. 125 (Trans. P. Barguet).

[97] *Digest* 47.11.10 with Bonneau 1969; and *Theodosian Code* 9.32.1 (= C.J 9.38.1); 64.27. Note the recently-published *Lex rivi Hiberiensis* of Hadrianic date. This law regulates the irrigation system of the middle Ebro River and contains elements reminiscent of Egyptian practices, see Beltrán Lloris 2006.

Chapter Three: Hydrology, Geology, and the Irrigation of the Fayum in Antiquity

Irrigation systems do not exist in isolation. They are part of broader “landscapes of irrigation” which are influenced, but not strictly determined, by the particular local effects of climate and topography.[1] For that reason, the geological, geographical, and hydrological realities of a region are a key component of the interpretation of any irrigation system.[2] For the irrigation system of the Graeco-Roman Fayum, this requires an understanding of the Nile and its characteristics, as well as of the Fayum Basin itself. The realities of irrigation agriculture in the Nile Valley and Fayum Depression differed as a result of the peculiar geography of the latter. The rich documentary evidence available from the Fayum, however, provides sufficient information to form a general overview of the irrigation system as it operated in the Graeco-Roman Period.

[1] The term “landscapes of irrigation” is borrowed from Wilkinson 2003: 71.
[2] Foster, Woodson and Huckleberry 2002: 127.

The Nile and Irrigation Agriculture in Egypt

The Nile River and its evolution have been studied extensively by hydrologists and geologists.[3] As a result, it is one of the best known river systems in the world.

The Nile and its Basin

The Nile River is fed primarily by seasonal rains in the highlands of Ethiopia (the Blue Nile) and by the Great Lakes of Central Africa (the White Nile).[4] It flows for some 6,650 km through Sudan and Egypt before emptying into the Mediterranean Sea through its deltaic branches (Figure 2). The Nile is the longest river in the world, but is remarkable for several other reasons, not the least of which is the fact that it does not receive any additional tributaries north of the join between the Blue Nile and the White Nile at Khartoum. Thus, for almost 1750 km, the Nile continues as a single channel through the North African desert, providing the only significant source of moisture along its course.

Over the course of millennia, the Nile has slowly cut a deep valley into the soft limestones and sandstones between Nubia and modern Cairo and evidence of this process can be seen in the cross-section of the modern Nile valley.[5] The original ground surface represented by the high desert is interrupted by relatively steep cliffs to east and west, the result of down-cutting during an early phase of the Nile. These cliffs descend to the low desert, a narrow step on either side of the Nile, which is particularly

[3] A general introduction to the geology of Egypt is provided by Sampsell 2003. For details of the geology, see Said 1981; 1993; for hydrology, see Shahin 1985; 2002: 272-302; Butzer 1976 considers the geomorphology of the Nile from an ecological perspective. The following overview is based upon their work.
[4] The Blue Nile, or Atbara River, is the primary source of water and sediment in the Nile system.
[5] See the frequently-reproduced cross-section of the Nile near Sohag in Butzer 1976: Figure 1.

pronounced on the west bank. The valley then descends further to the modern flood plain, which is slightly convex and has the modern river channel at its highest point. The valley narrows somewhat at several locations as the result of encounters with geological features which could not be so easily eroded by the Nile, forming the cataracts and the large basins which impede the progression of the inundation.

The convexity of the valley floor is the result of aggradation during the annual flood which characterized the Nile until the completion of the Aswan Low Dam in 1902.[6] Each season, the force of the flood would carry large quantities of sediment down the river; when the Nile overflowed its banks, the bulk of the coarsest sediment fell out of suspension first, while smaller amounts of finer particles were carried away from the channel. This natural process created the wide, coarse, and well-drained levees which run along the banks of the Nile and form the highest point in the center of the valley.

Another remarkable feature of the Nile is its low slope. Between Khartoum and Elephantine there is a drop in elevation 1 m in 13 km, but between Elephantine and the Mediterranean, the slope is even less.[7] The lack of hydraulic velocity inherent in such a low slope contributes to increased sinuosity and braiding of the river channel, particularly in Middle Egypt, where the Nile follows a meandering path with many small islands and subsidiary channels. Linear concentrations of now-isolated ancient villages indicate the location of relict channels of the river.[8] Over the course of time, the Nile has

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[6] Butzer 1976: 15-18.
[7] Butzer 1976.
[8] Butzer 1976: 17, 33-8. Note that Pliny (v.ix.50) locates Heracleopolis Magna on an island in the Nile. Cf. Strabo 17.1.4.

also tended to shift its course eastward. This has resulted in the abandonment of relict channels and a series of fossilized west-bank levees which run north-south, roughly parallel to the modern channel.[9]

Seasonality and Predictability of the Inundation

The most noteworthy aspect of the Nile is the regularity of its annual inundation.[10] Following the rains in the highlands of Ethiopia, the flood crest reached southern Egypt by the middle of August and northern Egypt around four to six weeks later. Land in the natural basins was submerged to a depth of approximately 1.5 m. By the beginning of October most of southern Egypt was dry and northern Egypt shortly afterwards. The exceptions were at the lowest elevations, near the sides of the valley, where the water could not escape and swampy conditions sometimes prevailed.[11] The regularity and fertility of the inundation made it a powerful symbol for the Egyptian people and the calendar was divided into three seasons based around the flood.[12]

Each year the flood deposited rich sediment in the valley, obviating the need for fertilizer. It also washed away damaging salts that had accumulated in the soil, increasing fertility. Deposition of the sediment caused the valley bottom to aggrade over

[9] And relict towns; Memphis is now more than 3 km west of the Nile. See Thompson 1988: 12.
[10] Butzer 1976: 17-18.
[11] Butzer 1976.
[12] *Akhet*, Inundation (June-October); *peret*, Growing (October-Mid-February); and *shemu*, Drought (February-June), see Shaw (ed.) 2002; Ikram 2010: 8.

time, however, perhaps as by as much as 10 cm per century and led to the expansion of the Delta northward.[13]

Variable Height of the Inundation

If the timing of the inundation was extremely predictable, its level was not. Flood levels could be variable and have a major impact on agricultural production and on the course of the Nile itself. Particularly high floods caused aggradation in some areas and avulsion in others. These high energy events caused old channels to be abandoned and new channels to be cut with devastating effects for the inhabitants of Egypt.[14] In years of low flood height, marginal land remained unirrigated and famine could result.[15]

Irrigation Agriculture in the Nile Valley

The earliest agriculture in Egypt relied on agriculture within the natural basins.[16] This was especially true in Upper Egypt, which was likely the most agriculturally productive before the application of technological enhancements. In fact, it has been suggested that the earliest Egyptian state formed in Upper Egypt precisely because of this large number of natural basins in the region.[17]

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[13] Butzer 1976. The total volume of sediment was not distributed equally, but depended upon local conditions.

[14] The edict of Hadrian of 24-31 May, 136 CE (*SB* III 6944 (A/B); *P.Oslo* III 78 = *FIRA* I^2 81 (C); *P.Heid*. VII 396 (D).) may attest to an event of this type, see Jördens 2009: 430-1 for discussion. The event must have been serious, as taxes were forgiven as a result. See also the Abrochia Declarations, Jördens 2009: 432-3. For scientific evidence of low floods during the Old Kingdom, see Stanley, et al. 2003.

[15] See above (Chapter Two) for a discussion of attempts to reconstruct past flood heights.

[16] Butzer 1976: 18-22. The best description of basin agriculture is given in a description of flood-recession agriculture in Mali, see Harlan and Pasquereau 1969.

[17] Wenke 1989. See also Chapter Two.

From early times, however, the ancient Egyptians modified and adapted the landscape using technological innovations to maximize the area affected by the inundation and offset the effects of abnormally high and low floods. These modifications seem to have been relatively rare, but may have had a profound impact on the productivity of Egypt. The first attempts at modifying the landscape involved the construction of dykes around field systems in the basins. Relict river levees formed part of the system as did major transverse dykes constructed to slow the dissipation of the water and increase absorption.[18] This modified form of basin agriculture is normally referred to as “artificial irrigation”.[19] The goal was to trap flood water on marginal lands that were otherwise inundated only for a brief period. Small branch canals helped water to reach low lying areas away from the river, while drainage canals helped to release the water from one basin to another. It is possible that many “canals” could merely have been breaches in the naturally occurring levees beside the Nile, to permit the free flow of water.[20] Nevertheless, the introduction of artificial irrigation was the most important single alteration of ancient agriculture in Egypt.

The Fayum Depression

In antiquity, as today, the Fayum is one of the most agriculturally productive regions of Egypt (Figure 3). Its topography has been studied intensely by geologists, hydrologists,

[18] Some were still visible in the last century, see Butzer 1976: 16.
[19] Butzer 1976: 18-21.
[20] Butzer 1976: 21.

and archaeologists as it preserves evidence for many aspects of past landscape now obscured by the geomorphology of the Nile Valley.[21]

Formation of the Fayum

The Fayum is a natural depression of ca. 1700 km^2 that eroded from the bedrock either by wind action or by solution weathering.[22] This process also formed a number of smaller depressions in the surrounding landscape, including the Wadi Rayan and the Gharaq Basin in the south and a series of small basins along the desert fringe of the northeast Fayum. The Fayum is not an oasis as it does not obtain its water from the aquifer, but from a branch of the Nile.

The Bahr Yusuf

At some point, the Nile broke through the narrow limestone ridge separating the Fayum depression from the Nile Valley near modern Lahun. A branch of the river now known as the Bahr Yusuf entered through the Fayum Gap, supplying water to the region and transmitting the inundation. Sediment deposition from the flood fell out of suspension as the Bahr Yusef passed Hawara, building up a series of fertile plateaux at the eastern end of the depression.

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[21] A general introduction to the landscape of the Fayum is provided by Hewison 2008. For the archaeology: Caton-Thompson and Gardner 1934; Wendorf and Schild 1976; Davoli 1998. Major geological studies: Beadnell 1905; Gardner 1929; Caton-Thompson and Gardner 1934; 1937; Little 1935; Sandford and Arkell 1929; Pochan 1935-6, Ball 1939. Hydrological works: Hanbury Brown 1892; Lucas 1902; Willcocks and Craig 1913; Audebeau 1930; Mehringer, Petersen, and Hassan 1979; 1986.

[22] Said 1993; Shahin 2002.

The connection with the Nile was tenuous, however. Major flood events could cause avulsion at the mouth of the Bahr Yusef closing its access to the river and causing a new channel to form elsewhere. Alternatively, heavy sediment deposition could alter the elevation of its headwaters and affect the total discharge downstream. This difficulty was compounded by the extreme sinuosity of the Bahr Yusuf, a feature which it shared with other branches of the Nile and which continued until quite recently.[23] Butzer reports that in the 19th century the Bahr Yusuf separated from the Nile between Asiut and Manfalut. Today it diverges at Dairut, ca. 80 km to the north. It is often remarked that changes of this sort would have profound effects on the communities along the Bahr Yusuf.[24] Any disruption in the flow of the Bahr Yusuf would, however, have been even more disastrous in the Fayum, where it was the only source of water. There may have been attempts to "canalize" the Bahr Yusuf and make it more stable in antiquity, but such schemes were generally ineffectual even in the early modern period.[25]

Originally, the Bahr Yusuf entered the Fayum and flowed rapidly downwards to the lowest point at the western end of the depression, probably cutting the erosive ravines known today as the el-Wadi and el-Bats drains along its paths.[26] When it reached the bottom of the depression, it pooled and formed a large brackish lake. It

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[23] Butzer 1976: 16.
[24] See above, n. 14.
[25] A reference to this type of activity may be preserved in *SHA Vita Probi* 9.3 (ca. 270-80 CE). Probus is said to have, "opened up the mouths of many rivers" (See Chapter Two). At best this would be a laborious and time-consuming way to fight a natural process which could be repeated at any time. In any case, constructions in or near the river channel could have their own unintended consequences for sedimentation and flow, see Gasser, et al. 1991; Merritt and Wohl 2003.
[26] More commonly referred to as the "Masraf el-Wadi" and "Masraf el-Bats". The word *masraf* means "drain", and indicates their modern use as paths for excess agricultural water.

would have continued this direct path with little agricultural benefit without human intervention. In all periods the course of the Bahr Yusuf in the Fayum was one of the defining features of its landscape and gave rise to certain administrative divisions.

The Birket Qarun

As in antiquity, the most conspicuous aspect of the Fayum landscape today is the Birket Qarun, the Fayum Lake.[27] Ancient authors were captivated by its seemingly miraculous presence in the desert landscape, if somewhat credulous about its size and origins (see Chapter Two). As there is no exit from the Fayum, the flow of the Bahr Yusef pools at its lowest point and, until recent times, could only be removed by evaporation.[28] As a result, the lake has probably always been brackish and slightly saline, although there is as yet no direct evidence for the salinity of the ancient lake.

The size of the Fayum Lake in antiquity has been the subject of scholarship for more than a century.[29] The Bahr Yusuf is assumed to have been in free association with the Nile during prehistoric times when the height of the Fayum Lake is known to have varied, and palaeo-beaches are visible along the rim of the depression.[30] It was doubtless at the mercy of variable flood levels and changes in the course of the Nile. The first direct textual attestation of the height of the lake in any period is, however, provided by Herodotos (II.149-50):

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[27] Clarysse n.d. for the origin of the name Fayum and its association with "Lake" in several languages.
[28] The pumping out of excess water was a solution first proposed by Willcocks and Craig (1913: 837) as a way to develop the Fayum. Today it is pumped into the Wadi Rayan.
[29] For example, Brugsch 1892; Maspero 1894; Fourtau 1896; Audebeau 1930; Caton-Thompson and Gardner 1934; 1937; Bell 1939; Gardiner and Bell 1943; Pearl 1954; Shafei 1960; Vergote 1962; Armayor 1985; Hassan 1986; Evans 1991; Cruz-Uribe 1992; Widmer 2002; Vandorpe 2004; Morini 2006; 2007.
[30] Caton-Thompson and Gardner 1934; Wendorf and Shild 1976.

> Such is this labyrinth; and still more marvellous is lake Moeris, on which it stands. This lake has a circumference of four hundred and fifty miles, or sixty *schoeni*: as much as the whole seaboard of Egypt. Its length is from north to south; the deepest part has a depth of fifty fathoms. That it has been dug out and made by men's hands the lake shows for itself; for almost in the middle of it stand two pyramids, so built that fifty fathoms of each are below and fifty above the water; atop each is a colossal stone figure seated on a throne. Thus these pyramids are a hundred fathoms high; and a hundred fathoms equal a furlong of six hundred feet, the fathom measuring six feet or four cubits, the foot four spans and the cubit six spans.
> The water of the lake is not natural (for the country here is exceedingly arid) but brought by a channel from the Nile; six months it flows into the lake, and six back into the river. For the six months that it flows out of the lake, the daily take of fish brings a silver talent into the royal treasury, and twenty *minae* for each day of the flow into the lake. Furthermore, the natives said that this lake drains underground into the Libyan Syrtis, and extends under the mountains that are above Memphis, having the inland country on its west. When I could not see anywhere the earth taken from the digging of this lake, since this was curious to me, I asked those who live nearest the lake where the stuff was that had been dug out. They told me where it had been carried, and I readily believed them, for I had heard of a similar thing happening in the Assyrian city of Ninus. Sardanapallus king of Ninus had great wealth, which he kept in an underground treasury. Some thieves plotted to carry it off; they surveyed their course and dug an underground way from their own house to the palace, carrying the earth taken out of the passage dug by night to the Tigris, which runs past Ninus, until at last they accomplished their end. This, I was told, had happened when the Egyptian lake was dug, except that the work went on not by night but by day. The Egyptians bore the earth dug out by them to the Nile, to be caught and scattered (as was to be expected) by the river. Thus is this lake said to have been dug. (Loeb Edition, Godley 1938)

Herodotos is followed by Diodoros (1.59.1-3), who provides additional details ca. 60-56 BCE:

> For since the Nile did not rise to a fixed height every year and yet the fruitfulness of the country depended on the constancy of the flood-level, he [Moeris] excavated the lake to receive the excess water, in order that the river might not, by an excessive volume of flow, immoderately flood the land and form marshes and pools, nor, by failing to rise to the proper

> height, ruin the harvests by the lack of water. He also dug a canal, eighty *stades* long and three *plethra* wide, from the river to the lake, and by this canal, sometimes turning the river into the lake and sometimes shutting it off again, he furnished the farmers with an opportune supply of water, opening and closing the entrance by a skilful device and yet at considerable expense; for it cost no less than fifty talents if a man wanted to open or close this work. The lake has continued to serve well the needs of the Egyptians down to our time, and bears the name of its builder, being called to this day the Lake of Moeris. (Loeb Edition, Oldfather 1933).

An additional version is given by Strabo (XVII.1.37) in the early Augustan period:

> Be this as it may, the Lake of Moeris, on account of its size and its depth, is sufficient to bear the flood-tides at the risings of the Nile and not overflow into the inhabited and planted parts, and then, in the retirement of the river, to return the excess water to the river by the same canal at each of its two mouths and, both itself and the canal, to keep back an amount remaining that will be useful for irrigation. While these conditions are the work of nature, yet locks have been placed at both mouths of the canal, by which the engineers regulate both the inflow and the outflow of the water. In addition to the things mentioned, this Nome has the Labyrinth. (Loeb Edition, Jones 1949).

Archaeologists, historians, and geologists have argued incessantly over the apparent contradictions which arise from the account given by Herodotos, who was followed by most other ancient authors.[31] Appeals to scientific evidence have been fruitless, as several early geologists and hydrologists used the statement by Herodotos as a datum in their reconstructions of historic lake levels.[32] Archaeologists and historians have then cited these geological studies to support their claim that Herodotos saw a high-level lake.[33] Much of the confusion seems to stem from Petrie's insistence that the

[31] See the commentary on the relationship between the accounts in Armayor 1985.

[32] E.g. Ball 1939. But see the promising new program of geological coring announced by Hassan and Tassie 2006; Foster, et al. 2008.

[33] Bell 1979; Garbrecht 1996. Only Armayor 1985 has mounted a serious challenge to the hypothesis in recent times, but his account is convoluted and unaware of even the early archaeological evidence.

ancient authors were correct. Of course, his identification of the ruins at Hawara as the Labyrinth was based upon the proximity of a high-level lake which confirmed the account of Herodotos.[34] The usual elevations given for the high-level lake seen by Herodotos range between 15 and 20 m ASL.[35]

Such a level would have submerged the nome capital, Shedet, which is ordinarily assumed to have been continuously inhabited since the 5th Dynasty.[36] New archaeological finds, however, have conclusively proven that the lake was relatively low during the Late Period. *In situ* pre-Ptolemaic deposits have been recovered from both Bacchias (ca. 15 m ASL) and Tebtynis (ca. 20 m ASL), indicating that those sites could not have been submerged and that the lake must have been at least 15 km to the west of Hawara at the time of Herodotos' visit. It seems that Herodotos should not be taken literally, but that his statement was merely meant as an indication that the lake was "impressive".

The Development of Fayum Irrigation

The origins of modified irrigation in the Fayum are unattested. As Shedet was occupied at a very early date it seems reasonable to conclude that modifications similar to those used in the Nile Valley to extend the reach of the inundation would have been used in the Fayum to extend the reach of the Bahr Yusef. These developments are usually

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[34] Petrie 1890. For a recent overview of the lake and its levels, see Morini 2007.

[35] The highest level was given by Petrie, see n. 34. Many researchers feel that the lack of known evidence for Old Kingdom settlement below 18 m ASL, is an indication of the height of the lake at that time, see Froriep 1981.

[36] Shedet was known at other times as Crocodilopolis, Arsinoe, and Ptolemais Euergetis.

attributed to the pharaohs of the 12th dynasty.[37] Specifically, Amenemhat II or III is alleged to have constructed an ambitious diversion dam across the Bahr Yusuf, whose remains may be seen today near Lahun, and which would have used sluices to regulate the flow entering the Fayum and direct excess water along a canal known to have existed to the north.[38] He is also sometimes credited with excavating a canal between Lahun and the lake and constructing the massive reservoir of ca. 100 km^2 behind a storage dam in the southeastern Fayum.[39] Before this purported Middle Kingdom intervention, the Fayum is assumed to have been a large, relatively marshy area with useful products, such as papyrus, reeds, fish, and fowl, but a limited amount of agricultural land.[40]

While there can be little doubt that the 12th dynasty pharaohs were very active in the general vicinity of the Fayum, having constructed their new capital at nearby Itj-Tawy and a series of pyramids at El-Lisht, Dahshur, and Hawara, there is no direct evidence for their participation in modifying the irrigation system. It seems that the earliest source to address these issues is Herodotos. He associated the lake with Moeris and, following him, Diodoros explicitly wrote that the barrage and the canal were constructed by "Moeris". As the name was sometimes applied in the Late Period to semi-legendary great pharaohs of the past, including Amenemhat II or III, Egyptologists

[37] E.g. Luft 1994; Callender 2000; Grajetski 2006, but without citation of ancient evidence for irrigation.
[38] Technically the term "barrage" is inappropriate, as those features are designed to raise the level of water in order for it to enter a canal, see Doolittle 1990: 13 and below. The term "barrage" is already used throughout the literature. For further discussion of the feature, see Chapter Two and Luft 1994.
[39] Garbrecht and Jaritz 1990. They also suggest that this was the Lake of Moeris seen by Herodotos. In any case, its existence, if contemporary, would also preclude a high-level Birket Qarun. The presence of such a reservoir might explain the comment of Pliny (*NH* v.9 and xxxvi.16) that there was a lake (*lacus fuit)* between the Arsinoite and Memphite nomes.
[40] Callender 2000.

concluded that the story in Herodotos and Diodoros preserved a folk origin for the features, a position which may have been proposed quite early by Petrie but only published somewhat later.[41] As Vandorpe has recently argued, however, another interpretation is possible.[42] Moeris may derive from *Mr-Wr*, or "Great Canal". If so, then any association with Amenemhat or other Middle Kingdom rulers is spurious. Archaeological attempts to date the diversion dam and a storage dam used as a reservoir in the southeast Fayum have been based only on comparative walling styles.[43]

The Ptolemies and the Draining of the Lake

It is commonly recognized that the Ptolemies greatly expanded cultivation in the Fayum, perhaps by as much as 1/3.[44] According to the most widely held point of view, the Ptolemies regulated the flow of the Bahr Yusuf into the Fayum and thereby were able to decrease the height of the Birket Qarun through evaporation. The land which emerged from the lake as a result of this process was then settled with veterans as part of an ambitious scheme to expand Greek settlement in the *chora*.

> In essence, this development consisted of a mix of drainage and new irrigation, the construction of new dykes, new canals and drains and the agricultural development of areas previously uncultivated. As suggested below, the change of the Fayum's name from the Marsh to the Arsinoite nome (named after the sister-wife of Ptolemy II) marked more than simply an act of royal recognition; the older name was now redundant.[45]

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[41] Repeated as early as Mahaffy 1891: 21 (*P.Petrie* I), who cites Petrie 1889. Still current without citation in Callender 2002; Cepko 2003; Bard 2008: 171; Ikram 2010: 90.
[42] Vandorpe 2004 with previous bibliography.
[43] Garbecht and Jaritz 1990.
[44] Thompson 1999b: 124, citing Butzer 1976: 74.
[45] Thompson 1999a: 109 and n. 10. See also the quotation from Thompson in Chapter Two.

The assumption is that the lake had been drained by that time. There are however problems with this interpretation.

While the ambitious lake-draining scheme of the early Ptolemies is a commonplace of histories of the Ptolemaic period, the claim is usually made without substantiation.[46] When a citation to an ancient source is provided, it is to the archive of Kleon and Theodoros, where some drainage activities are mentioned.[47] The archive does not, however, include any obvious reference to lake-draining activity. In fact, no ancient author attests to such an activity.

Most recent scholars cite Westermann, although a careful reading shows that he was not aware of an ancient source:[48]

> Under Ptolemy Philadelphus occurred the reclamation of an additional tract of land in the Fayum which was incorporated in the royal domain. This was done by again lowering the level of Lake Moeris, thus diminishing its size and bringing above water and beyond the water level another portion of the former lake bed. *The evidence of this is from geographic data*. Also the archaeological remains found in this region of the Fayum do not in any case antedate the reign of Philadelphus [emphasis mine].[49]

[46] Mahaffy 1895: 144-5; Bouché-Leclercq 1903: 242 ; Bevan 1968: 114-18; Hölbl 2001:62-3.
[47] A claim repeated without citation, for example, in Van Beek's recent dissertation (2006: 18), which is a new textual edition of the archive of Kleon and Theodoros. He explains the absence of such activity by arguing that the principal drainage of the lake had been completed by the time of the archive.
[48] Westermann 1917b, 1919, 1920, 1921, 1922.
[49] Westermann 1919: 162. Recent attempts to date the movement of the lake have been based upon the foundation date of communities, which may reflect the expansion of the system rather than the lowering of the lake. See, for example, Müller 2002; 2003a; 2003b; 2004; 2005; Müller and Lee 2005. Note the methodological criticism of Hoffman and Klin 2006.

The claim may be derived from a passage of Mahaffy in *P.Petrie* 2, or from Grenfell who follows him in the Introduction to *P.Fayum*.[50] Both authors were heavily influenced by Petrie, but it is worth quoting Mahaffy here:[51]

> Far more important are the problems of history and criticism raised by the discovery. In the first place my suggestion, that the second Ptolemy had dispossessed the Egyptian farmers of the Fayyûm for the benefit of his veterans, has been questioned by Mr. Petrie, who thinks it more likely that the new settlement was upon land recovered from the lake by a renewed draining operation, similar to that which had reclaimed the oasis in the days of the XIIth dynasty. When the country fell under careless or incompetent rulers the water-engineering was neglected, and so the lake encroached upon some portions of the oasis, while others were left unirrigated. This was sure to happen in the disastrous days of the decaying Persian occupation, and of the feverish hurry after Alexander's conquest. But if the 2nd Ptolemy, when settled on his prosperous and wealthy throne, sought means to provide for his veterans, whose wars were now over, we can imagine him taking up the old methods of his civilized predecessors, and regaining from the lake a large area suitable for his purpose. By this means land would be created, and a settlement obtained without the violence of dispossessing old inhabitants. Mr. Petrie suggests that the documents reproduced in Autotypes XXII and XXIII of Part I, which are among the oldest of the collection, refer to the very process of marking out the new lots.[52]

It appears that the draining of the lake is based solely upon an hypothesis of Petrie that the Ptolemies undertook a scheme similar to one he proposed to have been developed by Amenemhat II or III.[53] The entire contrivance was designed to salvage the testimony of the ancient authors regarding the height of Lake Moeris.

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[50] Grenfell, et al. 1900: 15 makes the accomplishment more specific: "...the scheme probably originated with Soter or even one of the Persian kings, who may well have reduced the lake to the maximum of ten metres above sea-level and so brought the edge of the second plateau out of water."

[51] Mahaffy 1893: 13-14.

[52] Mahaffy 1893: 13-14. The connection between specific documents and lake-draining activity is no longer accepted. See above, n. 47.

[53] Armayor 1985: 24 claims that the originator of the theory was Hanbury Brown (1892), but Brown thanks Petrie in his work.

It is also worth noting the assumption that the best new land was at the bottom of the depression, where hypothetical lake shrinkage had exposed the fertile sediments beneath.[54] Doubts can be raised about this interpretation for additional circumstantial reasons. For example, Apollonios, the *dioiketes* under Ptolemy II and one of the most powerful men in Egypt, received a 10,000-*aroura* land grant in the Fayum which is well known from the archive of Zenon, his property manager.[55] Yet his property is commonly assigned to the vicinity of Philadelphia, not the shore of the lake. It is difficult to believe that such a powerful individual, and one known for throwing his weight around in his own interests, would receive less than the best.[56] Either the land near the lake was not particularly good (it is unquestionably the worst land in the Fayum today), and/or the majority of expansion took place on the desert fringe and not in the vicinity of the lake.[57]

There are also reasons to doubt the “innovative” nature of the Ptolemaic expansion program which has been characterized as the establishment of a new irrigation system to support villages on the periphery of the Fayum. As Davoli writes:

> We still have much to learn about the settlement history of the Fayum. At Tebtynis and Bakchias, located respectively on the southern and north-eastern margins of the region, occupation levels datable to the Late Period have been reached in recent excavations. The fact that these two settlements existed before the Ptolemaic Period and were provided with water from two man-made canals located on the periphery of the region

[54] Found as early as Bouché-Leclercq 1903: 242. It is repeated or assumed by Lewis 1986: 37-45; Thompson 1981; 1999a; 1999b; 2007. See especially, Thompson 1999a: 109.
[55] See *P.Zenon.Pestm.* Suppl. A and SB XX 14624; Thompson 1999a: 118-20.
[56] Apollonios repeatedly used his position to extort public labor from the *architekton* Kleon to be used for the development of his private land, for example. See Lewis 1986 and Van Beek 2006.
[57] A position which is now more common, see Davoli 2010: 353-4, quoted in part below. The land at the desert fringe is surprisingly fertile, see Chapter Five. For the fertility of certain areas near the lake in the Islamic period, see Rapoport and Zohar n.d.

> raises questions about when these canals came into effective use, or what other sources of water the settlements may have drawn on before the Ptolemaic land-reclamation scheme.[58]

In this light, the repeated references to "the old dike" in the vicinity of the new projects undertaken by Kleon in the northeast Fayum take on new meaning, although it is impossible to assess the location and relative date of the feature without further information.[59] Certainly, the central portion of the Fayum was already inhabited and cultivated, presumably using techniques identical to those in more established areas of the Nile Valley.[60]

Scholars have interpreted the activity of Kleon and Theodoros as an innovative and ambitious new undertaking in the Fayum which was beyond the capabilities of traditional Egyptian agriculture, and was only made possible by the importation of skilled Greek engineers.[61] If a previous irrigation system already existed, even on the periphery of the Fayum, then it may be that Kleon and Theodoros were more administrators than engineers. An early deputy of Kleon was an Egyptian named Petechonsis.[63] Another deputy was Pathemios or Pathemis, whose name betrays a

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[58] Davoli 2010: 353, pre-empting one of the conclusions here, but perhaps unaware that Caton-Thompson and Gardner (1937) had proposed an Old Kingdom date for at least one of the canals in the vicinity of Bacchias. See below, Chapter Four.
[59] Van Beek 2006: 27 and n. 75, citing documents #92, 93, 96, and 111. See also, Thompson 1999a: 111 and n. 22. "New dikes" are mentioned in Van Beek 2006: #92 (*P.Petrie* III 37a), #93 (*P.Petrie* III 37b), and #97 (previously unpublished). Note also the possibility of an earlier system mentioned in passing by Van Beek (2006: 22 and n.66).
[60] In particular at the nome capital, Shedet, and at Medinet Madi/Narmouthis and Tebtynis. Confronted with ambiguities in the documents, Van Beek (2006: 22 n. 66) writes that some form of irrigation system may have been established, "as early as the 26th dynasty (664-525 BC)".
[61] See above n. 51.
[63] Westermann 1919: 162. See also Van Beek 2006.

Theban origin and raises the possibility that he was transferred to the Fayum.[64] There is no doubt that some of the Egyptians resettled from the valley believed that the Greeks were completely ignorant of irrigation issues in Egypt.[65]

Much of the discussion of irrigation in the Fayum has been mired in debates concerning the level of the Birket Qarun, but these disputes have finally been put to rest by recent discoveries. While there is no doubt that the early Ptolemaic Period saw a major expansion in the total arable land of the Fayum, there is no ancient evidence to support a project of draining the Fayum Lake and the innovative nature of the attested activity remains open to debate. If the peripheral areas of the Fayum could not have been inhabited until the introduction of a canal system, as is often supposed, then these Late Period remains suggest the presence of an earlier canal system in the vicinity.[66]

The Operation of Fayum Irrigation in the Graeco-Roman Period

There is sufficient information to describe the operation of the Graeco-Roman irrigation system of the Fayum, particularly in its early phases, in broad outline from an hydraulic perspective. Certain aspects of the evidence and the almost complete lack of archaeological investigation preclude a detailed reconstruction, however (see Chapter Four).

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[64] Van Beek commentary on #91 (*P.Petrie* III 43 (2) Verso, Column II, line 170). He writes: "Perhaps he advised Kleon and/or Theodoros, who were Greek architects, as a native expert in Egyptian irrigation."
[65] Thompson 1999b: 136-7, citing *P.Lond*. VII 1954 (Oct./Nov. 257 BCE) and 1955. "In agriculture, as in other local practices, they [Greeks] needed to learn the ways of the land. Such, at least, was the native view."
[66] As noted in Chapter 5, canal alignments have a limited lifetime and often need to be re-cut. The new alignments usually follow the general line of the old. The projects of Kleon and Theodoros may have been an extension of the current system or an undertaking of this type.

> Unfortunately, many irrigation features were recorded by individuals who know very little about water control, even though they appreciate its importance. The lack of experience some investigators have with irrigation has resulted in a variety of terms being used to describe similar features. For example, the terms "canal," "ditch," "channel," and even "aqueduct," have all been used in discussing functionally identical earthworks. Such inconsistency can cause confusion for a comparative analysis. There is also some confusion as to what is actually involved in canal irrigation.[67]

Unfortunately, imprecise or misleading terminology has been a common feature of studies of irrigation systems around the world. Doolittle's comments on the bewildering array of terms which have been used in studying prehistoric water systems in Mexico could describe the current situation in Egypt equally well. Archaeologists, historians, and papyrologists, whose training emphasizes other aspects of the ancient world, often have only a passing knowledge of hydrology and irrigation and have chosen to adopt local or modern terminology in their studies, whether or not it is precise or appropriate to the ancient material at hand. This problem is compounded in Egypt, where a large number of texts can be used to reconstruct the components of the ancient irrigation system, but where the ancient terminology is rarely preserved and often arcane, making it difficult to understand in context.

Translation of the sources into modern languages thus becomes a two-stage process of interpreting the ancient technical terminology and choosing the appropriate hydraulic terminology in one of a number of modern languages. This process provides two separate opportunities for error, either by mischaracterizing the ancient material

[67] Doolittle 1990: 11-12.

and its function or by importing imprecise and anachronistic terminology. Nevertheless, a remarkable amount of research has been conducted on the terminology of ancient irrigation as preserved on papyrus, most notably in the monumental work of Danielle Bonneau.[68] This brief summary of the irrigation system of the Fayum will attempt to employ standard hydraulic terminology used to describe irrigation systems in other parts of the world.[69]

Property Types:

All canal systems have three major levels, each with specific features: head, distribution and field.[70] Discussion of the Fayum irrigation system usually assumes that the head of the system is at Lahun, where the Bahr Yusuf enters the Fayum. From an hydrological point of view, however, the head is where the system first intersects with the river or stream channel, the key point in water distribution. From this perspective everything downstream from the intersection of the Bahr Yusuf with the Nile was part of a single ancient irrigation system, including the peripheral desert canal which carried excess water diverted away from the Fayum to the north from Lahun to Giza.[71]

Diversion dams, *barrages*, *weirs*, or other features designed to raise the hydraulic head of the main channel or to divert flow into a canal are often found at the

[68] Especially Bonneau 1993. But see also, Calderini 1920a; 1920b; Cadell 1970; Krüger 1991; Anagnostou-Calas 1994; Andrews 1994; Hengstl 1994; Manning 1994. The Demotic terminology has received only cursory study, see Bresciani 1994.
[69] Following the English terminology in Smith 1975; Nials and Gregory 1989; Doolittle 1990; Foster, Woodson, and Huckleberry 2002. The summary is based upon Bonneau 1993 and Van Beek 2006.
[70] Doolittle 1990.
[71] See Chapter Two.

head of the system.[72] No concrete evidence for such a feature is known at the source of the Bahr Yusuf in antiquity, but would not be surprising. Certainly, by the end of the Ptolemaic period "clever devices" are attested at the source of the Bahr Yusuf and at the Lahun diversion dam to help regulate flow (Strabo, quoted above). The presence of a regulation device, usually referred to as a *head gate*, at the source may also imply channelization, enlargement, or redirection to regularize flow.[73]

Confusion concerning the location of the head for the Fayum irrigation system results from the presence of a second regulation device at or near Lahun. As it is not at the head of the system, hydrologists would refer to this device as a *sluice gate*.[74] The ancient Fayum sluice gate was constructed, at least in part, of stone and seems to have had at least 4 apertures which could be opened or closed to regulate flow.[75] Unfortunately, this feature is often referred to as a series of "locks" in recent literature, but the latter term is anachronistic and has the more specialized meaning of a device used to raise and lower vessels on a waterway.[76] The sluice gate was located in the middle of a longer diversion structure, whose remains may perhaps be visible today.[77]

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[72] Doolittle 1990: 13-14.

[73] Doolittle 1990: 13.

[74] Doolittle 1990: 15. See below.

[75] For the structures referred to as *katakleides* in the papyri, see Van Beek 2006: #34, 86. Presumably, they are the *kleithra* described by Strabo (above). For problems in transporting stone to 'the locks' at Ptolemais, see Thompson 1999a: 115 and n. 42 and *P.Petrie* II 18a = III 42G (7) a.9-12. The term *thyra* (and *hexathyros*) was also used and seems to designate the same feature, see Pearl 1951; Bonneau 1993: 73-7. It is mentioned frequently because it was a responsibility of the *architekton*, see Van Beek 2006: #18, 19, 21, 34, 35, 38, 44, 48, 88, 118, 115 and *P.Koln* (V?)III 342. For the number of gates, see Van Beek 2006: #88, lines 7-20.

[76] Features of this type are not attested until the 1370s in the Netherlands. But see the confusing account of al-Maqrizi (Casanova, Trans. 1895-1920).

[77] The dates of the diversion structures known as the Gisr el-Bahlawan (Southwest) and Gisr el Sheikh Gadallah (north) have not been established. They have probably been reused in multiple phases. The papyri seem to refer to the diversion structure as *ochyroma* in *P.Petrie* II 13 (3) = III 42 C (8).1-2.

The term *barrage* designates a construction designed to impede flow, raising the hydraulic head of a channel in order to divert water into a nearby irrigation system; thus, the term is inappropriate at Lahun which seems to have only diverted excess flow into a canal running north in order to regulate the volume of water entering the Fayum.[78]

Every distribution system includes a *main* (or *principal*) *canal*, in this case the Bahr Yusuf, which brings water to the area to be irrigated.[79] From the sluice gate at Lahun, the canal proceeded to the nome capital, Shedet/Crocodilopolis.[80] Along its course several *distribution canals* diverged to follow the landscape at a high elevation.[81] At Shedet, where there was likely another set of sluice gates, additional distribution canals spread out to irrigate the central Fayum plateaux, just as they do today.[82] Smaller canals known as *lateral canals* or *branch canals* departed from the larger distribution canals at intervals and led to the immediate vicinity of the fields.[83] *Field canals*, in turn, led the water from the lateral canals to the individual fields, which were surrounded by *bunds*, built up earthen mounds designed to retain water on the fields until released

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78 But the term remains very commonly used in the literature.

79 Doolittle 1990: 14. The Nile was known as "the river", *potamos or Mēgas Potamos*, but the term was also colloquially applied to the Bahr Yusuf and some other canals in the Fayum, see Van Beek 2006: 25; Bonneau 1993: 5-12. Many other canals have names, such as the *Diōryx Kleonis*, but ancient dykes rarely do, see Van Beek 2006: 28

80 Referred to as *T3 Ḫn.t-n-Mr-Wr* in Demotic and even "the river" (*potamos*) in Greek.

81 Principally, the high-level desert canals which fed the northern and southern periphery of the Fayum. The distribution canals seem to be referred to by the term *dioryx*, which designates a comparatively large canal which led to a *hydragōgos* (P.Tebt III.703, 208BCE), see Bonneau 1993: 13-18. The latter should be the term for a lateral (or branch) canal. For *hydragōgoi*, see Van Beek 2006: #91, 97, 111, 90; Bonneau 1993: 21-2; for a *periagōgos* Van Beek 2006: #20.

82 Sluice gates in general are designated by the term *apheseis*, see Van Beek 2006: 26.

83 The divergence of two canals was known as a *dialēmma* or, perhaps, *stoma*, see Van Beek 2006: 26; Bonneau 1993: 68-72. Additional sluice gates may have been involved at some locations. For one at Theognis, see *P.Petrie* III 48.3-6; *P.Petrie* II 37 (5) = III 44 (2); *P.Petrie* II 13 = III 44 (1).5-6, 13; III 44 (3).3-5.

into *ditches* or *drains*.[84] Ditches could lead back to the higher order canals for recycling or could direct the excess water to lower elevations through a series of ditches of ever-increasing size. The latter seems the most common solution in the Fayum, although the Masraf al-Wadi and Masraf al-Bats may have been used for drainage in antiquity as they are today.[85]

Thompson has suggested that the introduction of canal irrigation in the Fayum led to differential agricultural practices within the Fayum.[86] She argues that on the periphery perennial irrigation was used near canals for orchards and vineyards, while a modified form of basin agriculture was practiced in the central portion of the Fayum. In actuality, canals were present in all parts of the Fayum, although vineyards and orchards, which do not endure standing water, may have been more common on the periphery.[87] The individual fields in the Fayum were undoubtedly flooded and the water retained behind bunds. There is, however, no evidence for "basin agriculture" in the sense normally used in the Nile Valley and irrigation techniques were probably quite homogeneous (see above).

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[84] An *eisagōgos* may have been a lateral or a field canal, Bonneau 1993: 23. A *perichōma* was a set of bunds around a field or set of fields. *Emblēmata* (later called *diakōmmata*, see Bonneau 1993: 44) were transverse dykes, see Van Beek 2006: 27-8; Bonneau 1993: 39-44. See also the model field system laid out with illustration in *P.L.Bat.* XX, pp. 254-6. The term *exagōgos* could be used for a ditch, see Van Beek 2006 #25. However, every canal could also serve as a drain.
[85] Of course, their paths will have changed somewhat since antiquity, particularly at their incipits where recent erosion will have lengthened them. This point is usually overlooked in topographical studies, e.g. Kraemer 2010.
[86] 1999b: 127-30. The idea that the Ptolemies revolutionized agricultural practices has a long history, see Johannesen 1923.
[87] Manning 1999; 2002; 2003; 2009: 157-8.

Construction Techniques

The papyri present a picture of canals lined with earthen dykes to contain their flow.[88] Frequent mention is also made of wooden stakes, which were pounded into the surface of the dykes to provide interior reinforcement, perhaps only at weakened points in the system.[89] Rushes were built into the dykes or packed onto their surface for stabilization.[90] The root systems of vegetation typical of canal environments would also have provided solidity.[91] The course of some canals could also be modified to manage or control the velocity of the water.[92]

While many of the canals were earthen constructions, it would be logical to assume that wherever possible more enduring features, such as bedrock, would have been utilized on at least one side of the canal. Some support for this view comes from

[88] For *chōmata* as dykes along canals, see Van Beek 2006: # 18, 20, 33, 41, 79, 88, 91-3, 95-7, 111; Bonneau 1993: 35-9. The term *dyke* is correctly applied to the high mounds along canals, but the use of the term in Egypt to mean *bund* or *embankment* when discussing the basins of the Nile Valley creates confusion. In Chapters Four and Five, the term *berm* is preferred for the features on the sides of canals.

[89] The practice of reinforcing the dykes with wood was known as *paraphraganismos*. See Van Beek 2006: #20, 90, 91, 113. The stakes, *katapēges*, were driven and then perhaps tied with ropes.

[90] *Thryon* (rush) and *kalamos* (reed). Reeds were perhaps also known by their Egyptian name, *anouchi*, see Van Beek 2006: 28.

[91] Note that the ancient site of Bacchias was known as Kom Umm el-'Atl ("The place of the mother of the tamarisk"), long before modern canals were reintroduced into the area.

[92] The term *skēlos* may indicate a drop-structure to diminish velocity in area of rapid change of elevation, see Chapter Five.

the archive of Kleon and Theodoros, where stone-cutting is a major component of the documents of the engineers responsible for the irrigation system.[93]

Management and Maintenance

As Doolittle writes of prehistoric irrigation systems in Mexico:

> In sum, canal irrigation systems are composed of a number of different types of features, each varying considerably in size and characterized by varying degrees of technological complexity. These features can be, and have been, combined in a seemingly infinite number of ways. Depending on the combination, canal irrigation can range from simple diversion of an ephemeral stream flow to a small single field, to the transport of water several kilometers, over numerous obstacles, through intricate networks of branch canals and onto elaborately prepared fields. ... The existence of such variety in different locales at different times attests to a complex sequence through which the technology developed.[94]

The management and maintenance of such a complex irrigation system must have been a daunting task. Frequent cleaning operations are attested by a maintenance contract dating to early in the Ptolemaic Period and by the *penthemeros* certificates of the Roman Period, although not every segment of every canal could have been cleaned in a single year.[95] In addition, the quantity and location of sedimentation in the channels would have depended on local aspects of canal hydrology and would not have spread

[93] The presence of documents attesting to stone-cutting activities has often been ignored, see Van Beek 2006: 31-5. Undoubtedly some of the activities were designed to procure material for harbors and sluice gates, but it may be that some documents indicate canal cutting. Further examination of the issue is required in light of the many bedrock channels near Karanis. See below, Chapter Four and Chapter Five.
[94] Water could also be taken directly from the main canal to a field. This was not always a good idea, as man-made breaches in the side of a major canal could destabilize the entire structure.
[95] See above, Chapter Two. Thompson 1999a: 113-14. She provides a calendar of maintenance operations according to 3rd century BCE papyri in Appendix C. Note the description of a maintenance contract in *P.Petrie* III 43 (2) iii = *Select Papyri* II 348.

the burden equally over the Fayum.[96] Wind-blown sand accumulation could also be a problem in canals.[97]

High-level management may have been complicated to some extent by existing administrative divisions. As noted above, the Fayum irrigation system really begins at the headwaters of the Bahr Yusuf. However, that point lay outside the boundaries of the Arsinoite nome and therefore out of the control of its officials.[98] This may explain why administrative circulars concerning irrigation are often addressed to the *strategoi* of the Heptanomia **and** Arsinoite nomes.[99] In any case, mismanagement outside the Fayum could have disastrous implications within.

Stability of the System

Earthen canal systems are known to breakdown and wear out. Intense changes in water velocity can be generated in systems leading to sudden breaches of the dykes, while the slow but cumulative erosive power of lower velocity water can also lead to collapse.[100] Unintentional breaches were a well-known problem in the Fayum, particularly at several

[96] Surely the reason why many penthemeros certificates attest to travel away from home communities to undertake compulsory service. Only two penthemeros certificates are from outside of the Fayum (Heptanomia and Hermoupolis Magna), see Sijpestein 1964.
[97] Thompson 1999a: 113 and n. 37 citing *P.Petrie* II 4(11) = III 42 D (2), 254 BC, where sand is cleaned out of a (new?) canal in the southern Fayum.
[98] Westermann 1917b: 427-8 points out that Kleon and Theodoros had responsibilities only within the Fayum.
[99] For example, *Select Papyri* II.225 = *P.Oxy*. XII.1409, quoted in Chapter One.
[100] For rough water disrupting system, see Thompson 1999a: 114 and n. 47, citing *P.Petrie* II 37 (5) = III 44 (2).

key points.[101] Instability is inherent in systems of this type, as even minor changes to channels upstream can lead to unpredictable variations in flow rate downstream.

Evidence of major maintenance and reconstruction programs is sometimes taken as evidence of decay or decline in the preceding period. The Persians, Ptolemies,[103] Romans,[104] and Byzantines[105] have all been accused of letting the system break-down. There is, however, no reason to believe that these work programs indicate decline rather than necessary periodic maintenance.[106]

Conclusions

The development of the Fayum irrigation system was not an event but a process. The innovation usually ascribed to the Ptolemies is a construction of modern scholarship which may have obscured long-term development of the system in preceding periods, but the dearth of evidence from those periods indicates that archaeological investigation may be the only available source of further information concerning the development of the system.

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[101] Intentional breaches in dykes are *diakomma*; unintentional are *ekregmata*. See Bonneau 1993 and Van Beek 2006: 29. Thompson 1999a: 115 for the need to check the build up of dyke near a gorge in *P.Petrie* III 39i.12-13, ii.9-10, iii.9-10. Could this be the el-Bats or el-Wadi drain?

[103] Mahaffy, *P.Petrie* II, p. 13, for both Persian and Ptolemaic neglect. (Quoted above).

[104] Westermann 1917a: 239 and n.6, following Wilcken, feels that the operations recorded in Suetonius *Augustus* 18 demonstrate Ptolemaic neglect. Further, "Competent engineering and an effective system of irrigation had given them [the canals] hard upon 600 years of life. The decline of this system gave them back to the desert," Westermann 1919: 163-4 commenting on actions of Probus ca. 270-80 CE. As an attempt to check decline.

[105] Préaux 1947: 15, writing about the periphery of the Fayum "…ces terres que la négligence des temps byzantines rendit au sable que les ensevelit encore aujourd'hui."

[106] The claim that they indicate decline may say more about scholarly biases against certain periods than about the reality of irrigation in ancient Egypt.

Chapter Four: The Archaeology of Irrigation Systems in the Fayum and Around the World

The Graeco-Roman Period irrigation system of the Fayum has been studied from various perspectives using the documentary evidence preserved in the papyri (Chapter 3), but very few archaeologists have ever investigated this important feature of the ancient landscape. A few medieval historians and early modern travellers commented on the relict channels and abandoned villages which could be seen in the Fayum. Later, several of the early excavators made similar comments about the location and size of abandoned canals and speculated about their date and origins. It was not until the 1920s, however, that Gertrude Caton-Thompson and Elinor Gardner published a comprehensive examination of one part of the system from an archaeological perspective. Despite the remarkable prescience of the researchers and the ambitious early application of geoarchaeology and other interdisciplinary approaches to the problem, their interpretation of the system was hampered by the undeveloped state of canal studies at the time. Since then, no serious archaeological research has been undertaken on the subject. Thus, the Fayum canal system remains virtually un-studied despite the wide range of methodologies now employed around the world for the study of canals. Clearly, the time is ripe to undertake a re-assessment of the Fayum canal system.

Early Observations of the Irrigation System

Several early travellers mention the canal system of the Fayum. In his *Tarikh al-Fayum*, the Ayyubid historian ‘Uthman ibn Ibrahim **an-Nabulsi** described the geography and inhabitants of the Fayum in his time, ca. 1245 CE, as part of survey designed to increase agricultural output.[1] The work is full of antiquarian details concerning the landscape and its history and includes important information concerning the operation and location of the contemporary irrigation system. The peripheral Fayum villages which had been abandoned by that time, including Karanis, are occasionally mentioned.

Another description of the Fayum is featured in the writings of the Mamluke period historian and polymath Taqi al-Din Ahmad ibn 'Ali ibn 'Abd al-Qadir ibn Muhammad **al-Maqrizi** (1364-1442). One of his more than 200 preserved works is an historical and topographical description of Egypt.[2] The author is prone to fanciful details and occasionally seems to have been rather credulous. Nevertheless, he is the only preserved writer to describe the massive dam regulating the flow of the Bahr Yusuf at Lahun and the operation of its sluices as well as other aspects of Fayum irrigation.

Several early excavators mentioned the relict canal system preserved in the desert on the periphery of the Fayum. Petrie remarked on the massive channel visible

[1] Keenan 1999; 2003.
[2] Maqrizi 1906.

on the periphery of the Fayum depression and followed its course along both the northern and southern branches.[3] Grenfell, Hunt, and Hogarth commented in particular on the ancient, “well-defined watercourse which divides the mound” at ‘Umm el-Atl (Bacchias).[4] Modern agricultural expansion had already begun in the northeast Fayum since Petrie’s observations, however, and they also reported survey pegs in the desert indicating expansion plans, “a little within the line of the ancient canal bed explored by Prof. Petrie in 1890. Within this reclamation Umm el ‘Atl will eventually be included.”[5]

The long-term excavation project (1924-35) of the University of Michigan at Karanis focussed exclusively on the kom. Little mention was ever made in their publications concerning the surrounding landscape, although it seems to have been commonly accepted by the team members that the earliest habitation at the site was on the south side of the kom near the ancient canal, even if the conclusion was only an informed supposition. Husselman writes:

> The general topography of the site must also be considered in assigning dates to houses. The excavations definitely showed that the town spread from the south, close to the canal which was the source of the water supply, northward, expanding at the same time both to east and west.[6]

Caton-Thompson and Gardner

While some early archaeologists noted the presence of relict canals in the Fayum, the pioneers of canal studies in Egypt were the unlikely duo of Gertrude Caton-Thompson

[3] Petrie, et al. 1891: 29-32, esp. 30.
[4] Grenfell, Hunt and Hogarth 1900: 35.
[5] Ibid.
[6] Husselman 1979: 8.

and Elinor Gardner. In 1924 Caton-Thompson, a prehistorian, began a project to study the abundant Palaeolithic and Neolithic sites on the north shore of the Fayum Lake.[7] Under the auspices of the British School of Archaeology in Egypt and its director, Sir Flinders Petrie, and later the Royal Anthropological Institute, she was granted a large concession and began to locate and record the well-preserved and remarkable sites in the area. Almost immediately, she recognized that the location of the prehistoric sites was directly linked to the changing shorelines of the ancient Fayum Lake and that any attempt to reconstruct the changing prehistoric occupation of the landscape would require a detailed understanding of the geology of the region and a reconstruction of the lake's changing characteristics over time. As a result, Elinor Gardner joined the project as geologist in 1925.

From the beginning, the conception of their project was remarkable for several reasons. First, the pairing of archaeologist and geologist to investigate the complex relationship between humans and the landscape foreshadowed the development of geoarchaeology as a discipline.[8] Second, the study of the natural environment and the evolving cultures within a wide area over time using survey and excavation presaged the emergence of landscape studies in the later twentieth century. Third, the investigation and publication of historical sites by a project with primarily prehistoric objectives was a rare example of diachronic research in Egypt. While the terminology to accurately

[7] For an overview of Caton-Thompson's archaeological career in Egypt, Yemen and Zimbabwe, see her autobiography, Caton-Thompson 1983, and the biography in Drower 2004.

[8] Rapp and Hill do not mention the work of Caton-Thompson and Gardner in their history of the geoarchaeological scholarship, 2006: 1-24. It is, however, referred to as one of the "milestones in the history of interdisciplinary archaeology," Butzer 1976: 1.

describe their methodology had not yet been developed, there can be no doubt that Caton-Thompson and Gardner recognized the revolutionary nature of their research:

> ...the work as it proceeded burst the original bounds of inquiry, and developed into a regional survey embracing the historic as well as the prehistoric remains in the area. This unpremeditated expansion was inherent in the method of inquiry which, it was quickly recognised, needed to be framed, not on established models of predynastic excavation viewed as a purely archaeological job, but on *anthropogeographical* lines, in deference to the unique opportunities suggested by the peculiar local physical conditions provided by shifting lake margins of past ages. These, without precedent at the time in archaeological experience, invited a fresh method of treatment which would endeavour to do justice to those conditions in relation to man's reactions to them, as well as to use old lake-levels as stratigraphic agents of archaeological control.[9]

Caton-Thompson's and Gardner's three seasons of work (1924-25, 1925-26, and 1927-1928) were published in a series of preliminary articles on geology, on the Fayum Lake, and on the Neolithic cultures of the region.[10] A comprehensive synthesis of their archaeological conclusions was later published in two volumes as *The Desert Fayum*.[11] While their methodology was quickly adopted by others, many of their conclusions were not and there was prompt, if not always fair, criticism by other geologists and archaeologists.[12] Their more general conclusions about the Fayum and its prehistoric habitation have to some extent been superseded by more recent work, but Caton-

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[9] Caton-Thompson and Gardner 1934: 1. Emphasis mine. Their methodology was quickly adopted elsewhere, for example by Louis Leakey in Kenya, see Caton-Thompson and Gardner 1934: 1, n.1.

[10] Caton-Thompson 1925; 1927; 1928b; 1928c; 1928d; 1935a; 1935b; Caton-Thompson and Gardner 1924; 1929; Caton-Thompson, Gardner and Huzzayin 1937; Gardner 1927; 1929; Gardner and Caton-Thompson 1926.

[11] Caton-Thompson and Gardner 1934. Gardner also published a monograph on the lacustrine molluscs of the Fayum (Gardner 1932).

[12] Petrie 1925; 1926; Sandford and Arkell 1929; J.B. 1935; Little 1935. For a more favourable view, see Burkitt 1935; Myers 1935; Wainwright 1937. Caton-Thompson, Gardner and Huzzayin 1937 is a reasoned response to much of the criticism, which incorporates additional research but is often ignored in the literature.

Thompson's and Gardner's investigation of the Ptolemaic canal system near Karanis remains the lone, in-depth archaeological analysis of canals in the Fayum.

The Ptolemaic Irrigation System

At the very beginning of her work on the north shore of the Fayum Lake, Caton-Thompson recognized a number of Graeco-Roman sites in the landscape:

> During the first season (1924-5) a group of small mounds with Graeco-Roman sherds, and a long line of low eroded embankment south of the L. Basin were noticed. A cutting into the mound exposed the wall of a mud-brick house. As the site was clearly a small settlement of classical age, and our programme was already overloaded with prehistoric questions, investigations were not pursued, nor was the purpose of the embankment ascertained.[13]

While the embankment and Graeco-Roman sites were a low priority in 1925, a rare series of heavy rainstorms in November 1927 changed the situation. Shortly after the rains, seedlings began to sprout along the embankment in parallel lines running through the desert. These traces, and others subsequently located in the vicinity, were rapidly recognized as the remains of ancient canals preserved in the landscape (Figure 9).[14] Caton-Thompson and her team decided immediately to investigate the canal system, given the transient nature of the vegetal remains and the relationship between an irrigation system and long-term variations in the height of the Fayum Lake.

As a result, Elinor Gardner undertook the location, mapping, and recording of the canals, while her brother, Captain Guy Gardner, excavated a number of related

[13] Caton-Thompson and Gardner 1934: 140-1.
[14] Caton-Thompson and Gardner 1934: 141.

mounds and other features in order to provide dating evidence for the occupation of the system.[15] Recognizing the potential importance of the discovery for contemporary schemes to expand irrigation in the Fayum, the Irrigation Department, then part of the Ministry of Public Works, which also managed archaeological projects, supplied labor and a *carte-blanche* permit to explore the region.[16] As a result, Caton-Thompson and Gardner were free to pursue the irrigation system wherever its remains might be found, despite ongoing disputes with the University of Chicago concerning the boundaries of the archaeological concession.[17] Over the course of three months, more than 16 miles (ca. 25.7 km) of relict canals were traced on the ground revealing a complex, fragmentary, and at times confusing plan of the irrigation system (Figures 5-20).[18] However, Caton-Thompson and Gardner reached several important conclusions based on their examination of the system.

Extent and Source of the System

Caton-Thompson's and Gardner's first objective was to document the extent of the system as preserved on the ground. While recent plant growth aided in the initial location of relict channels, it was not uniform across the area and did not occur along

[15] Caton-Thompson and Gardner 1934: 140-53, Plates LXXXVII-C. Work was carried out from December 11, 1927 to March 20, 1928. Caton-Thompson 1960 is an obituary of Capt. Guy Gardner with discussion of his contribution to the archaeological work.

[16] In exchange for plans and a full report. They were submitted by Gardner in April 1928 to Ahmad Bey Ragheb, then with the Department of Irrigation in the Fayum. Only a summary of the full report appears in *The Desert Fayum*. See the discussion in Caton-Thompson and Gardner 1934: 8-9, 142. Attempts were made to locate this report in the archive of the Irrigation Department at Medinet al-Fayum during two visits in October and November 2008. While it could not be found, the discovery of an off-print signed by Gardner and dated 1926 suggests that the original report may still exist in the archives.

[17] For the treatment of the team by various individuals and institutions, see Caton-Thompson and Gardner 1934: 6-9.

[18] Caton-Thompson and Gardner 1934: 140-53, Plates LXXXVII-C; the plates are duplicated here with the kind permission of the Royal Anthropological Institute as Figures 5-20.

every channel. Rather, plant development seemed to be related to the amount of comparatively rich soil preserved in the berms on either side of the sand-filled canals, and this contrast was reflected in the development of parallel lines of growth on either side of the channels. This process occurred most dramatically in areas where the preserved berms were comparatively substantial. However, the low embankments seen on the desert surface did not always provide an appropriate medium for growth, as some of them were not accumulated deposits of silt removed from the canals during maintenance operations, but heaps of bedrock removed during the initial excavation of the canals and subsequently covered by wind-blown sand.

In all cases the canal alignments could only be followed for a relatively short distance before they disappeared. In order to trace the canals further and to examine the construction of the canals, Gardner excavated "several hundreds of trenches" at intervals across individual channels and beyond their last known position.[19] This prospection often extended the known length of the canals for a short distance, but usually the channels became shallower and shallower until they could no longer be identified. As the canals were unquestionably constructed to maintain their slope, the relatively short segments which were preserved suggest that most of the alignments were preserved only where the channel had to cut through bedrock; whereas above-ground portions, which would have been built-up above the surrounding landscape using soil, had deflated by wind erosion and no evidence for them remained.

[19] Caton-Thompson and Gardner 1934: 141. The trenches were not individually published. Selected sections are marked on Caton-Thompson and Gardner 1934: Plate LXXXVII (Figure 5) and the following section drawings, but the scale is not sufficient to relocate them accurately.

Caton-Thompson and Gardner requested aerial photography from the Cairo office of the Royal Air Force, which had specific instructions to support archaeology in Britain and abroad. They hoped to be able to identify additional channels and to accurately map the system. For some reason, though, the flights never took place - an omission which later resulted in something of a scandal in *The Times*.[20] Nevertheless, the remains of nine substantial canals (labeled A-I) were recorded over an area of ca. 20 square miles (ca. 51 km^2) in the desert to the north of ancient Karanis.[21] All of the channels lay between sea level and 20 feet above sea level (ca. 0 - 6.1m ASL) and ran along the slopes above a series of small, naturally-occurring basins (named, from west to east, the X-, L-, and K-Basins).

Nature of the Irrigation System

All of the canals located by Caton-Thompson and Gardner were segments of channels cut into the bedrock. Deflation and other processes had apparently removed the lighter sediments where berms had been constructed on the surface to contain the flow.[22] For that reason, it was not possible to establish connections between the identified components of the system despite the numerous trenches cut in likely locations.[23]

All of the channels had been filled with wind-blown sand, some of which was designated as "fine white lake sand", some as "yellow drift". Only Canal A at the eastern

[20] Caton-Thompson and Gardner 1934: 141. See also Crawford 1928 and Caton-Thompson 1928a. The founder of aerial archaeology archaeology in Britain O. G. S. Crawford, unaware of the details, blamed Caton-Thompson and Gardner publically for the missed opportunity.
[21] Karanis is indicated by its modern name, Kom Aushim, on Caton-Thompson and Gardner 1934: Plate LXXXVII (Figure 5).
[22] Caton-Thompson and Gardner 1934: 145.
[23] See above, n. 18.

extremity of the system contained a "hard silty layer of clay and sand of varying thickness" and no evidence was found of the "Nile mud" so typical of the Egyptian landscape. Based upon the fact that river sediments of typical type were not visible in the contemporary lake, the authors concluded that river-borne silt had fallen out of suspension earlier in the system.[24]

Another trench excavated closer to Philadelphia revealed the relict main channel as it ran north towards Bacchias (Figures 19-20).[25] The U-shaped channel was ca. 135 feet wide between the berms. The berm on the Fayum side was built up from channel clean-out, while that on the desert side was really a reused terrace of the Pleistocene lake at ca. 17.5 m ASL; 5 feet of windblown sand surmounted a hard layer of "Nile mud" with the remains of many reeds preserved *in situ* which was excavated to a depth of an additional 10 feet. Excavation was abandoned before the bottom of the channel could be reached, but the channel was estimated to be 16 or more feet deep based on the slope. Water marks in the interior of the channel indicated that it had rarely, if ever been filled beyond a height of 22 feet from the projected bottom. A section drawing of the channel was produced (Figure 19), but little additional detail was provided in the publication.

[24] Caton-Thompson and Gardner 1934: 142.

[25] Brief mention of this trench "three tenths of a mile north of the Gerza road" is made in Caton-Thompson and Gardner 1934: 144 and Plates civ, cviii.

Dating of the System

As the relict canal channels had been excavated into the soft bedrock, their construction could not be dated stratigraphically. However, the excavation of several groups of ancient houses and a reservoir which were found in close proximity to the channels permitted certain conclusions about the period of use of the canals (Figures 11-12).[26] Excavations in the houses recovered ceramics datable to the early Ptolemaic period (Figures 13-18) and numerous coins of Ptolemy II Philadelphos were identified.[27]

Caton-Thompson and Gardner used this evidence to suggest that the canal system was part of the well-known expansion of Fayum agriculture which occurred in the early third century BC, and that it was directly related to activity described in the recently published Kleon and Zenon archives.[28] The fact that several channels were unfinished, combined with the limited date range of the numismatic evidence, led

[26] See further Chapter 5 and Appendix 2. The excavation of related features is an accepted technique used today for dating canal alignments within broad periods. See below.

[27] Caton-Thompson and Gardner 1934: 150-152. Apart from one coin which was arguably dated to the reign of Ptolemy III Euergetes. The coins were sent to Cambridge for inspection and, presumably, remain there. The majority of the ceramics excavated from the Ptolemaic houses were given to the Bankfield Museum in Halifax, Yorkshire, but seem to have been transferred subsequently to the Kirklees Museums in West Yorkshire. See, Museums Libraries Archives Council, Cornucopia. "Bankfield Museum: overview of collections." http://www.cornucopia.org.uk/html/search/verb/ListIdentifiers/set/location/462. Retrieved 2010-08-04. Additional ceramics from the reservoirs were sent to University College, London, and "Newbury". The latter may be the West Berkshire Museum in Newbury. See the comments on dating in Appendix 2.

[28] The Kleon (*P.Petrie* I-III; Bouché-Leclercq 1908) and Zenon archives (P.Cair.Zen I-V). See also Caton-Thompson and Gardner 1934: 152. Their at times close relationship with the University of Michigan team would have ensured a general knowledge of recent papyrological publications concerning the irrigation system.

Caton-Thompson and Gardner to conclude that the irrigation system was, "an experiment which failed, and it reverted to desert before the accession of Euergetes.[29]

Function of the Irrigation System

Caton-Thompson and Gardner concluded that the irrigation system must have been fed by a high-level canal from the east and that its primary objective was to reach Dime (Soknopaiou Nesos), although no connection to the undated field systems visible in aerial photographs of that site was ever located.[30] The irrigation system, however, was used to irrigate the series of Basins to the north of Karanis *en route*. The desiccated remains of vine-clippings and date palms were recovered during their excavations, showing that the basins had been irrigated and cultivated in antiquity.[31] Caton-Thompson and Gardner hypothesized that the abandonment of the irrigation system was related to problems with the water supply to the east, perhaps under the influence of a 1926 article by A. Boak.[32]

Limitations of the Study

Caton-Thompson and Gardner accomplished a remarkable amount in a very short period of time and with limited resources. However, there are certain unavoidable limitations inherent in their published account. Most notably, their report is extremely short (14 pages and 16 plates) and lacks the detail considered standard in more recent

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[29] Caton-Thompson and Gardner 1934: 152.
[30] Caton-Thompson and Gardner 1934: 143-4. Debates about lake levels during the Ptolemaic period had raised the possibility that the objective was to drain the basins of lake water. Gardner did not believe that Dime was the ultimate objective, Ibid. n. 4.
[31] Caton-Thompson and Gardner 1934: 142.
[32] Caton-Thompson and Gardner 1934: 152; Boak 1926.

publications of canal alignments. This was the result, in part, of publication costs, and was unavoidable considering that the irrigation system was not the focus of their research.[33]

However, the vast number of trenches and the extreme length of the system were ill-suited to such a brief report. Only selected vertical trench profiles are indicated and they often differ wildly in size and depth without a clear explanation visible in the longitudinal sections; precise measurements cannot be taken from them (Figures 6-7). Unfortunately, the authors did not have the benefit of canal excavation experience and did not record, or at least did not publish, many of the smaller details of construction and variation which might have helped in their interpretation. A related omission concerns the drawing of sections. Gardner, a geologist, went to great pains to record the sections which had been excavated and give an overall impression of channel shape and size. However, the drawings do not include the berms identified on the surface; if the berms were, in fact, used to contain the flow at peak flood, that information would be essential to interpretation.

More serious was their assessment of the dating and use of the system. While they correctly used the date of related structures to infer a period of use, they did not take all of the known small rural sites into account. For example, while they believed that the system to the north of Karanis had been abandoned by the time of Ptolemy III (246-222 BCE), they labelled on their map a site at the northern end of the L-Basin as a "Roman Gebel". They do not report the basis for their dating of the site, which is

[33] Although a much longer report was submitted. See above, n. 15.

otherwise unremarked in their work. Assuming that it is of Roman date, it is difficult to imagine how such a remote site could have functioned without a water supply. The very presence of a Roman site should indicate that at least part of the irrigation system lasted much longer (see also Appendix 2).

The failure of the Royal Air Force to provide aerial photography was a missed opportunity. Most early aerial photography of Egypt is focussed on individual sites, rather than the landscape as a whole. Properly taken images might have assisted in the location of missing parts of the irrigation system, particularly in the vicinity of Canal A and points further east, but the loss of a chance to record a large pre-modern desert landscape in the Fayum is most regrettable.

The irrigation system might also have benefitted from detailed consideration in the broader context of the recently-published papyrological evidence concerning Fayum irrigation. Caton-Thompson and Gardner pay lip service to the information contained in the documentary sources in their brief report and cannot, of course, be blamed for leaving the task to specialists. It is, however, a great shame that their work has only rarely been cited by papyrological works on Fayum irrigation and even then as a curiosity.

Subsequent Research

Faced with intense criticism of their conclusions concerning the various levels of the palaeo-lakes and their dates, Caton-Thompson and Gardner returned to the Fayum in

1935.[34] They conducted further work in an area to the east of Bacchias, in the vicinity of "Izbet George", where several of the lakeshores were clearly preserved.[35] As part of their work, they excavated a series of long trenches perpendicular to the ridge in order to expose the geology.

In their trenches were the exposed profiles of two major relict canals: a high level canal at ca. 19 m ASL and a lower canal at ca. 17 m ASL. Both channels appeared to depart from the main ancient alignment to the southeast. The high canal was traced for ca. 900 m but it was lost as it approached an Old Kingdom kom rising from the 18 m ASL contour line.[36] A single Old Kingdom sherd recovered from the interior of the high canal led the excavators to suggest that the canal itself might have dated to that period, as the kom would not have been viable otherwise.[37] The lower canal paralleled the line of the Abdullah Wahbī canal on the north side of the latter and appeared to continue all the way to Bacchias. Near Izbet George, two sinuous branches of the lower canal diverged, crossed and reconnected over a distance of ca. 1 km.[38]

Recent Research on the Fayum Irrigation System

Relatively little archaeological work has been done on the Fayum irrigation system since 1937. A survey project conducted in the southern Fayum identified the probable

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[34] Caton-Thompson, Gardner and Huzzayin 1937, with figures.
[35] The village no longer appears on the 1:50,000 maps of the area, but the 1957 Arabic 1:100,000 *Medinet al-Fayum* sheet preserves a site at the location titled "Izbet Khrāmbu" (or Izbet Khrtbu?). In brackets beneath is "Nhrbt".
[36] The Old Kingdom kom was the well-known Kom 5 reported by Petrie 1891: 31. See also Caton-Thompson and Gardner 1934: 101.
[37] A suggestion which has remained unchallenged, but also virtually unnoticed, since then.
[38] It is virtually certain that one channel was cut to replace the other in an unstable area along the slope.

location of the desert canal in the vicinity of Kom Talit.[39] Additional work by the project documented the remarkably well-preserved canal alignments and irrigation basins at Medinet Watfa (ancient Philoteris) but did not excavate them.[40] Another recent publication has used de-classified satellite imagery to trace the line of the Graeco-Roman canal in the vicinity of Hawara and to speculate on the reasons for its abandonment in Late Antiquity.[41]

Garbrecht and Jaritz conducted an examination of a relict storage dam, usually referred to as the Itsa-Shidmoh Dyke, in 1988.[42] The research was primarily concerned with the question of whether the dyke had supported a large reservoir which could be filled by the annual flood and later used to extend the irrigation season in part of the Fayum. They concluded that the dyke dated to the early Ptolemaic period, or earlier, and that it had been used to fill the al-Mala'a Basin. Excess water spilled over into the al-Gharaq Basin.[43] However, their conclusions were based primarily on comparison of masonry styles and the knowledge that agricultural production was increased in the Fayum under the Ptolemies.

[39] Rathbone 1996; 1997; 2001.
[40] Römer 2003; 2004.
[41] Kraemer 2010, republishing, with many corrections, Kraemer 2007.
[42] Garbrecht 1987a 1987b; 1996; and Jaritz 1990; 1992.
[43] They also felt that this artificial lake, not the Birket Qarun, was the Lake Moeris seen by Herodotus.

A World Archaeology of Irrigation Systems

The emergence of geoarchaeology as a discipline has opened up new avenues for the archaeological investigation of irrigation systems.[44] In places as diverse as Cambodia, Peru, and Iran, archaeologists have worked to develop effective methodologies for describing and interpreting canals and related features and theoretical models for interpreting them at various levels of analysis. Karl Butzer's seminal study of *Early Irrigation Agriculture in Egypt* remains one of the defining works of geoarchaeology, but the impediment created by meters of Nile alluvium has to some extent restricted the detailed study of the irrigation system and its development over time.[45] More recent research in Egypt has tended to focus on the alluvial geoarchaeology of the Nile.[46]

Among the Old World cultures, developments in Mesopotamia, where historic and prehistoric canals have a 5,000 year history, have been particularly important.[47] Arguably, however, the most innovative approaches have been developed in the arid environments of the New World.[48] Taken together, these developments have established a veritable "World Archaeology" of irrigation systems which can be applied

[44] For recent general introductions of geoarchaeology, see Rapp and Hill 2006 and Goldberg and Macphail 2006. For alluvial geoarchaeology, see Brown 1997. Jusseret 2010 attempts to combine geoarchaeology with social archaeology.
[45] Butzer 1976.
[46] E.g. Hassan 1981; 1997; Stanley, et al. 2003; Stanley and Jorstad 2006; Bunbury, et al. 2008. But concerning the Fayum, see also Hassan 1986; Hassan and Tassie 2006.
[47] Adams 1965; 1966; 1981; Neely and Wright 1994. A recent overview from a landscape perspective is provided by Wilkinson 2003. See also, Bienert and Häser (eds.) 2004; Morozova 2005.
[48] Doolittle 1990; Foster, Woodson and Huckleberry 2002.

anywhere.[49] They are adopted here, with an emphasis on methodologies applicable to arid environments.[50]

Locating Relict Irrigation Systems

The first goal of every archaeological study of irrigation systems has been to delineate their extent and a variety of techniques have been applied to this task with more or less success. Many alignments are discovered accidentally, in the cuts of construction sites or natural erosive features, or through conversations with farmers and others familiar with the landscape. In undisturbed areas, traces of the system may be visible on the ground. Relict berms are often the most noticeable feature and can be seen in oblique lighting conditions, but parallel ribbons of surface artifacts or rock may be indicative also.[51]

Remote sensing is the most recent and perhaps the most obvious source of data for the study of canal systems.[52] Satellite imagery has been particularly effective in high-visibility landscapes or in areas where low-level aerial photography is prohibited or discouraged.[53] The advent of more cost-effective high-resolution imagery has eliminated some of the problems inherent in trying to use coarse imagery to locate relatively small

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49 Scarborough 2003; Ortloff 2009.

50 The single best work on the archaeology of irrigation systems in arid environments is Foster, Woodson and Huckleberry 2002. Focussing on the Hohokam canal systems of southern Arizona, the work synthesizes all prior methodologies into a handbook of research for archaeologists and forms the basis for the discussion here.

51 Foster, Woodson and Huckleberry 2002: 116.

52 Parcak 2009; Trement and Pasquinucci 2000

53 Philip, et al. 2002; Gregory and Parcak 2002; Wouter, et al. 2004

channels.[54] Some recent, high-resolution imagery has already been used effectively in the Fayum for other purposes, but it has not yet been applied to the irrigation system in any detail.[55]

Traditional aerial photographs, however, are often a more cost-effective tool than satellite imagery, and they can be taken at relatively low-altitude with better resolution.[56] Aerial photos taken for military purposes and declassified satellite photographs from the last century have the added advantage of documenting the landscape before significant modern alterations.[57] They have proven to be remarkably effective in the desert and pre-desert regions of the Middle East and North Africa,[58] while infra-red and near-infra-red photography has proven useful in identifying canal systems in areas of dense vegetation or cultivation.[59] In Egypt, the emphasis has been on identifying relict river channels.[60]

Locating alignments using pedestrian survey and other terrestrial techniques, such as coring, are less cost-efficient than using satellite and aerial imagery in the long run. Nevertheless, they are a necessary adjunct and are the only means of "ground-truthing" the interpretation derived from the remote sensing data. Coring over fixed intervals along transects using a hand-auger is a relatively simple technique when the

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[54] Note the debate concerning scale and phantom canals in Pope, et al. 1989; 1993; Adams, et al. 1990.
[55] For other uses, see Bakir and Rantrua 1990; Bitelli 1997. Kraemer 2007; 2010 attempted to use Google Earth imagery in the eastern Fayum.
[56] Antje and Rod 2005; Bitelli, et al. 1997
[57] Stein, et al. 1985; Kennedy 1998; Philip, et al. 2002, Bescoby 2006
[58] e.g. Kennedy 1990; Blumberg, et al. 2004; Wilkinson, et al. 2006; Moshier and El-Kalani 2008; Wilkinson, et al. 2010.
[59] Nichols 1988.
[60] E.g. Sneh and Weissbrod 1973.

approximate location is already known, but is slow and inefficient for larger systems.[61] Ground penetrating radar (GPR) and magnetometry can also provide excellent results in suitable areas, where the channel fills contrast sufficiently with the geological background, but are only practical over limited areas.[62] Distinguishing ancient from modern alignments can be problematic in the absence of artifacts and requires a good knowledge of local conditions.[63] In any case, prospection techniques must be suited to the landscape, the scale of the irrigation system, and the desired results.

Investigation of Irrigation Systems: Excavation

Once irrigation systems have been located and recorded, selective excavation has proven to be the most efficient and accurate means of further investigation, especially to date the introduction and chronological development of the canal systems.[64] In the American Southwest, backhoe trenching is the most popular technique as it is a rapid means of cutting numerous vertical sections perpendicular to the alignment, but it cannot be done everywhere. Excavation is usually conducted to a depth and width well beyond the dimensions of a channel in order to expose any related features, including alignments, which may have been cut by the canal or buried by its associated sediments or berms.[65] It is also common to excavate trenches beyond the known alignment in hopes of locating and excavating lateral channels. When the latter are located, attempts

[61] Stein 1986; Bunbury, et al. 2008; Giraudi, et al. 2009.
[62] Foster, Woodson and Huckleberry 2002: 117. For GPR in arid environments, see Conyers 1998; 2004 Conyers and Cameron 1999.
[63] Foster, Woodson and Huckleberry 2002: 118.
[64] Howard 1993; Foster, Woodson and Huckleberry 2002: 117.
[65] Additional features such as *caliche* formations and stains of iron/manganese which leach out of waterlogged channels may also be visible as a result. Foster, Woodson and Huckleberry 2002: 118.

are made to work back to the intersection of the two channels, establish their relative date, and locate any water-control features.[66]

Documentation of Relict Systems

Accurate description of the channel profile is undertaken following excavation. Drawings and photographs record the plan and vertical profile of channel, berms, and associated features. Slope may only be determined accurately once a number of profiles have been exposed along the alignment. Given frequent variations in construction techniques and occasional lack of care by workmen, however, some excavators feel that the channel bottom can be a poor indicator of slope. Over a relatively great distance, surface slope may be a more reliable guide.[67]

Sediments in the channels and the berms and any bankwash or other surface deposits are recorded according to one of several standards, such as USDA Soil Nomenclature, and sampled for particle-size analysis.[68] Particular attention is given to the bedding of the sediments which is indicative of the mechanism of deposition. Bedrock and soil are recorded according to geological and pedological nomenclature.[69] Various types of sampling may be conducted for laboratory analysis by specialists,

[66] Foster, Woodson and Huckleberry 2002: 119 and Fig. 5.14.
[67] Foster, Woodson and Huckleberry 2002: 119.
[68] Foster, Woodson and Huckleberry 2002: 119. A general introduction to sediment analysis in archaeology is provided in Stein and Farrand (eds.) 2001. See also, Hassan 1978.
[69] Vogel 2002.

depending upon the objectives of the project.[70] Formation processes, including cultural modifications, should also be considered.[71]

Dating of Irrigation Systems

While ceramics can provide secure, datable evidence in stratified contexts, quantities are often low and their presence in the canal channels is fortuitous.[72] Some ceramics may have been moved downstream by the flow and examination is needed to determine whether abrasion and rounding of sherds indicates water-borne deposition.[73] In the absence of other evidence, the date of associated sites may be used to provide a broad chronological range for canal operation.[74]

One aspect of canal maintenance present in almost every culture is periodic burning-off of vegetation which would otherwise choke the flow within a channel.[75] *In situ* deposits of carbonized organic material are ideal for C^{14} testing and have proven useful in dating the use and abandonment of irrigation features. There is, however, still a relatively large margin of error, even when calibrated to dendrochronology, leading to

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[70] Foster, Woodson and Huckleberry 2002: 121-4. Common samples include those used for dating (see below), for particle-size analysis (sediment), for environmental reconstruction of the surrounding landscape and of the channel itself (pollen, ostracode/mollusc, fish remains, charcoal/ash), and for determining geological parent material (sediment).
[71] Foster, Woodson and Huckleberry 2002: 130-1. For example, modern irrigation systems sometimes sacrifice efficiency for equality or other considerations, Kalu, et al. 1995. This serves as a reminder that non-hydraulic considerations may be at work in the relict channels.
[72] Foster, Woodson and Huckleberry 2002:126.
[73] Ackerly, et al. 1987; Allen 1989. Surface sherds will have been affected by post-depositional processes unique to arid environments, see Fanning, et al. 2009 for a discussion of the surface record in an Australian context.
[74] Foster, Woodson and Huckleberry 2002: 126. The technique is less accurate the longer a canal alignment is occupied.
[75] Bakhry 1992, for a discussion of the weed problem in modern Egyptian canals.

interpretation within only broad periods.[76] Testing of unrelated charcoal or other organic materials is possible, but the "old wood" problem limits its applicability.[77]

An intriguing attempt has been made to use archaeo-magnetism to date canal sediments themselves, but it does not yet appear to have been widely adopted outside of the United States.[78] Samples must be taken by specialists and only certain types of sediments are viable. The most reliable recent technique is Optically Stimulated Luminescence (OSL) dating of sediments, but it can be expensive and requires dedicated laboratory facilities.[79] Only a combination of techniques can ultimately succeed in establishing the phases of construction, use and abandonment of a canal system.

Palaeohydraulic Analysis of Canal Alignments

Once an alignment has been located, excavated, documented, and sampled, it is possible to begin an analysis of its hydraulic properties. As higher-energy flows will transport larger particles, the particle size of sediments filling canal channels may be used as proxy evidence to estimate water velocity.[80] Sediment analysis has also been applied to determine the nature or causes of the abandonment of particular canals and innovative attempts have been made to assess the efficiency and stability of canal systems stratigraphically.[81] The overall health of an irrigation system may be inferred

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[76] Helbaek 1972; c.f. Neely and Wright 1994.
[77] Rick, et al. 2005 discuss the "old shell" problem.
[78] Eighmy and Howard 1991; Ellis and Brown 1998.
[79] Bishop, et al. 2004; Berger, et al. 2004a; 2004b; 2009; Fiebig 2009. For a general introduction to using luminescence dating, including OSL, for archaeological purposes, see Duller 2008.
[80] Huckleberry 1991; Howard 1993.
[81] Allen 1965; Huckleberry 1999. Bakhry and Khattab 1992 discuss the flow regime of modern Egyptian canals; Bakry and Awad 1997; Kahlown and Kemper 2004 discuss problems of seepage.

from its stability and may be combined with analyses of ostracodes/mollusks, pollen and macrofossils to determine the presence and type of cultivation along the banks, annual duration of canal operation, maintenance frequency, periods of abandonment, variability of annual flood levels, and patterns of environmental change.[82]

The estimate of water velocity may be combined with the cross-sectional area of the channel to determine flow-rate.[83] From these basic physical characteristics of individual canal channels it is possible to calculate maximum annual discharge of each channel and of the system as a whole. The annual discharge may be used in turn to estimate maximum irrigable area under various crop types, and the carrying capacity of the landscape.[84] These determinations are, however, only as accurate as the underlying data.

Beyond the Physical Remains

It is possible to move beyond basic palaeohydraulic reconstructions of individual canals and canal systems. As sophisticated organizational skills are required to construct and maintain canal systems, the archaeological remains of canals have been used to infer patterns of social organization.[85] In particular, there has been considerable discussion of the role of irrigation in state formation. The recognition that the construction and administration of irrigation systems do not require a central state authority, but are often conducted by local irrigation communities, has greatly advanced the

[82] Palacios-Fest 1994; Huckleberry 1995; Foster, Woodson and Huckleberry 2002: 126-8; Adams, et al. 2002; Borsch 2004.
[83] Farrington 1980; Howard 1993; Huckleberry 1999.
[84] Huckleberry 1991; Howard 1993; Foster, Woodson and Huckleberry 2002: 124-5.
[85] e.g. Butzer 1976; Howard 1993; 2006.

interpretation of canal systems (Chapter 2).[86] Additional studies, both archaeological and ethnographic, have focused on cooperative action at the local and regional levels,[87] legal restrictions and water rights issues,[88] and health issues,[89] to name only a few topics. Contextualized and interdisciplinary studies of the Fayum irrigation system remain out of reach, however, pending further archaeological investigation.

Conclusions

The pioneering study of the ancient irrigation system in the Karanis hinterland is a remarkable testament to the talents of Caton-Thompson and Gardner. It is disappointing that their work is not more widely known among Graeco-Roman archaeologists working in the Fayum and that no one pursued the questions they raised about irrigation and agriculture in that area. This lack of attention is all the more surprising as the canal system has been at the heart of several debates concerning the occupation history of the Fayum and its economic viability. However, the development of dynamic geoarchaeological methods for the study of irrigation systems has opened up new possibilities for archaeological fieldwork on the Fayum irrigation system and the time is ripe for a re-examination of Caton-Thompson and Gardner's work.

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[86] Butzer 1976; Hunt and Hunt 1976; Hunt 1988; Hunt, et al. 2005; *contra* Wittfogel 1957.
[87] Hunt 1986; 1990.
[88] Caponera 1978.
[89] Watts and El Samiha 1997.

Chapter Five: Preliminary Results of Survey and Excavation

Archaeologists have investigated hydraulic systems around the world for many years. As a result, they have developed a sophisticated fieldwork methodology and several elaborate interpretive frameworks for studying hydraulic systems. The disciplinary restrictions on the study of the Egyptian past have stunted the application of these innovative approaches to the ancient hydraulic systems of Egypt. In 2007 and 2008, the author conducted independent fieldwork on an ancient canal system known to exist near the ancient site of Karanis (Kom Aushim) in the northeast Fayum as a member of the UCLA/RUG Fayum project, directed by Drs. Willeke Wendrich (UCLA) and René Cappers (Groningen) with the approval of the permanent committee of the Supreme Council of Antiquities of Egypt.[1] The survey and excavation conducted as part of this fieldwork is the first archaeological re-examination of the canals originally discovered by Caton-Thompson and Gardner in the 1920s and is the first application of recent archaeological techniques to the study of the ancient irrigation system in the Fayum.

[1] The project has since added Professor Simon Holdaway (Auckland) as an additional co-director.

The Survey Zone

The UCLA/RUG Fayum Project holds one of the few large-area archaeological permits in Egypt. The concession covers an area of ca. 250 km² on the north shore of the Fayum Lake, the Birket Fayum, extending from the Dynastic temple of Qasr as-Sāghah in the northwest to the Greco-Roman village site of Karanis in the southeast. This large area approximates the concession given to Caton-Thompson and Gardner in the 1920s and encompasses most of the sites they investigated, including the unique Neolithic period sites of Kom K and Kom W, as well as the greater part of the Graeco-Roman irrigation system which they identified in 1927 and 1928. The permit area also includes the remains of several small rural sites dating to the Greco-Roman period and the larger ancient villages of Kom Aushim (Karanis), Qaryat Hamra, and Qarit Rusas (see Appendix 2).[2]

The survey zone lies on a desert plateau to the northeast of the Fayum Lake and outside the Fayum proper (Figure 22). From the highly saline modern lake at ca. -47 m BSL, the landscape rises sharply to the north at a series of exposed geological outcroppings. The Tertiary marine beds of the Birkat Qārūn Series are composed of a series of alternating, superimposed limestone, sandstone, and shale layers. Above them, and filling the numerous depressions on the plateau at ca. 0 m ASL are Pleistocene marine deposits, most visibly diatomaceous deposits, associated with an early and much larger lake. The plateau rises gently to another escarpment ca. 15 km to the north

[2] Qaryat Hamra is a Roman period site as yet unconnected with an ancient name. Qarit Rusas, sometimes referred to as Tel er-Rusas, although it is a rocky outcropping rather than a kom or tel, also dates to the Roman period and may be identified with an ancient village known as Niloupolis, see Bonneau 1979b: 259.

where the Eocene Qasr as-Sāghah formation is exposed and rises to more than 200 m ASL (Figure 23).[3]

The plateau north of Karanis is much more varied in elevation than the areas to the east and west. Several large geological depressions, which were designated (from east to west) the K-, L-, X-, and Z- Basins by Caton-Thompson and Gardner, dot the landscape over an area of several kilometres and the easternmost two basins form a viable agricultural area today (Figure 22). Outside the basins, most of the plateau is a deflated desert landscape typical of the Western Desert of Egypt. Erosion of the lighter surface sediments has deposited a dense layer of heavier chert pebbles across the surface forming a desert pavement (Figure 24). Dunes are actively being formed to the west by the predominant north and northwest winds, but they have not yet intruded on the survey zone.[4]

Modification of the Landscape

Virtually all of the survey area lies in what is today outside the main cultivated area of the Fayum. While certain areas to the north of Karanis were irrigated in antiquity, the area must have been reclaimed from the desert originally and has since returned to its natural condition. The deflated desert surface provides excellent visibility, but the landscape has been modified significantly since the visits of Caton-Thompson and Gardner. The modern Cairo-Fayum Highway runs roughly northeast to southwest along the north side of the ancient village of Karanis and now separates the site from its

[3] Caton-Thompson and Gardner 1934; Wendorf and Schild 1976; Said 1993: 78-81.
[4] Gad and Abdel-Samei 1999, for a discussion of desertification in the Fayum.

cemetery. Clearing, levelling, and construction have altered the landscape on either side of the highway for a distance of some 50 m. In addition buried gas lines, electrical cables and phone lines run parallel to the highway and have added to the distortion in that part of the landscape. Major industrial parks now exist along the highway north of Karanis and along the desert edge to the west of the site. Composed of several dozen factories, warehouses and offices, these areas have been completely transformed and, in many cases, walled off from the surrounding landscape. Dumping of manufacturing wastes severely limit the surface visibility of archaeological remains.

To the west of Karanis and, to a lesser extent, to the north of the cemetery, large tracts of land have been given over to quarrying. The impact has been greatest to the west, where mechanical excavators have removed surface sediments and bedrock to a depth of up to 16 m (Figures 25-6). Some of these open quarries are several kilometres in circumference and virtually all archaeological sites in the area have been completely destroyed. In addition, the removal of clay and other fine particles from the quarries has deposited a layer of fine dust over the surrounding landscape, especially to the south and southeast of the quarries, where it is driven by the prevailing winds. This powdery covering rules out examination of the natural surface in many areas.

Military activity has also altered the landscape. To the north of Karanis in what Caton-Thompson and Gardner referred to as the K-Basin, lies the modern military airbase of Kom Aushim and its attendant housing complexes (Figure 22). This area has been levelled to facilitate the construction of runways, surrounded by perimeter fences, and is off limits to non-military personnel. Additional military areas exist to the west and northwest of the airbase. In particular, two major Soviet-era anti-aircraft installations, now abandoned, are still officially off-limits.[5] One occupies a topographic high point south of the L-Basin overlooking the Fayum Lake, the other lies on a rise just to the north of the same basin. Both have transformed major parts of the landscape, as heavy equipment was used to level an area more than 500 x 500 m in each case and massive concrete bunkers have been installed below ground. Apart from the obvious physical damage caused by these primary installations, the landscape has also been disturbed by a number of access roads and smaller secondary installations which surround them. Construction debris and occasional toxic deposits litter the periphery of the military sites.

At some time following the investigations of Caton-Thompson and Gardner, intensive irrigation agriculture was reintroduced into the survey area. While less obviously intrusive to the casual observer than recent constructions, the impact of agricultural activity, including deep mechanized plowing, has had the greatest impact on the landscape. Tractors equipped with accurate levelling systems are used to make each plot horizontal (Figure 37); this practice ensures that irrigation water remains on the plot for as long as possible and that it is equally distributed. The result is a series of uniform terraces which obscure topographic features and destroy archaeological evidence on the surface.

Another pernicious aspect of modern agriculture has been the extension of fields along the desert edge by shattering the bedrock (Figures 54-5). In several locations,

[5] Cyrillic newspapers buried just below the surface sand at one of the sites suggest that they were occupied until at least the late 1960s or early 1970s.

particularly to the west of Karanis and inside the K- and L-Basins, backhoes and other heavy machinery have been used to crack and remove the weathered but well indurated surface limestone and sandstone, exposing the poorly-indurated and relatively fertile marine shales beneath. In these areas even canals cut into the bedrock have been completely obliterated.

Both the K- and L-Basins and their immediate vicinity are now subject to intensive farming, but an ambitious series of development plots has also been laid out in the desert to the north of those basins and sold to investors. Large cement lined canals and subsidiary water distribution systems have been established in a grid over a large area (Figure 22). While it seems unlikely that the individual plots will ever be irrigated given the increasing demand for water in the Nile valley and the consequent scarcity of water already visible in the Fayum today, the preparatory earthmoving in the area has had a detrimental impact on the archaeological record, including the destruction of at least part of the so-called "Kom K Pits" (a Neolithic food storage site) and a series of purportedly-Roman period burials near a small gebel to the north of the L-Basin (Appendix 2).[6]

Apart from the numerous small agricultural villages which dot the landscape of the K-Basin and L-Basin, several larger villages have been established to service the airbase and its staff (Figure 22). Most notable are the cleverly-named Qarya Number One, Qarya Number 2, and Qarya Number 3, which have been established on a

[6] Of course, the location of ancient sites by the construction teams has also led to extensive robbing. It is most obvious at the so-called "Roman Gebel" and on along ridge running west from the site of Karanis where numerous rock-cut tombs have been looted (See Appendix 2, Figures 27-8). Several informants spoke of local "wizards" who sold their services to identify buried treasure below the ground.

limestone ridge between the basins.[7] All of the villages have been constructed on rocky prominences in order to avoid unnecessary occupation of the limited agricultural land. This has resulted in the destruction of several ancient settlements, which seem to have occupied similar positions for similar reasons. All of these factors have affected visibility and preservation and have made archaeological fieldwork more difficult and time-consuming in the northeastern Fayum.

Methodology

During two seasons, between September and December 2007 and September and December 2008, the author examined the ancient hydraulic system preserved in the survey area. The fieldwork had two primary objectives: 1) to relocate and reassess the relict canal alignments identified by Caton-Thompson and Gardner in 1927-8 in the light of recent methodology, and 2) to attempt to locate and assess new alignments unknown to Caton-Thompson and Gardner, particularly in the vicinity of Karanis. Given the vast area included in the permit, the author utilized a combination of field walking, communication with local informants, and consultation of satellite imagery in order to locate the canals. They were then inspected visually on the surface and later by excavation in selected areas.

The canal project purchased georectified, color (16 bit, 5-band) 2.4 m resolution Quickbird satellite imagery from Digital Globe through MapMart.com.[8] It encompassed

[7] Referred to locally as "First Village", "Second Village", and "Third Village".
[8] The imagery was captured on 06/26/2002 (western section), 06/03/2008, and 07/09/2008 (eastern sections).

an area of ca. 262 km^2 extending from to the northwest of the X-Basin to slightly east of Karanis. Pan-sharpening in ArcGIS improved the resolution to ca. 0.70 m. The inclusion of a near-infrared band permitted the production of false-color, near-infrared imagery.[9]

Two factors had a fundamental impact on the methodology of the project. The first was the profound transformation which the landscape has undergone since the 1920s. In many areas visibility and accessibility were restricted on the ground and it was necessary to rely upon the satellite imagery in conjunction with brief, inconspicuous visits rather than a program of unrestricted field walking. The second factor was the limited topographic information presented by Caton-Thompson and Gardner in their original publication. Gardner created her base topographic map from scratch at a scale of 1:50,000 (Figure 5); while the map is accurate and represents a major accomplishment in itself, its scale is not sufficient to facilitate quick relocation of the individual canal alignments in the field. In fact, the lines designating each canal alignment are marked on the map with heavy line-weights and correspond to a width of between 50-500 m on the ground. This problem is compounded by the fact that the map is marked with topographic lines at 20 foot intervals based upon the height of the 1920s lake, while the modern 1:50,000 topographic map is marked in 10 m intervals in the desert (but 1 m intervals in cultivated areas). The resulting representations of the landscape are very different and not easily reconciled on the ground although the placement of the major topographic features and the relative positions of individual features are beyond doubt.

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[9] A recent discussion of the value of satellite imagery for archaeology, with a special emphasis on Egypt, is provided by Parcak 2009.

This representational margin of error is compounded by the lack of easily recognizable modern features on the map. In fact, the site of ancient Karanis (designated “Kom Aushim”) and the lake-side prominence known as Qarit Rusas (“Tel er-Rusas”) are the only two points which may be securely located. The modern highway near Karanis is not represented, nor had any of the current settlements been established in the 1920s; the shore line of the lake has also been altered as the result of a rising water level. Large-scale earthmoving in the quarries and the agricultural areas has also distorted the geographical contours of the survey area, often into forms which cannot be reconciled with the topographic maps.

Field Survey Methodology

The project began with an attempt to relocate the westernmost, and presumably least-disturbed, canal alignment, Canal G. The author walked a series of SW-NE transects perpendicular to the reported canal alignment in its approximate location. The feature was located relatively rapidly with the aid of oblique early morning and late afternoon light which caused the low berms of the canal to throw shadows on the desert surface (Figure 29). However, it required two weeks of additional field walking to locate all of the preserved portions of the alignment, which had been frequently interrupted by quarrying activity.

The satellite imagery was of limited application even after a portion of the Canal G alignment had been located. The relatively narrow distance (ca. 6.0 m) between the parallel preserved berms made the soil marks indicating the canal alignment virtually indistinguishable from the dozens of desert tracks which run through the landscape near the modern quarries, even after their approximate location was known (e.g. Figure 168). Thus, visual inspection on the ground, a time-consuming and exhausting process, was the only reliable and effective means of locating the remaining portions of the canal.

As it was obvious that a similar program of intensive field walking would be impracticable in the more developed portions of the landscape, a new strategy was adopted. The canal alignments would be more easily located if Caton-Thompson and Gardner's map could be superimposed on the modern landscape more accurately. In order to accomplish this, the emphasis of the project was shifted to the relocation of the numerous small rural sites marked on their map. The underlying assumption was that these habitation sites would be considerably easier to identify as they occupied prominent positions in the landscape, covered a wider area, and would be more likely known by local people. Five of these sites were tentatively or conclusively identified by the project (See Appendix 2):[10]

Once the approximate location of these five habitation sites had been obtained, their coordinates were used to geo-rectify Caton-Thompson's and Gardner's topographic map. Their canal alignments were then superimposed on the 1:50,000 modern topographic base map (Figure 30) and the satellite imagery (Figure 31) using ArcGIS. Subsequent re-examination of the satellite imagery in the vicinity of the rectified alignments resulted in the immediate identification of Canal E (Figures 32-33) and the probable location of several other alignments as crop and/or soil marks in the

[10] Recorded on Caton-Thompson's and Gardner's map as "Ptolemaic Houses", "Ptolemaic Settlement", "Roman Gebel", and "Roman Houses". A brief description of each site is presented in Appendix 2.

landscape. The project then undertook a long-term iterative process of satellite image analysis and targeted field walking which resulted in the relocation of many of the previously-identified canal alignments and the identification of several possible new alignments.

Excavation Methodology

Nineteen trenches (FD 007-27) were excavated across the preserved canal alignments in order to provide evidence beyond that which was visible on the surface (Figures 34-6).[11] The two primary objectives were to expose the channel profiles and describe their hydraulic characteristics and, if possible, to obtain datable artifacts from their fills. Excavation was conducted by hand and carried out stratigraphically according to the field procedures established by the UCLA/RUG Fayum Project.

Trench locations were generally chosen in order to expose or clarify features, such as particularly high or wide berms or the absence of such, visible on the surface. Whenever possible the trenches were laid out in proximity to known habitation sites in the hope that there would be more datable artifacts in those locations. However, several trenches in the immediate vicinity of Karanis were laid out in order to investigate areas which seemed probable locations for canals on topographical grounds, rather than on the basis of any surface remains (Figure 121).

The fact that virtually all of the preserved canal alignments had been cut into the bedrock precluded several aspects of canal excavation practiced elsewhere. In particular, mechanical excavation was ruled out for practical and political reasons, and it

[11] FD 009 – 010 – 011 were contiguous squares comprising a single trench.

was unnecessary to excavate into sterile layers below the bottom of the channel, as is commonly done by archaeologists investigating canals in other countries. The thick deposits of windblown sand found in all of the canals, along with the relatively great depth of some of the channels, thwarted attempts at prospective coring with a hand auger. The absence of silt or other water-borne sediments in most of the channels precluded particle size analysis and quantification of flow regimes.

All ceramics recovered from the canal excavations were kept, except for those coming from surface and topsoil deposits immediately adjacent to the ancient kom at Karanis. There, only diagnostic ceramics were retained as erosion from the sloping sides of the kom, combined with early modern *sebbakh*-mining activity, had contaminated a large area. Other artifacts, including bone, shell, wood, and glass, were submitted to the Fayum Project for examination by specialists. Where appropriate, sediment samples were taken from canal fills for particle size analysis and optically stimulated luminescence (OSL) dating. Unfortunately, it was not possible to obtain permission to remove the sediment and OSL samples from Egypt. They remain in storage with the other artifacts inside the UCLA/RUG storehouse at Karanis and will be examined on site at a future date.

Re-examination of the Canals Located by Caton-Thompson and Gardner

What follows is a brief summary of the preliminary findings of two seasons of archaeological investigation of the previously identified Graeco-Roman irrigation system north of ancient Karanis. The individual canal alignments are presented alphabetically according to the designations assigned by Caton-Thompson and Gardner. They should be considered in conjunction with the original map made by Caton-Thompson and Gardner (Figure 5). More detailed descriptions of individual trenches are provided in Appendix 1, while relocated small rural sites are documented in Appendix 2.

Canal A (Figures 5-6, 37-8)

The alignment to the east of Karanis designated as Canal A by Caton-Thompson and Gardner fell outside the concession boundary of the Fayum Project and could not be relocated on the ground. On the 1934 map, the canal is shown moving west for ca. 500 m before turning sharply south in order to bank around a small topographic prominence (Figures 5-6). The canal then continues for ca. 1,500 m to a bifurcation illustrated between two sets of "Roman Houses". Three smaller off-take channels, designated A I, A II and A III, branched off from the channel heading west and north.

Today the entire area is under cultivation. All of the fields have been plowed and levelled in order to maximize the use of irrigation water. However, a slight indentation in the 20 foot contour line shown on Caton-Thompson and Gardner's map is unquestionably the path used by the modern highway to ascend the slope above. This makes it virtually certain that the topographic height which the canal skirts on its western side is the bedrock outcrop today occupied by the village of Izbet Darouri/Izbet Sarhān. Local informants pointed out the presence of artifacts at a large and conspicuous sand dune standing isolated among the fields slightly south east of the village of Izbet ‘Ashūr (Figure 38) and it seems extremely likely that this is the site of the “Roman Houses” indicated to the west of Canal A on Caton-Thompson and Gardner's map (See Appendix 2).[12] As Canal A is illustrated as shallow but relatively wide (30-40 feet in some places) in the original report, it was hoped that the alignment might be visible in the satellite imagery but the only linear feature in the immediate vicinity turned out to be a buried natural gas pipeline.

It is worth noting that the only major water feature in the vicinity today is the Masraf Azzam, a drain for irrigation water from the surrounding fields which leads into a series of brackish fish farms in a depression to the south. It may be that the ancient channel served a similar purpose by bringing irrigation water from an as yet unidentified main canal lying at a higher elevation to the east and by channelling wastewater back into the main canal at a lower elevation to the south. In fact, the modern Masraf Azzam may follow or closely parallel the ancient canal alignment. Given that two points on opposite sides of the canal could be established, the “Roman Houses” west of the canal and the topographic highpoint at Izbet Sarhān, it might have been possible to locate the buried channel using cores taken at fixed intervals along transects across the landscape but the project’s permit did not permit excavation or sampling in the area east of Karanis.

There is insufficient evidence to determine whether or not Canal A served as the main canal in the area or not. It is possible that Canal A was the main channel along the

[12] The site has been known to the archaeological authorities for some time, but the title to the land was abandoned by the SCA after trial excavations. No published report exists.

desert edge in antiquity and that it brought water from the east and hugged the hillside in order to maintain the highest elevation possible along its length. If so, it should have turned to the west just to the south of its last known position and would then have passed immediately to the north or south of Karanis. The canal described by Caton-Thompson and Gardner does not seem very substantial, however, considering the number and size of the canals it would have fed to the east.

Canal B (Figures 5-6, 9-10, 39)

Canal B was described by Caton-Thompson and Gardner as “the great cut”. They record a width of 42 feet and a depth of 16 feet at its maximum extent and there can be no doubt that Canal B was a major undertaking. Its purpose was unquestionably to break through a local topographic high point in order to irrigate the K-Basin from the east (Figures 5-6). As they were unable to locate a connection between Canal B and Canal A farther east, they felt that this alignment had only been partially completed and then abandoned.

Canal B was relocated (36R N29.8919, E032.70858, 5.0 ± 6.0 m ASL) running to the west of the modern highway ca. 900 m south of the modern police checkpoint. Proximity to the perimeter guard posts of the Kom Aushim airbase precluded detailed study. However, the channel could be followed running east-west along a stretch at least 340 m long. It seems to have been reused as an irrigation canal which has been badly maintained and polluted by sewage and chemical effluent from a nearby factory. The modern canal which reuses the channel is identified on the 1:50,000 topographic map series as the Tira’at Kawm Ūshīm (Kom Aushim Canal) and is shown entering the airbase where it feeds the “Shooting Club Pool”. Tall reeds and other vegetation grow abundantly in the bottom of the channel and obscure its full dimensions. The most easily accessible portion of the channel was ca. 8.6 m wide and ca. 6.0 m deep and the vertical cuts into the bedrock were remarkably smooth (Figure 39). Further investigation of this alignment would require special permission from the authorities and additional equipment in order to enter the channel.

It is difficult to believe a project the size of the Canal B cut would have been undertaken but never used in antiquity. None of the canal alignments identified by Caton-Thompson and Gardner could be traced back to a hypothetical main canal, even in the comparatively undisturbed landscape of the 1920s. This should serve as a warning that relatively isolated channels may once have been a functioning part of the ancient irrigation system. If it was ever in use, Canal B could have delivered irrigation water to the entire K-Basin. In fact, an analogous arrangement exists today: only ca. 100 m to the north of the cut and running parallel to it for some distance is the modern Tira’at al-Jamhūrriyyah (Canal of the Republic) which skirts the northern end of the K-Basin and heads south along the rocky ridge between the K-Basin and the L-Basin in order to irrigate both, although from an elevation ca. 5.0 m higher than that of Canal B (Figure 30).

Canal C (Figures 5-6, 40-7)

Caton-Thompson and Gardner reported Canal C as a major channel running generally southeast and then turning in a gentle arc towards the northwest where it terminated at a major embankment (Figures 5-6). Although they are not explicit about the function of Canal C, it seems from their map that the channel brought water from a major canal located to the east in order to feed many or all of the canals lying to its west. They were however unable to find any connection between Canal C and the other channels.

The probable location of Canal C (36R N29.31665 E30.53899, 11 m ASL) was identified to the north of Karanis between the cemetery and the modern village of Qarya Thalatha where a small section of badly damaged channel ca. 82 m long was preserved amidst the quarries (Figure 42). The isolated easternmost section of Canal C, along with a nearby feature labelled as a "Ptolemaic House", on Caton-Thompson and Gardner's map now lies inside the perimeter of the military airbase at Kom Aushim and both are inaccessible. Most of the western section of the channel has been destroyed by quarrying activity. A distinctive bend in the channel illustrated on Caton-Thompson and Gardner's plan seems to be reflected by the path of a modern road which is clearly visible in the satellite imagery (Figure 41) but no correspondence could be determined on the ground.

Excavation of the preserved section of canal (FD 027) provided several diagnostic ceramics but revealed only a very shallow channel (Figures 42-4). Another more substantial profile of the canal (ca. 4.90 m wide x ca. 0.55 m deep) was preserved in a quarry face just to the north of the military housing facility ca. 260 m to the northwest of FD 027 (36R N29.6060, E32.68433, 14 m ASL), but it could not be excavated as it ran in a northwesterly direction under some adjacent houses (Figure 45).

There is little doubt that Canal C served as an important channel in the Karanis hinterland. Its irregular course, which carefully hugged the topography, was undoubtedly intended to preserve the maximum elevation possible. The greater hydraulic head resulting from this elevation would have permitted irrigation of the western K-Basin and eastern L-Basin with its discharge. In fact, it seems extremely likely that Canal C would have continued to the north or northwest of its last known position and would ultimately have connected with the Canal E alignment.

It is worthy of note that irrigation water could be brought to an elevation of ca. 10 m ASL along the Canal C alignment; surely this indicates that it would have been equally possible to direct a channel right up to the eastern side of the Karanis Kom or along its northern side, both of which are at elevations between -10 and -5 m BSL. The fact that no channel has ever been identified in those locations leaves open the question of how the inhabitants of the Kom, most notably the excavated bathhouse on its northern slope, obtained water.

Canal D (Figures 5-6, 48-9)

Caton-Thompson and Gardner illustrated the northern end of Canal D running along a northwest-southeast line roughly parallel to Canal E and extending south east for ca. 3 km as it gently turned to the southwest towards a major ancient embankment (Figures 5-6). Eight spur channels are illustrated on their plan extending for short distances to the northeast from Canal D. A house or group of houses of unidentified date are marked on the northeast side of the channel towards its northern end.

Numerous unsuccessful attempts were made to locate Canal D. Most of the remaining bedrock along the ridge is now buried beneath the houses of Qarya Ula and the agricultural land at the western edge of the ridge has been sharply terraced. A modern canal in the vicinity utilizes a cut in the bedrock, but it was impossible to confirm that it was a reused portion of Canal D (Figures 48-9). Attempts to question local informants in the area were met with resistance and even hostility, perhaps owing to the proximity of a house belonging to the commanding officer of the Kom Aushim airbase. The latter is placed on the eastern side of a rocky outcrop which is the ideal location of the "House" shown to the west of Canal D on Caton-Thompson and Gardner's map.

The proximity of Canal D to Canal E suggests either that they were not contemporary or that Canal D was fed by Canal E and ran from northwest to southeast. The latter alternative seems more likely as Canal E is at a slightly higher elevation, and as there is no other explanation for the large number of feeder channels on the northwest (i.e. uphill) side of Canal D. It may be that Canal E was first used to irrigate the L-Basin and that only once that operation had been completed excess water was diverted into Canal D. The southern end of Canal D curves around a small but substantial depression which arguably should have had its own designation as a basin. Today the southern end of that basin is full of standing brackish water which has pooled there from the surrounding fields; a large earthen embankment at its southern end may preserve the alignment of the "embankment" indicated on the 1934 map (Figure 47). It could also have served as a reservoir or catchment for agricultural waste water contained by the large embankment on its southern side in antiquity.

Canal E (Figures 5, 7, 9, 32-3, 50-3)

Caton-Thompson and Gardner illustrated Canal E as a long linear alignment running from southeast to northwest cutting across the high limestone ridge separating the K- and L-Basins (Figures 5, 7). At its extreme northwestern end it turns slightly to the west. Just south of its midpoint an offset channel 18 feet long by 3'4" wide and 2 feet high had been tunnelled beneath the limestone in a northeasterly direction along the western rim of the K-Basin near a "Ptolemaic House" marked on their plan.

Canal E was relocated using satellite imagery which showed it as a series of soil marks running through an open area on the eastern side of the modern village of Qarya Ula and as a series of crop marks in the fields to the north and south (Figure 32). Examination on the ground revealed that the area had been badly disturbed and that the limestone bedrock had been removed and the area bulldozed level. Nevertheless, it was still possible to discern two clear parallel lines of plant growth running on either side of the channel (Figures 33, 50). A trench (FD 024) was excavated across the alignment near the modern school at the southern end of the empty lot and revealed a major U-shaped channel 2.1 m deep and 8.0 m wide. The sides of the channel, which were cut into the geological clay, were nearly vertical in the upper half but somewhat eroded below, suggesting that water never or only rarely filled the channel to its maximum capacity (Figures 51-3).

There is no doubt that the primary purpose of Canal E was to irrigate the L-Basin. It may also have served to supply water to the "Ptolemaic Settlement" (see Appendix 2) which is indicated ca. 1 km to the northwest of its terminus. Further examination of the settlement could provide important evidence for interpreting the construction and abandonment of the irrigation system. Given the relative elevations involved, Canal E was probably connected to Canal C and obtained its water from the southeast.

Canal F (Figures 5, 7, 10, 54-60)

Canal F was located by Caton-Thompson and Gardner on the topographic high point which separates the K-Basin from the L-Basin (Figure 5). It ran east-west for ca. 500 m through the local limestone before turning to the southeast at its eastern extremity. The channel was 6 feet deep and circa 10 1/2 feet wide. At the western end of the channel was a tunnel beneath the limestone bedrock which ran underground for 112 feet before re-emerging for a final 23 feet and ending in a vertical rock face. They concluded that the channel was unfinished but that it would have joined the K-Basin to the L-Basin.

Canal F was relocated thanks to the information provided by a local informant. Virtually the entire channel has been destroyed by the breaking of bedrock in the area (Figure 54) and most of its course lies beneath modern fields to the west of the road leading north from the village of Qarya Ula. The mouth of the eastern end of the tunnel was relocated (Figure 55) and a trench (FD 025) was laid out to explore the channel, although excavation had to be abandoned because of the now high water table in the vicinity (Figure 56-8).[13] Some 200 m to the east an additional shallow rock cut channel in line with the tunnel mouth was investigated (FD 026) at a point where it deviated to the northwest (Figures 59-60). As Caton-Thompson and Gardner's map shows the eastern end of Canal F deviating to the southwest, this is either a newly discovered channel associated with Canal F or they made a minor error on the map.

Caton-Thompson and Gardner felt that, “The unfinished conduit suggests that canalisation into the L. Basin, additional or optional to that provided by the ‘E’ channel, had been intended”.[14] Thus they felt that canal path was designed to bring water from the east to the west. This is surely incorrect. As the eastern end of their channel turns to the southeast where there is a lower elevation, it is virtually certain that water was intended to move from west to east. If so, the most likely source would be Canal E, assuming that the two were contemporary. An arrangement of this type is consistent with the irrigation of both the K- and L-Basins from a source in the southeast which would have minimized the total length of the canal alignments and kept them closer to the major habitation sites from which teams could be dispatched for maintenance operations.

[13] Rising groundwater is frequently cited as a risk to the sites on the periphery of the Fayum, but has rarely been documented. For an exception, see Keatings, et al. 2007.
[14] Caton-Thompson and Gardner 1934: 143.

Canal G (Figures 5, 7, 29, 61-105)

At ca. 6.5 km in length, Canal G was the longest of the alignments identified by Caton-Thompson and Gardner. It ran in a generally northwesterly direction from a point near the western end of Canal H to the southern end of the X-Basin (Figure 5). Its course closely followed the topography, hugging the north side of a ridge which separates the basins from the true Fayum depression to the south. A number of "Ptolemaic Houses" were excavated on its southern bank and provided datable evidence for the use of the channel (Figures 5, 11-12; Appendix 2). Although Caton-Thompson and Gardner were able to trace the alignment for a remarkable distance over the surrounding desert pavement, they were unable to identify a connection between Canal G and any of the other alignments. They chose to believe that it was probably fed from Canal C using an embankment (Figure 47) which could be seen at the southern end of the L-Basin. The latter conjecture seems unlikely, as it would have lowered the elevation of the water derived from Canal C needlessly.

Canal G was relatively easily located, although several sections of the alignment had been destroyed by quarrying since the 1920s. For most of its length it is visible as a light, sandy ribbon which stands out against the darker desert pavement to either side (Figure 29). Substantial berms up to 0.50 m high and composed of windblown sand built up on bedrock boulders removed from the channel are preserved on one or both sides of the alignment over much of its length. There are, however, numerous sections without berms, presumably in those areas where deep excavation of the bedrock was unnecessary.

Several trenches (FD 007-014) were excavated along the Canal G alignment in order to elucidate features which were visible on the surface. They demonstrated that there was active agriculture along the canal alignments as well as at its presumed terminus in the X-Basin. Small off-take channels were located on the north side of the alignment (FD 009-010-011, Figures 75-84) and an intact ancient field system is certainly preserved in the vicinity. In addition, an area of more widely separated berms (FD 012, Figures 85-94) may have facilitated the installation of garden plots along its banks. Carbonized threshing remains were recovered from the channel bottom near the "Ptolemaic Houses" (FD 014, Figure 103) further attesting to agricultural activity in the area.

At a few points (e.g. FD 013) along its length Canal G is only ca. 0.30 m deep (Figures 95-9). This indicates that the maximum flow in the channel was relatively modest even though it served to irrigate a large area. Either the crops selected for the area required relatively little water or the flow was maintained over a relatively long period each year. Carbonized threshing remains of bread wheat were recovered from one of the trenches (FD 014, Appendix 1) and this may support the latter interpretation.

The relatively shallow depth of the channel in certain key locations also indicates that deeper excavation was undertaken solely to maintain the slope of the channel. This fact should serve as a warning that even the extremely wide and deep cuts found to the east (e.g. Canal B, Canal E) may never have been filled to capacity. The greater size of a channel is not necessarily an indication of a greater discharge but does signify the economic value of developing the irrigation system.

Extensive irrigation could be accomplished even with a shallow water level in the canal. Two small cuttings in the bedrock on opposite sides of the canal (FD 014, Figures 102, 105) undoubtedly served as an installation for a removable gate used as a water-control device. Temporary gates of this type, usually made of wood or reeds woven to form a thin but strong barrier, are still used in the area today.[15] When inserted vertically into the channel they serve to obstruct the flow causing water to back up in the channel behind the device. The greater hydraulic head which results could be used to overflow the banks upstream or to direct water to a higher elevation along a lateral canal. Similar devices were probably used throughout the ancient irrigation system.

A disjunction in the canal alignment was revealed in trench FD 012 (Figures 88-91). Associated with a change from berms ca. 12 m apart to berms ca. 6 m apart and differences in the geometry of the channel sides, it appears that the two sections of channel were constructed separately and did not meet at a perfect angle. It is impossible to ascertain whether the disjunction was caused by two teams meeting at that point as part of a single phase of construction or by the addition of a later western segment. Therefore, it remains possible that the western portion of the canal is later than the eastern portion, if only slightly.

[15] Referred to as “tapons” by American archaeologists, see Foster, Woodson, and Huckleberry 2002: 112.

As Canal G was located at the distal end of the irrigation system north of Karanis, it should have been the last alignment to be established and the first to be abandoned. The houses along its banks which were excavated by Caton-Thompson and Gardner contained many coins of Ptolemy II Philadelphos, so the canal should have been in use by some point in the early to mid-third century BCE (Appendix 1). The segment of Canal G to the east of the houses and its now lost feeder system must have been constructed even earlier for the site to be habitable.

A large deposit of carbonized threshing remains, dated by C^{14} to 70 BCE - 40 CE, and a restorable cooking pot of the late first century BCE or early first century CE (Figure 104) were found in the channel bottom at FD 014. Both artifacts would have been disturbed by flow in the channel, indicating that portion of the alignment had gone out of use by that time. While the ceramics and other artifacts recovered from the excavation of the houses (Figures 13-18) will require a detailed re-examination given the great developments in ceramic analysis which of taken place since the 1920s, the finds from trench FD 014 indicate that at least the western portion of the canal was abandoned at some time in the late first century BCE or early first century CE and that it was never reused.

Canal H (Figures 106-14)

The alignment designated as Canal H by Caton-Thompson and Gardner was preserved for ca. 2 km as it skirted the topography in a shallow arc along the topography south of the L-Basin (Figures 5, 7). Its function is somewhat enigmatic. It appears to have run from east to west and must have commenced in the vicinity of Canal D or Canal E. Its western terminus was comparatively close to the southeastern terminus of Canal G, but no connection was made between the two by Caton-Thompson and Gardner and intervening low ground may have precluded Canal H as a feeder for Canal G.

The entire landscape has been transformed in the vicinity of Canal H. Terracing at the southern end of the L-Basin has removed large areas of bedrock and dozens of farm-villas have been established there. To the south, quarrying has removed a vast swath of the landscape and even some hills shown on the 1995 1:50,000 topographic map have been removed.

Two enigmatic linear features were identified using the satellite imagery and were subsequently excavated (FD 015, Figures 106-9; FD 016, Figures 110-14) in an attempt to confirm the location of the Canal H alignment. Both trenches (36R N29.54286, E030.86353, 9 m ASL; 36R N29.54108, E 030.85988, 6 m ASL) revealed reasonably wide (ca. 4.0 m) but very shallow (0.20 m) features which may have served as channels, but neither could be certainly confirmed as ancient. A group of "Ptolemaic Houses" indicated to the south of the western terminus of Canal H could not be re-located, but had already been "completely destroyed" by looters by the 1920s and were subsequently "cleared" by Caton-Thompson and Gardner.[16] Any remaining evidence for the houses would most likely be found within the walled compound of the large cooperative cattle farm in the vicinity.

[16] Caton-Thompson and Gardner 1934: 149.

Canal I (Figures 5, 115)

Caton-Thompson and Gardner describe Canal I as a possibly incomplete east-west canal alignment between the K-Basin and the L-Basin (Figure 5). It was composed of three unconnected sections 39-54 feet wide but cut only 14 inches into the shale below. It is tempting to suggest that these cuttings may have served another purpose rather than as a canal, particularly given that the unfinished channel of Canal F (see above) appears to have been cut from one end towards the other, rather than as a series of cuttings which were later deepened and connected. Canal I could not be located on the ground with any certainty. There is, however, a modern east-west running canal in the appropriate location today (Figure 115). It is fed from the modern Tira'at al-Jamhurriyah to the west and serves a number of fields in the area. It may rest directly on top of the ancient alignment.

Canal K: A Newly-Identified Alignment (Figures 116-18)

One previously undocumented alignment, designated Canal K, was located within bounds of the survey area and may have formed a part of the irrigation system. The feature is a low pair of parallel berms only ca. 1.0 m apart which can be traced in the desert north of Canal G for ca. 3.0 km (Figure 116). The course of the feature has been badly disturbed but runs roughly parallel to the latter alignment and mimics its southwest-west-northwest turn to follow the topography towards the X-Basin. Its eastern end was traced to within a few hundred meters of the Canal G and Canal H alignments. A small test trench (FD 021) across the channel near its western terminus showed that it was only ca. 0.50 m wide but no artifacts were recovered (Figure 118). It is possible that the channel served as a drain for agricultural water running downhill from the fields irrigated by Canal G or as a lateral supporting its own series of small fields. A modern date for the alignment could not be ruled-out, however.

The lack of water-borne sediment in all the channels requires comment as it precluded several types of palaeo-hydraulic analysis. Caton-Thompson and Gardner felt that the sediment typical of Nile floods had fallen out of suspension much earlier in the system.[17] This is undoubtedly true, but the implication is that the flow in the channels was always low-energy. One might add that it also indicates that any of the geological sediments which eroded from the bedrock surrounding the channels themselves were either indistinguishable or were so small and well-sorted by their original deposition in a low-energy marine environment that they were transported and discharged into the K- and L-Basins.

Investigation of the Main Canal at Karanis

Ancient documentary evidence preserved on papyrus records the presence of a main canal skirting the desert edge at a high elevation along the northern side of the Fayum depression (Chapter 3). The canal must have separated from the Bahr Yusef at or near Lahun gap. It then turned northward near the site of a Hawara to pass Philadelphia (Kom al-Kharaba al-Kabir) and Bacchias (Kom al-Atl) before reaching Karanis (Kom Aushim). This main canal, known in the Ptolemaic period as the Dioryx Kleonis, provided

[17] Caton-Thompson and Gardner 1934: 142.

the only known source of irrigation water to the northwest Fayum. Caton-Thompson and Gardner were able to trace the relict channel to a point just southwest of Bacchias, but the precise location of the channel has never been established in the vicinity of Karanis.[18]

Most of the ancient villages along the rim of the northwest Fayum are situated on the desert plateau uphill from the canal. This observation has led most fieldworkers in the Fayum to assume that the main canal would be found at or near the foot of the kom on the south side of Karanis (Figure 129).[19] One of the primary objectives of the work undertaken in 2007 – 2008 was to relocate and investigate this channel and any lateral channels which may have serviced the kom (Figure 121).

Prospective Excavation near Karanis – North Side of the Kom

The fact that an ancient canal alignment (Canal C) existed at an elevation of ca. 10 m ASL only ca. 1 km to the north of Karanis raised the possibility that other lateral channels, or a branch of Canal C, may have existed on the north side of the kom where the elevation is between -10 and -5 m BSL. The likelihood that some sort of waterway existed on the north side of the kom was also inferred from the presence of a bathhouse excavated there.[20] It seemed inherently unlikely that the inhabitants of the north side of the kom would have transported large quantities of water from a main canal to the south.

[18] Caton-Thompson and Gardner 1934; 1937.
[19] E.g. Davoli 1998: 73-4 and Bagnall, et al. 2004: 132, Figure 5.2.1, where the depression on the southern side of the kom is indicated with an arrow as the location of the ancient canal.
[20] El-Nassery, Wagner and Castel 1976. For the claim that public fountains supplied by baked clay pipes were in use at Philadelphia, see Yeivin 1930.

The ridge which extends to the northeast of Karanis was repeatedly examined for any sign of a relict channel (Figure 120). Given the relative elevations involved it would have been possible to bring an alignment from a source in the vicinity of Canal A or Canal B all the way down the top of the ridge and directly into the northeastern side of the kom. Modern activity has disturbed much of the area but a relatively untouched landscape remains immediately to the northeast of the site. No trace of a canal or other hydraulic feature could be detected in the satellite imagery or located on the ground despite frequent visits.

While an alignment following the ridge would have been the most efficient means of delivering water to the site, an alternative route could have followed a lower elevation to the north. The modern Cairo-Fayum highway runs northeast to southwest at the bottom of a natural depression between the kom on the south and the Karanis cemetery on the north (Figure 120). An alignment along the depression could have irrigated a relatively large area of Tertiary sediments in close proximity to the settlement, brought water within 50 m of the site, and ultimately reconnected to the main canal slightly west of Karanis.

Examination of the satellite imagery revealed two linear features with low berms in appropriate locations (Figures 121). A feature to the north of the highway was excavated (FD 018; Figures 122-4) but turned out to be a buried natural gas pipeline. A second feature to the south of the highway was also excavated (FD 019; Figures 125-8) but was determined to be a relict stretch of the early modern King’s Highway with a buried electrical cable following its path. No evidence for a watercourse of any kind could be identified on the north side of the kom.

Prospective Excavation Near Karanis – South Side of the Kom

As it seemed probable that the main canal lay on the south side of Karanis, trenches (FD 017, FD 020, FD 022, and FD 023) were laid out in an attempt to locate the relict channel (Figure 121). Previous researchers had sometimes assumed that the path of the canal followed a sandy concave depression visible in aerial photos between the foot of the kom and the modern canal, the Bar Wahbī (Figures 129-20). Trench FD 017 (36R N29.51434, E030.89910, -18 m BSL) was laid out across the depression in order to explore the possibility (Figures 131-9).

Beneath the sand, FD 017 exposed geologically bedded layers over a distance of 24 m. Sandstone at the northern end of the trench gave way to a layer of Tertiary shale emerging from beneath it to the south (Figure 132). However, at the very southern extremity of the trench a series of stratified canal deposits were identified in close proximity to the modern canal. It appears that the shale layer had been cut to form the northern bank of the channel which could be discerned descending beneath the modern canal. A very hard gray layer of silty clay had then been formed inside the channel and been piled up to form a berm. The surface of this clay was riddled with cracks caused by desiccation and coated with a layer of salts (Figures 133-4). At some time after its construction part of the berm was removed, perhaps for use as fertilizer. A period of abandonment seems to be implied by a very thin layer of windblown sand resting upon the cut berm.

Above the sand was a thick, hard layer of gray and yellow clay and silt deposited in micro-laminae ca. 1 mm thick which covered the previous berm. This layer was unquestionably water-deposited and belongs to a new phase of canal use. The fact that the gray and yellow clay extended over the previous berm suggested that the channel had been widened to the north, although any associated berm had been removed by the late cut. Above another layer of windblown sand was a virtually intact berm composed of sand along with shale and sandstone cobbles which sloped sharply downwards to the south beneath the modern canal. The preservation of the berm indicates a narrowing of the channel or a realignment of it farther to the south during this phase. A very thick layer of windblown sand filled this final channel and was capped by organically rich debris cleaned out of the modern canal. At some late date, perhaps during the active period of *sebbakh* robbing at the site, the berms on the northern side of the channel were removed as can be seen in a cut which extends through all of the preserved layers (Figures 135, 139).

Three superimposed canal profiles were preserved in FD 017 but cannot yet be given absolute dates. The proximity of the trench to the base of the kom at Karanis promised the presence of diagnostic artifacts and stratified ceramics were recovered from each layer, but have not yet been fully analyzed. Sediment samples were taken from each layer and curated with the UCLA/RUG Fayum Project in the hope that OSL dating may be possible in the future.

Trench FD 020 (36R N29.30859 E30.54041, -19 m BSL) was laid out slightly to the west of FD 017 in an area where the higher ground next to the modern canal extended much further outward in the hope that the berms and channels would be better preserved and could be exposed over a greater distance (Figures 141-6). Indeed, FD 020 revealed the same superimposed layers of canal sediments and berms found in FD 017 but with a greater portion of the downward-sloping channel visible at the extreme south (Figures 142, 145). Once again, part of the relict berms on the north had been partially removed in a late phase, suggesting that the depression visible along the south side of the kom may be partly the result of robbing. The trench provided a rich ceramic sample which will be examined and compared to the results from FD 017. Additional sediment samples were taken for OSL analysis.

Trench FD 022 (36R N29.30996, E30.54391, -18 m BSL) was located ca. 615 m to the northeast of Trenches FD 017 and FD 020 on the north side of the modern canal (Figures 147-57). A long, linear relict berm could be discerned on the surface where it appeared to diverge from the line of the modern canal by up to 15 m (Figures 147-8). Massive bushes growing in the berm indicated rich sediments beneath. The objective was to obtain a greater exposure of the interior of the main canal than was possible in the earlier trenches. As the trench was comparatively remote from the kom, it was also considered possible that less robbing of the berms might have occurred.

The earliest phase detected in FD 022 was a layer of hard, gray geological clay which had been cut to form a shallow, concave channel (ca. 4.0 m wide x ca. 0.25 m deep). A low berm on the north side of the channel was composed of material removed from the cut (Figure 152). Surprisingly, the south baulk also displayed a concave canal profile in section indicating that the original channel split in two at this point, although the precise relationship between the two channels could not be established (Figure 154). The channel was filled with a hard-packed but not clearly-laminated layer of silty clay which probably represents water-borne deposition in the channel. Above, an additional layer of light brown laminated clays in the channel continued all the way to the surface. The latter was riddled with roots and may have undergone initial pedogenesis making it only appear to be different from the canal fill below.

In a later phase a second berm was constructed slightly to the north of the earlier berm and running parallel to it (Figure 150). It was composed almost entirely of sand but the saddle between the two berms had been thinly lined with clay forming another channel ca. 1.0 m wide (Figure 151). This second channel ran right through the square and was undoubtedly some type of off-take or lateral channel designed to keep water at a higher elevation. Its source lies to the east and it could not be determined whether it was fed by the canal or by a water lifting device. In a final phase, the square was abandoned and covered with windblown sand.

The most remarkable feature of FD 022 was the very shallow channel revealed next to the modern canal (Figures 153-7). The channel is superficially similar to the lowest channel in FD 017 and FD 020, but here it rests at a comparatively high elevation and is extremely shallow. It is possible that the channel in FD 020 dates to a different phase or is only a lateral associated with a much deeper channel. A relatively large ceramic sample was obtained from FD 022 and should permit the construction of a relative chronology linking its channel with the phases identified in FD 017 and FD 020. Samples were taken for OSL analysis.

A final attempt to examine the main channel at Karanis was undertaken in Trench FD 023 (Figures 161-6). The trench was located ca. 100 m to the southwest of FD 022 in an area where a high elevation was maintained for nearly 10 m on the northern bank of the modern canal. In FD 020, a higher elevation was indicative of excellent berm preservation beneath. However, the excavation revealed a massive area of modern robbing; hard, gray geological clay with many large white inclusions had been cut in vast swaths throughout the square and numerous small, deep cuts pitted the bottom (Figures 163, 166). Plastic and other garbage were recovered from a depth of more than 1 m beneath the surface. The entire trench was contaminated and no canal alignment could be positively identified. This very recent robbing activity seems to have been designed to remove the geological clay which local informants report is desirable as an admixture in the nearby fields but it is possible that the primary objective was the robbing of the relict berms on the north side of the ancient canals.

Analysis of the datable evidence recovered from the relict canals on the south side of the Karanis kom is not yet complete. There are good reasons, however, for thinking that these channels are ancient rather than early modern. Silt and organic matter removed from the modern Bahr Wahbī has a very distinctive appearance (Figure 140). While it is hard and gray, like the lowest of the relict channels, it contains many small bivalves. Bivalves of this type cannot develop without perennial irrigation. The fact that they, and the remains of other freshwater creatures, are absent from all of the layers below provide circumstantial evidence that they must predate perennial irrigation development in the early-modern period. The precise chronological and spatial development of modern agricultural expansion near Karanis requires further research.[21]

The three relict channels identified below the modern Bahr Wahbī on the south side of the kom add a new phase to known periods of construction in the canal system. Previously, the only known canals to pass the south side of the kom at Karanis were the Ptolemaic Dioryx Kleonis, the early-modern Bahr Tamiya, and the modern Bahr Wahbī. The presence of an additional channel, demonstrates that at least one more period of canal cutting took place in the immediate vicinity of Karanis. Whether this phase was localized or part of a broader re-cutting of the irrigation system remains to be determined.

The series of relict canal alignments identified on the south side of the kom at Karanis provide a promising beginning to the archaeological investigation of the main canal alignment in the vicinity. Variations in the width of the channel over time along with the apparent sinuosity of each channel indicate that further exploration could be

[21] For example, (Petrie 1890: map) does not show a modern canal in the vicinity of Karanis, but provides only a rough sketch of the Fayum. Grenfell, Hunt and Hogarth (1900: map) indicate the Bahr Wardan ending near Bacchias and a branch of the Bahr Tamiya irrigating the land immediately south of Karanis.

profitable. The most promising venue lies to the east, outside the current permit boundaries, where the modern channel drops sharply in elevation over a stretch of ca. 5.0 km (Figures 22, 30). Careful investigation of the alignment, combined with the experience gained from the excavations at Karanis, may reveal locations where the modern and ancient canals diverge substantially and detailed analysis of the channels is possible and particular phases, such as the construction of the early modern Bahr Tamiya and Bahr Wardan may be identified.

Preliminary Conclusions

Re-examination of the complex Greco-Roman irrigation system first identified by Caton-Thompson and Gardner has revealed significant variability and detail in the archaeological record which was previously unrecognized. While further intense examination of the irrigation scheme would probably result in diminishing returns, the rapid development of the area is destroying what remains of the system. A priority in any future study should be the sampling of the endangered small rural sites in the Karanis hinterland (Appendix 2). The occupation history of these sites should provide a more developed interpretive framework with which to interpret the construction use and abandonment of the irrigation system.

Prospective excavation near the modern canal at Karanis has produced remarkable results. The relict channels uncovered in the area attest to a complex series of major adaptations of the canal system, a much more varied history of use than is usually assumed. Additional exploration using a mechanical coring device and selected excavation used in collaboration with a thorough geo-archaeological assessment of the sediments could provide numerous insights into the agricultural history of the northeast Fayum. It may also be possible to answer several important questions regarding the date and mechanism behind the abandonment of the Fayum villages, including Karanis, in Late Antiquity.

Chapter Six: Conclusions

Irrigation systems are a common feature of archaeological landscapes around the world and have been studied by archaeologists from a wide variety of approaches. In Egypt, the realities of conducting fieldwork have conspired with disciplinary divisions between archaeologists, philologists, and historians and between Egyptologists and Classical scholars to inhibit an interdisciplinary and diachronic view of the agricultural landscape (Chapter One). Nevertheless, irrigation systems have been a fundamental part of the landscape since the emergence of the Egyptian state and have played important social and economic roles (Chapter Two).

Documentary sources provide a detailed picture of the irrigation system of the Fayum during the Graeco-Roman period (Chapter Three), but little attempt has been made to study them from archaeological perspectives. The pioneering work of Caton-Thompson and Gardner in the 1920s is a notable exception, but has been largely ignored by archaeologists of the Graeco-Roman period and has never been integrated with the documentary record. In addition, further archaeological investigation of the Fayum irrigation system has been minimal since their time (Chapter Four).

While the work of Caton-Thompson and Gardner foreshadowed numerous methodologies now used to study irrigation systems, many other developments have taken place since the 1920s. The complex range of geoarchaeological approaches which have been developed by archaeologists working in other countries form a “World Archaeology of Irrigation” which may be adapted and applied to local circumstances. These approaches permit interpretation at multiple scales beyond what was possible for Caton-Thompson and Gardner (Chapter Four).

Fieldwork conducted in the Fayum by the author is a first step towards the application of these approaches to the irrigation system. Although the landscape has been badly damaged by development since the 1920s, the irrigation system identified by Caton-Thompson and Gardner was relocated and re-examined in 2007-8 (Chapter Five). Field survey and selected excavation of canal alignments provided additional details concerning the system and its development over time, while archaeological prospection near Karanis identified the relict remains of early high-level main canals along the periphery of the Fayum (Appendix 1). Careful study of the landscape also led to the re-identification of several small rural sites in the Karanis hinterland (Appendix 2).

The Graeco-Roman Irrigation System Near Karanis

It is simply not possible to overstate the importance and quality of the work done by Caton-Thompson and Gardner in the northeastern Fayum. Their open-mindedness and scholarly curiosity led them to recognize a rare opportunity to examine the Greco-Roman irrigation system and to follow up on it despite the fact that their resources were limited and the subject matter was not directly related to their own research on the prehistoric period. Their examination of the irrigation system was a logical and careful endeavour which combined traditional survey and excavation with approaches which, in hindsight, can only be described as geoarchaeology and landscape archaeology. Many of these approaches presaged commonly accepted methodologies utilized for the study of irrigation systems today.

It is noteworthy that the pioneering work of Caton-Thompson and Gardner was not followed up by other archaeologists. Indeed, it seems that very few archaeologists of the Graeco-Roman period have ever read the work of Caton-Thompson and Gardner. Certainly, none have undertaken further fieldwork on the irrigation system or the numerous small sites associated with it. This latter point is worth emphasizing because the hinterland north of Karanis was, until recently, the only intact Graeco-Roman agricultural landscape in the Fayum, but much of it has since been lost without undergoing examination.[1]

Re-examination in 2007-8 relocated many of the remaining components of the irrigation system. Excavation of sections across the alignments in the light of methodologies developed in other areas detected numerous subtle variations in the channels indicative of their construction techniques and phasing. Preliminary analysis of the finds has extended the occupation history from the early Ptolemaic period to the late first century BCE or early first century CE. The longer period of occupation and

[1] The landscape in the immediate vicinity of Philoteris (Medinet Watfa) is well preserved but does not approach the scale of that north of Karanis.

significant number of small rural sites in the area prove that the system was not a brief, failed attempt at reclamation of the desert wasteland, but a viable long-term endeavour which produced a dynamic and populated landscape. Further investigation of the finds promises to provide more detailed dating of the irrigation system and its associated sites.

The Main Canal at Karanis

It is a fact that ancient Karanis could not have been established and occupied for so long without a canal to provide fresh water for irrigation and consumption. The corollary is that the development and management of the irrigation system had a fundamental impact on its inhabitants. Accurate dating of the establishment, modification, and abandonment of the main canal should provide data critical to interpreting changes in population, agricultural production, and political and social relevance of the community over time.

The prospective excavations undertaken at Karanis in 2007-8 are the first attempt to locate the main canal there since the 1920s. The discovery of superimposed relict canal alignments beneath the modern Bahr Wahbī have proven the efficacy of geoarchaeological approaches to the irrigation system of the northeast Fayum. Just as in other parts of the world, once a path of appropriate slope and direction has been established, later canals very often follow the same line, even when laid out after long periods of abandonment. But canal systems are not static. They cannot simply be constructed and then maintained with only limited annual attention; canals are dynamic features which are extremely susceptible to exterior changes in flood regime and environment. They can also wear out and require periodic re-excavation, consolidation, and modification in order to maximize discharge and adapt to changes outside the system.

The super-imposed relict channels identified at Karanis attest to this process of periodic change within the system. Variations in the course of the alignment during different phases have left portions of the previous channels high and dry and it seems probable that investigation at additional locations will reveal better preserved profiles and additional phases of the alignment. Further excavation or mechanical coring would be most profitable between Karanis and Bacchias, where ancient channels are known to have existed, agricultural development has been comparatively recent, and where the current irrigation system is most likely to depart from the course of earlier canals.

Future Prospects

Two seasons of survey and excavation in the vicinity of ancient Karanis have relocated the irrigation system first documented by Caton Thompson and Gardner in the 1920s. Although many of their sites and canal alignments have been damaged or destroyed in the intervening years, much of the system remains accessible. Re-examination of accessible areas has added chronological depth to the occupation history of the irrigation system and articulated details of its operation. Archaeological prospection on the south side of the kom at Karanis resulted in the location of three relict canal alignments providing the first archaeological attestation of the main canal at Karanis as it evolved over time. Much work remains to be done in order to locate and assess additional components of the system and to integrate the scattered archaeological remains into a cohesive picture of the irrigation system of the Fayum as a whole. The logical next step is a coherent program of archaeological investigation of the irrigation system as a whole with the collaboration of geoarchaeologists. Only then will it be possible to interpret the irrigation system and its components within the context of social and economic history derived from the documentary sources.

Figures

Figure 1: Drawing of the restored Scorpion Macehead, Dynasty 0. Attendants with broom and basket stand before King Scorpion, who wears the crown of Upper Egypt and brandishes a hoe at the side of a diverging waterway. The waterway irrigates the fields below. Traced after Smith 1998: 12, Figure 12.

Figure 2: Landsat ETM image of Egypt showing the green band of the Nile Valley meandering through the desert landscape. Data freely available from http://landsat.gsfc.nasa.gov/data/. Accessed 10/10/2007.

Figure 3: Landsat ETM image of the Fayum depression. Data freely available from http://landsat.gsfc.nasa.gov/data/. Accessed 10/10/2007.

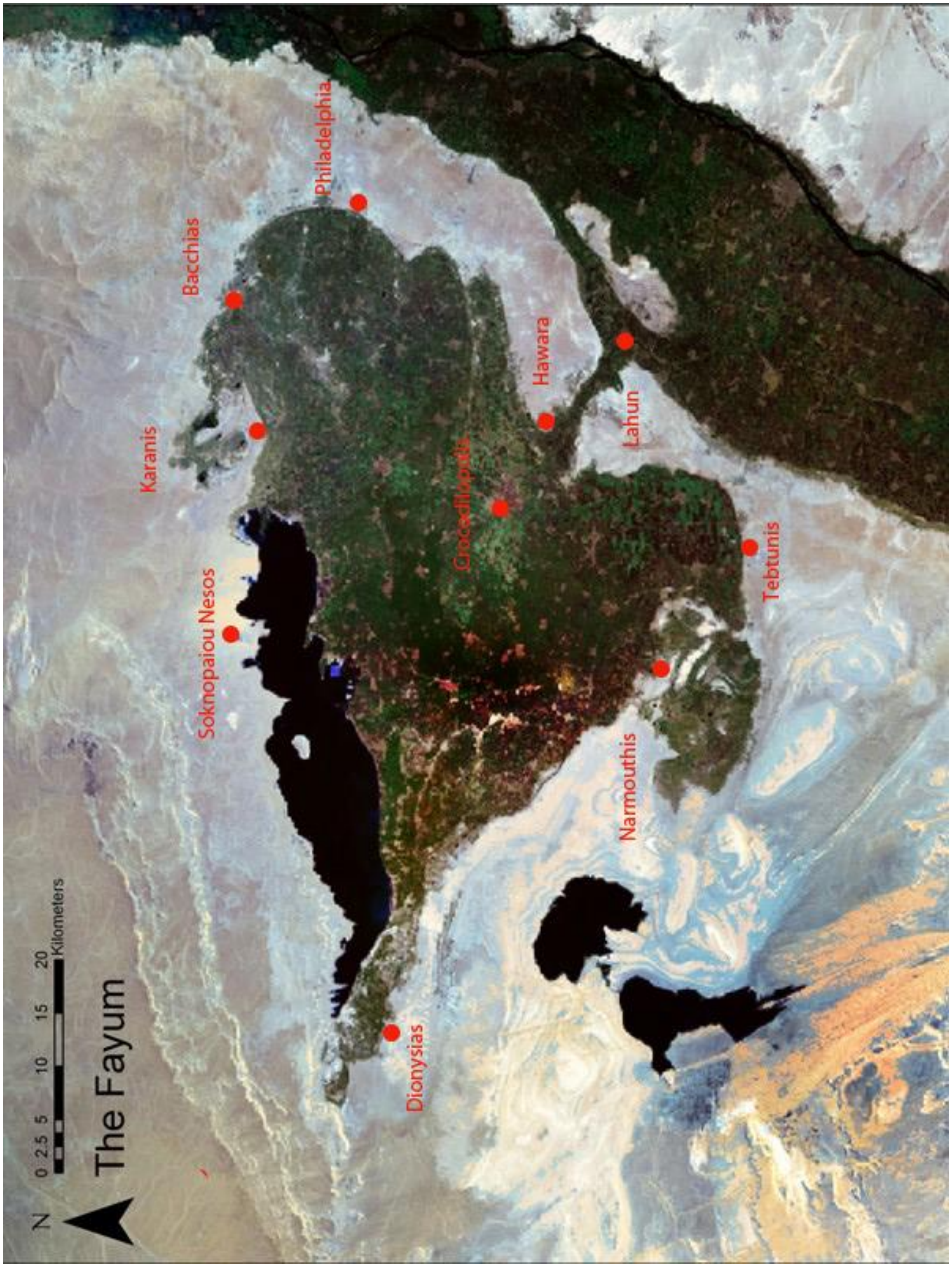


Figure 4: Landsat ETM image of the Fayum depression showing ancient sites mentioned in the text. Data freely available from http://landsat.gsfc.nasa.gov/data/. Accessed 10/10/2007.

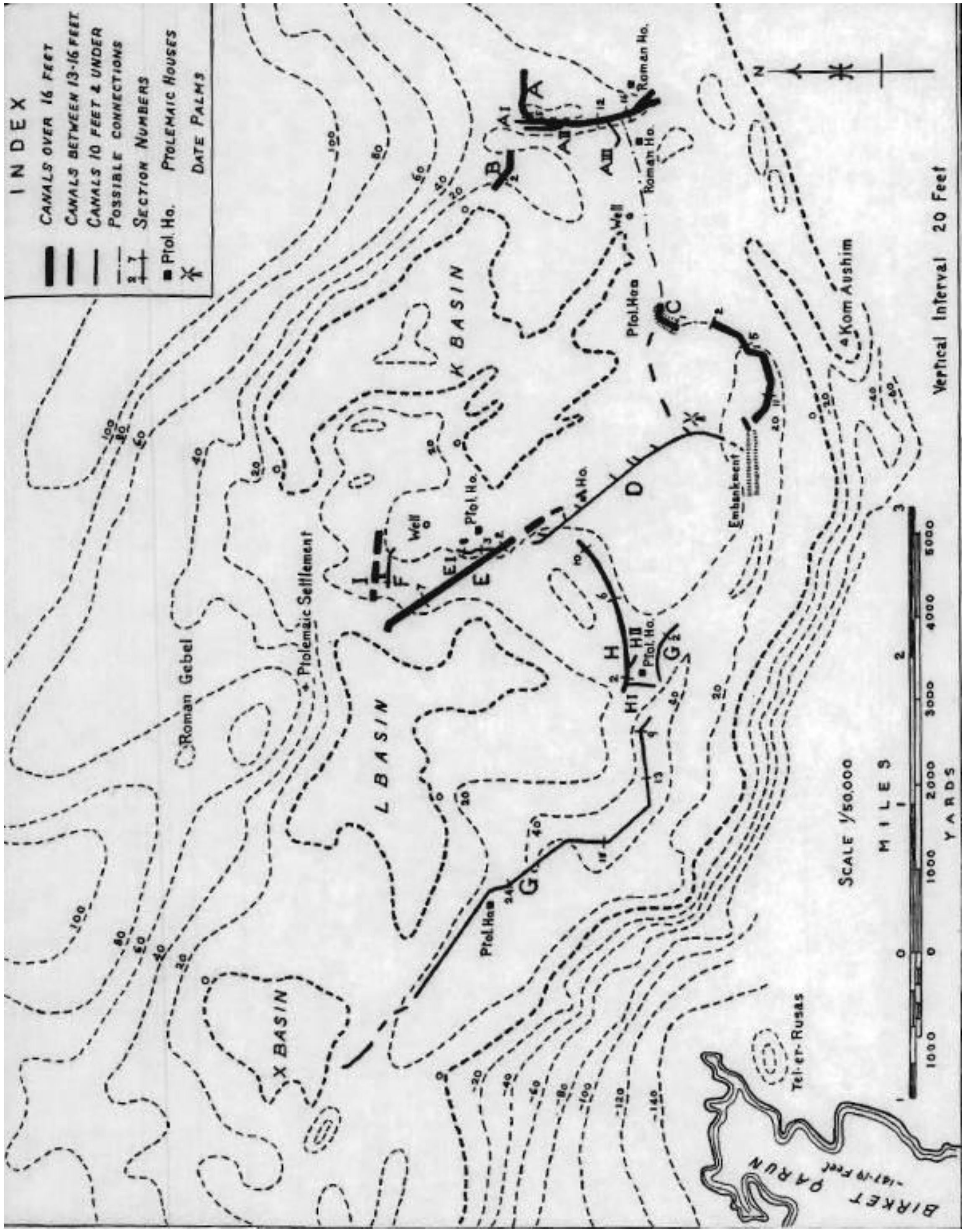


Figure 5: Caton-Thompson and Gardner 1934: plate lxxxvii. Topographic map of the northeast Fayum showing the location of the irrigation system discovered in 1927-8. Reprinted with the kind permission of the Royal Anthropological Institute.

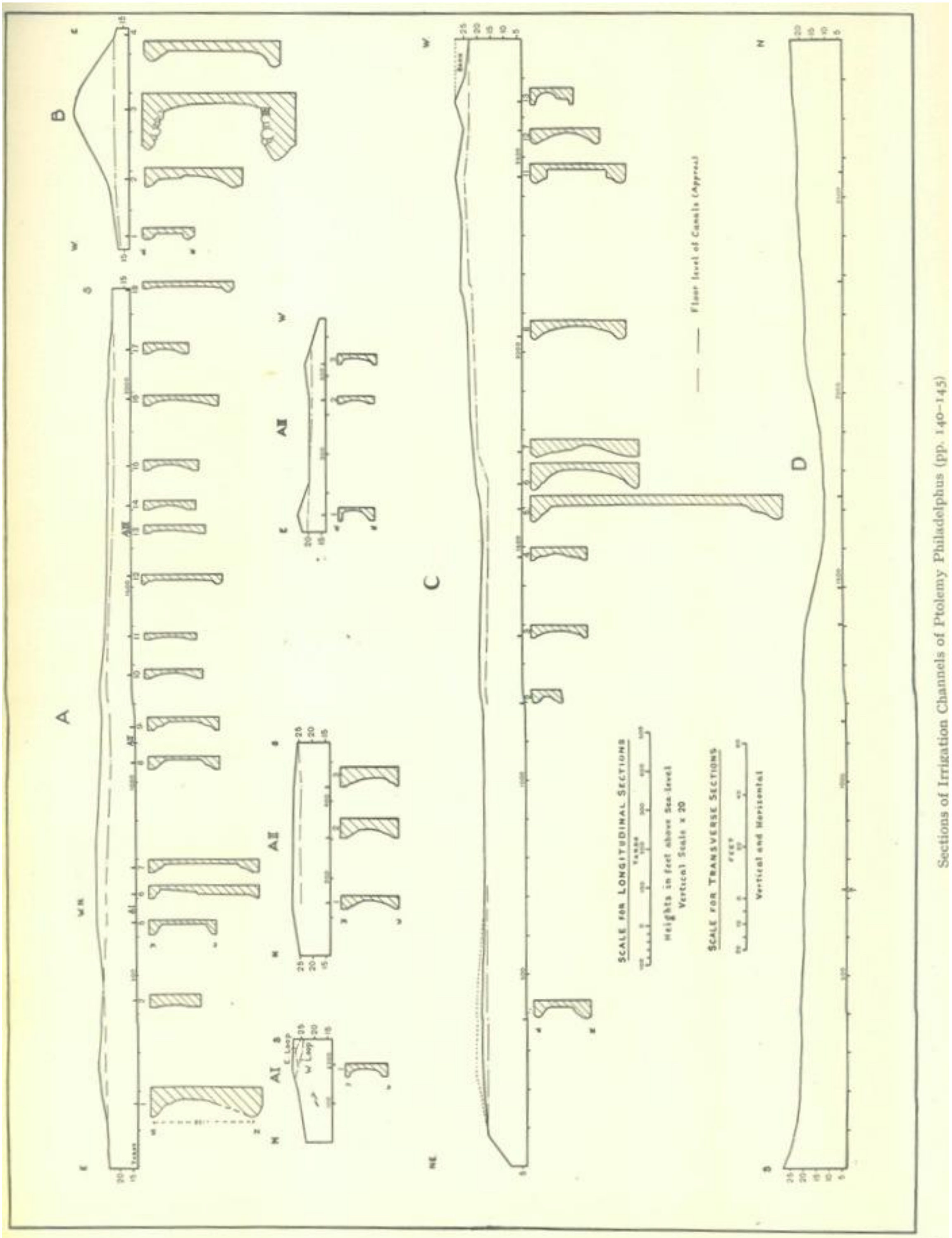


Figure 6: Caton-Thompson and Gardner 1934: plate lxxxviii. Sections of canals A-D. Reprinted with the kind permission of the Royal Anthropological Institute.

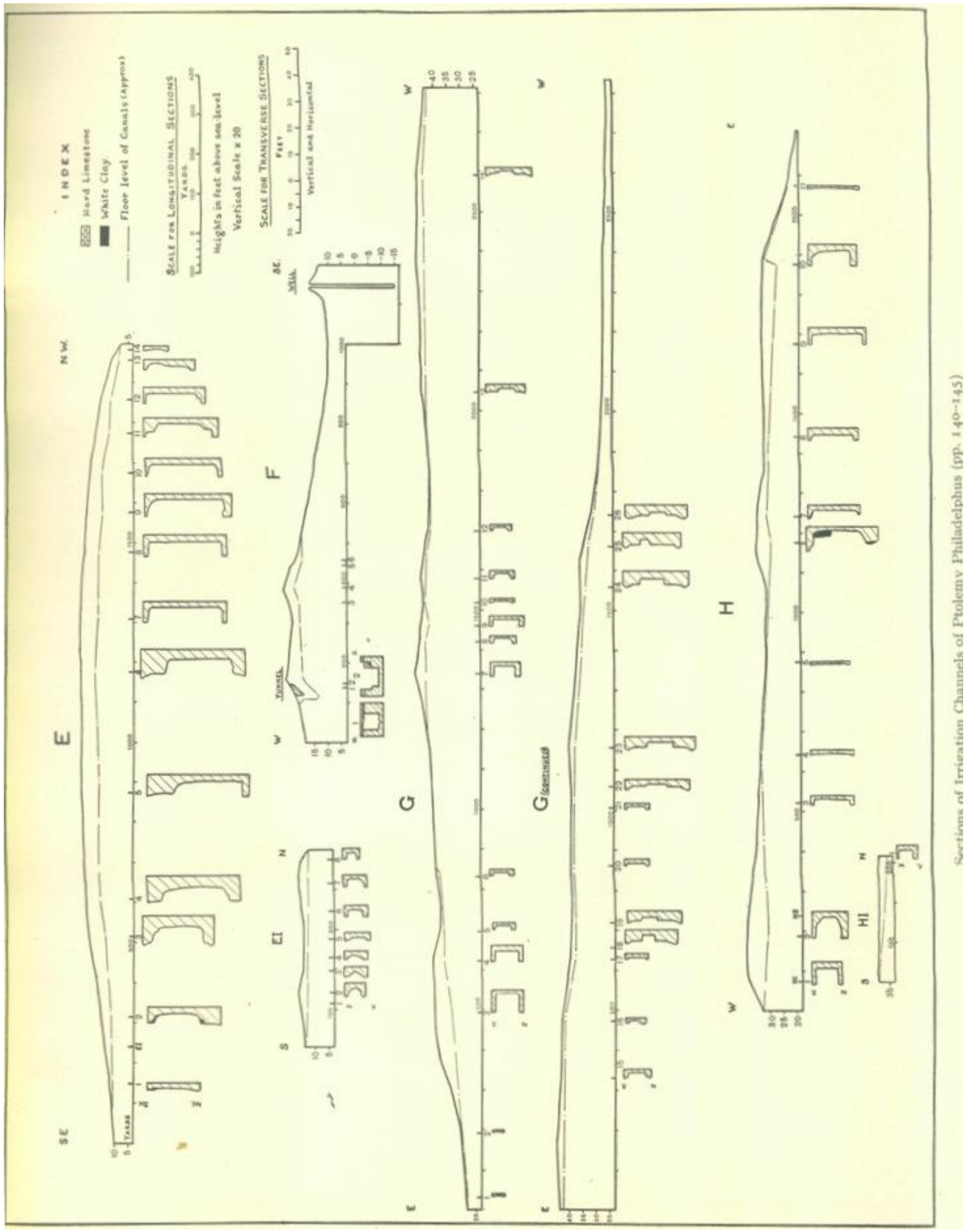


Figure 7: Caton-Thompson and Gardner 1934: plate lxxxix. Sections of canals E-H. Reprinted with the kind permission of the Royal Anthropological Institute.

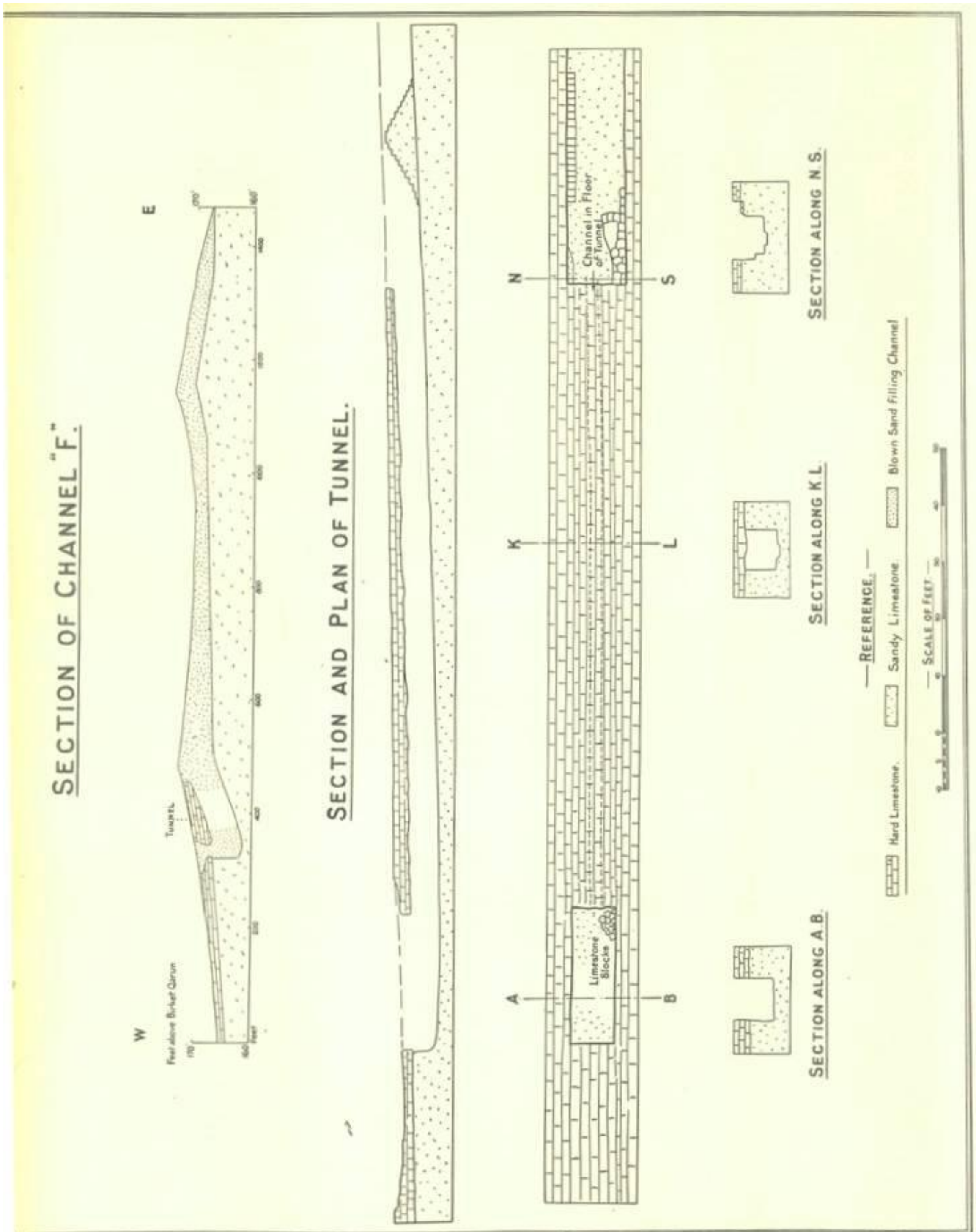
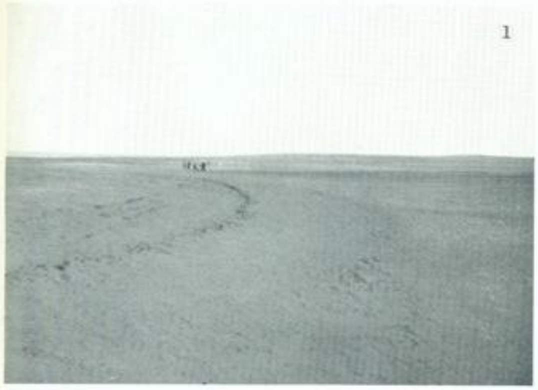


Figure 8: Caton-Thompson and Gardner 1934: plate xc. Plan and section of the tunnel in Canal F. Reprinted with the kind permission of the Royal Anthropological Institute.



Canal E, shown by sprouting vegetation (p. 141)

The same canal three weeks later (p. 141)

Line of cross-canal I (p. 143)

Canal B, partly cleared (p. 143)

Crack marking edge of buried channel; weeds on infilling only (p. 141)

Irrigation Channels of Ptolemy Philadelphus

Figure 9: Caton-Thompson and Gardner 1934: plate xci. Photographs of surface features and the partially excavated Canal B. Reprinted with the kind permission of the Royal Anthropological Institute.

Reservoir (pp. 143, 149)

Canal F, after clearance (p. 143)

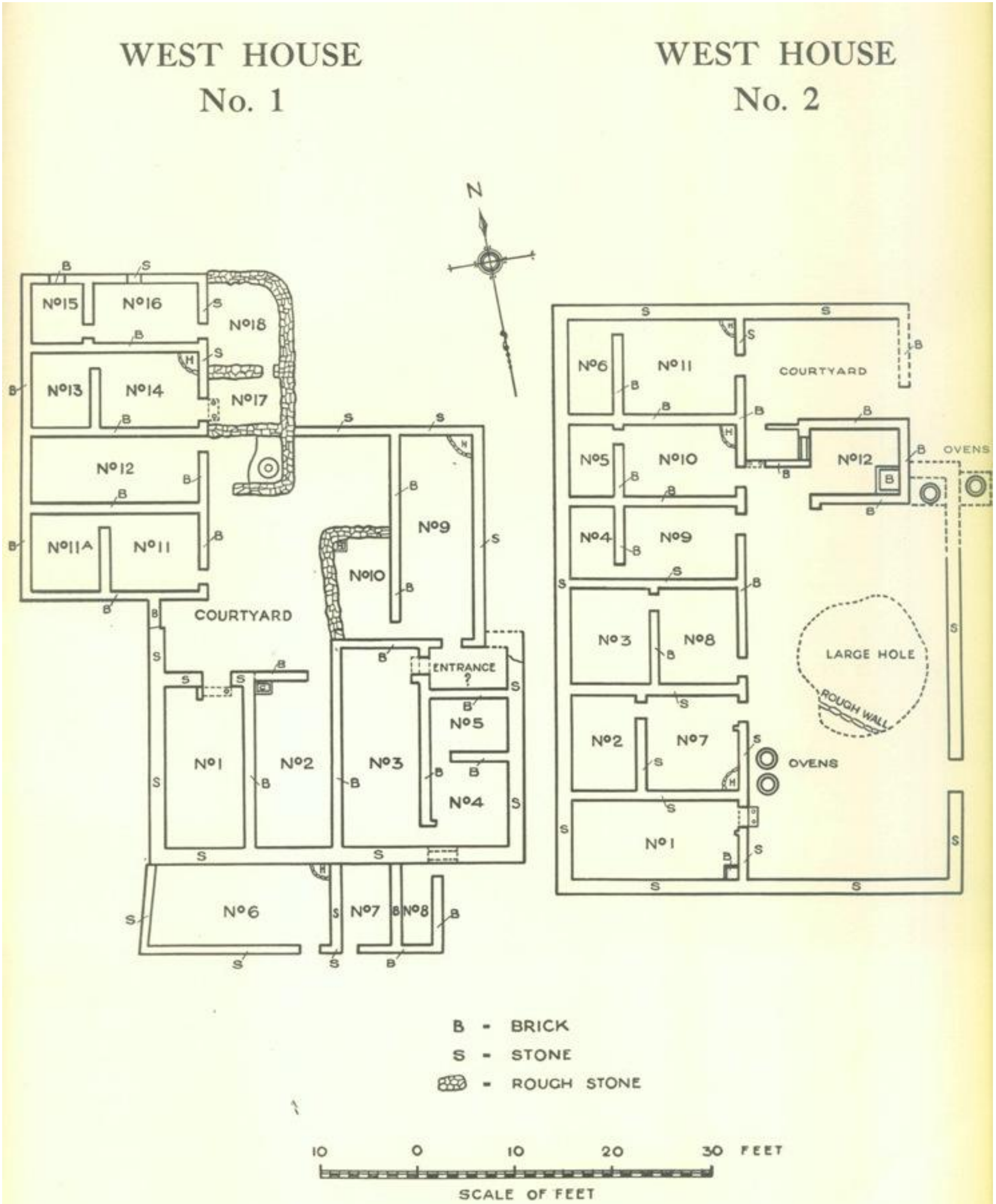
Canal F, before clearance (pp. 142–143)

Canal F, with tunnel, overlooking L basin (p. 143)

Excavation of canal B (p. 143)
(see pl. xci, 5)

Irrigation Channels of Ptolemy Philadelphus

Figure 10: Caton-Thompson and Gardner 1934: plate xcii. Photographs of the reservoir and canal excavations. Reprinted with the kind permission of the Royal Anthropological Institute.



Irrigation Houses (pp. 145–148)

Figure 11: Caton-Thompson and Gardner 1934: plate xciii. Plans of houses excavated along the Canal G alignment. Reprinted with the kind permission of the Royal Anthropological Institute.

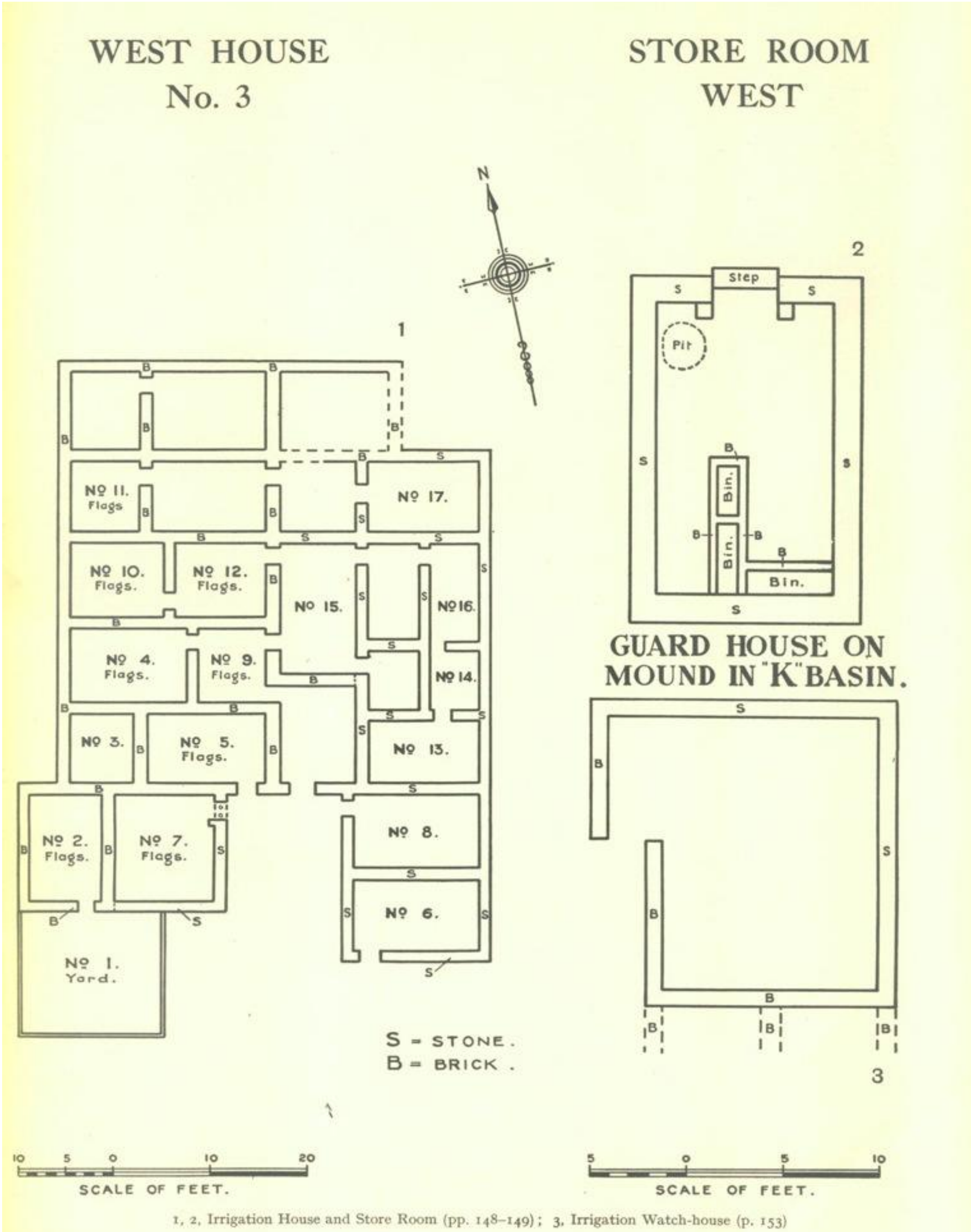


Figure 12: Caton-Thompson and Gardner 1934: plate xciv. Plans of houses excavated along the Canal G alignment and of a "guard house" in the K-Basin. Reprinted with the kind permission of the Royal Anthropological Institute.

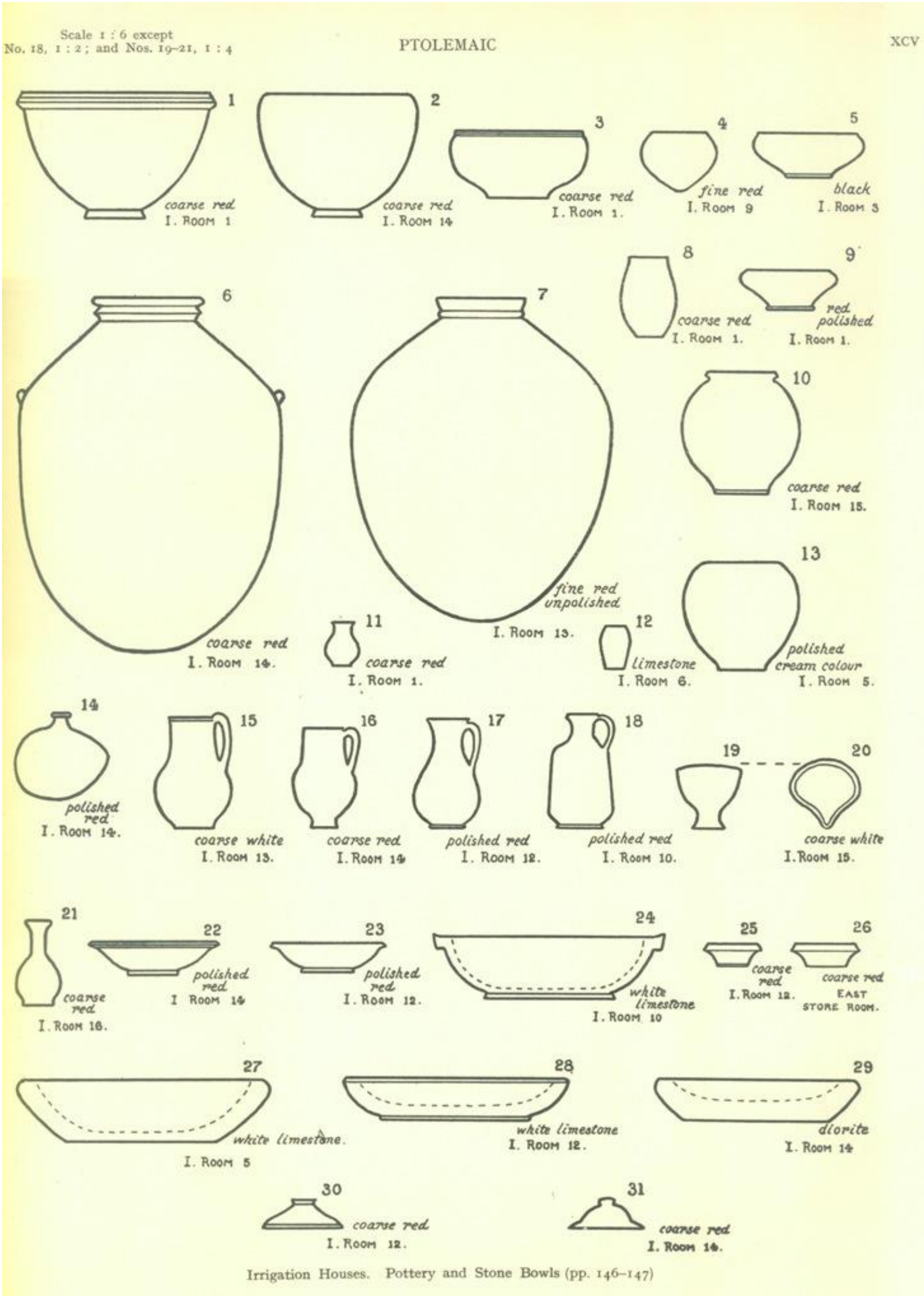


Figure 13: Caton-Thompson and Gardner 1934: plate xcv. Profiles of ceramic and stone artifacts recovered from houses excavated along the Canal G alignment. Not reproduced to scale. Reprinted with the kind permission of the Royal Anthropological Institute.

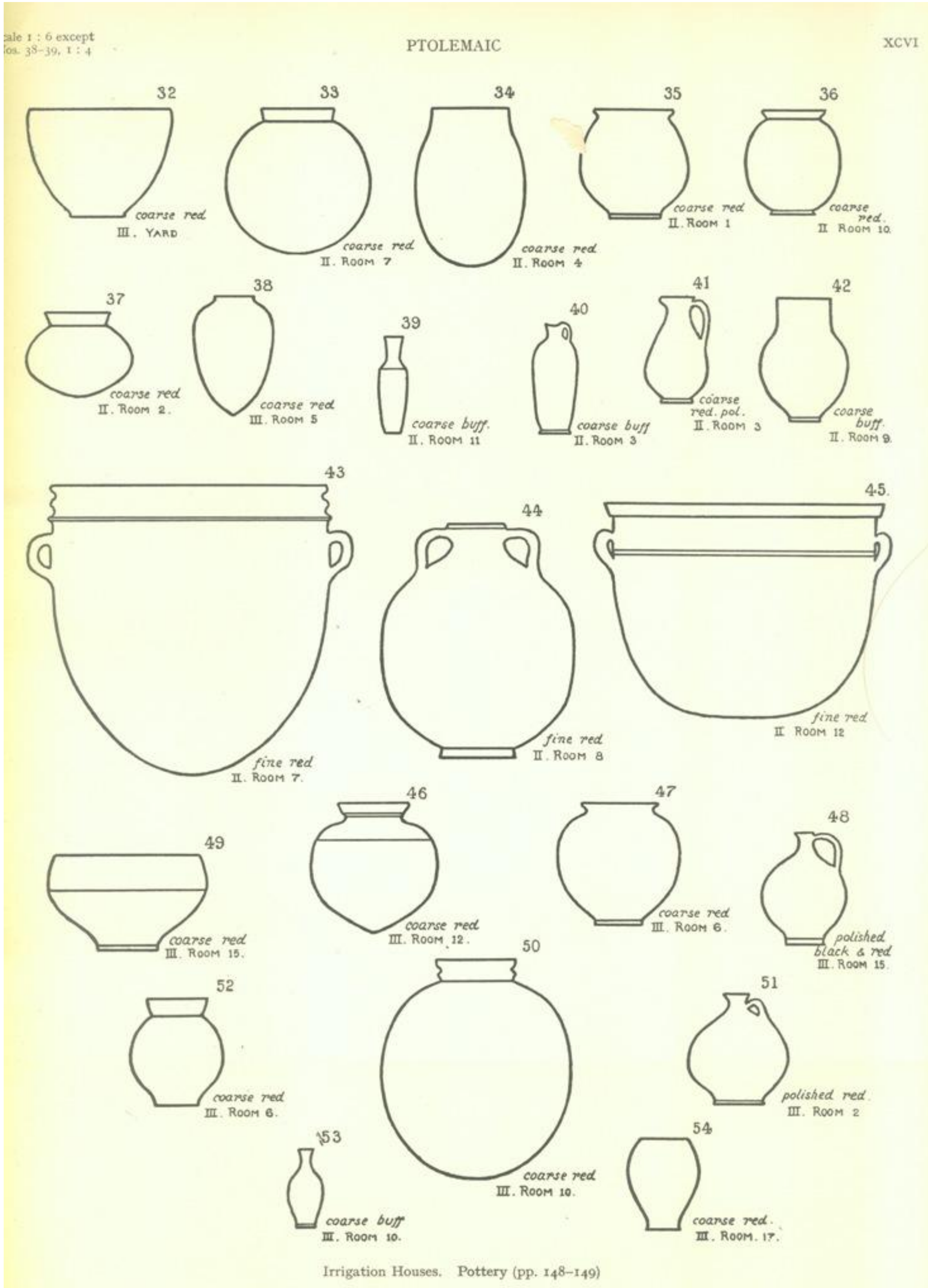


Figure 14: Caton-Thompson and Gardner 1934: plate xcvi. Profiles of ceramic and stone artifacts recovered from houses excavated along the Canal G alignment. Not reproduced to scale. Reprinted with the kind permission of the Royal Anthropological Institute.

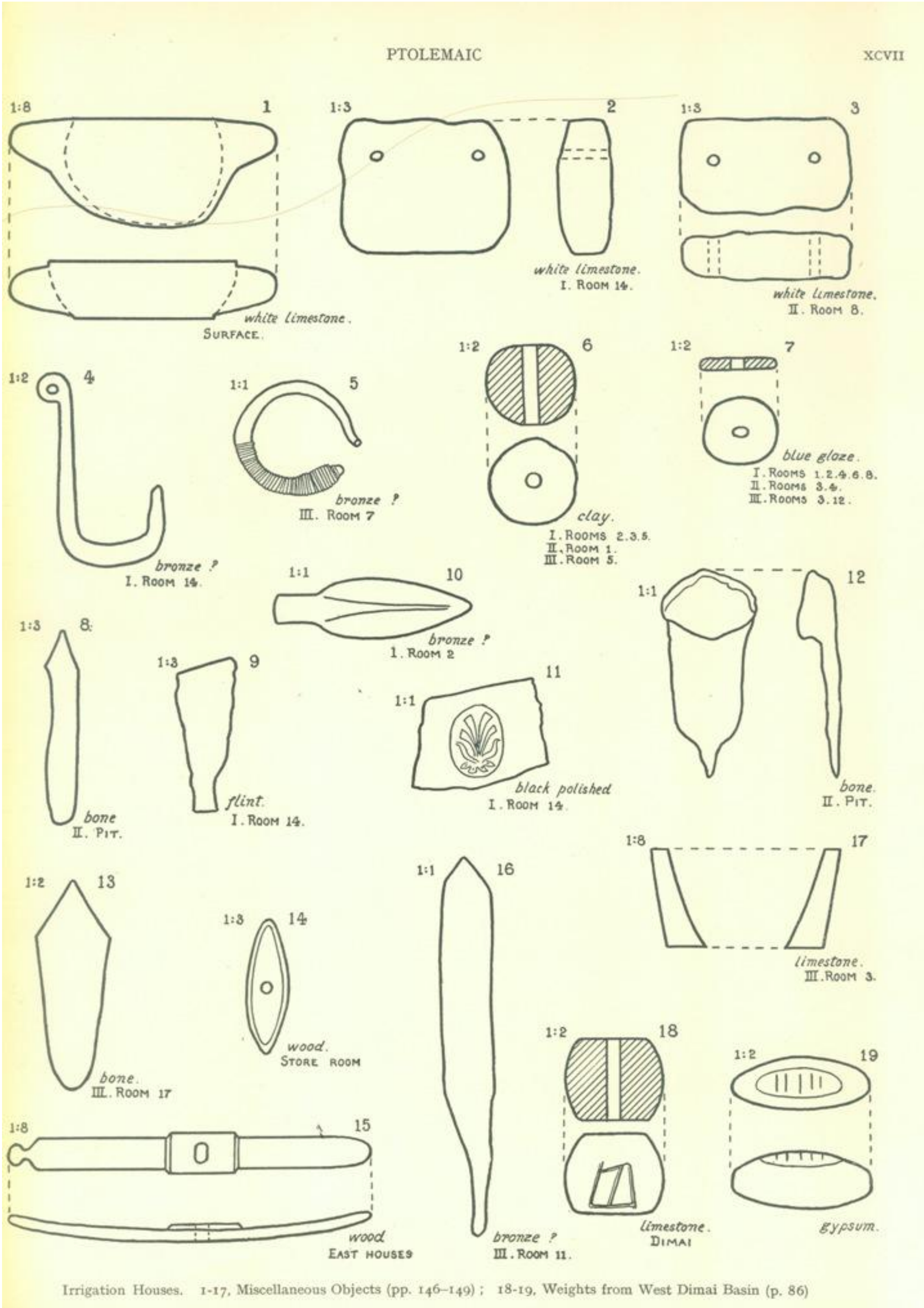


Figure 15: Caton-Thompson and Gardner 1934: plate xcvii. Artifacts from excavated houses. Not reproduced to scale. Reprinted with the kind permission of the Royal Anthropological Institute.

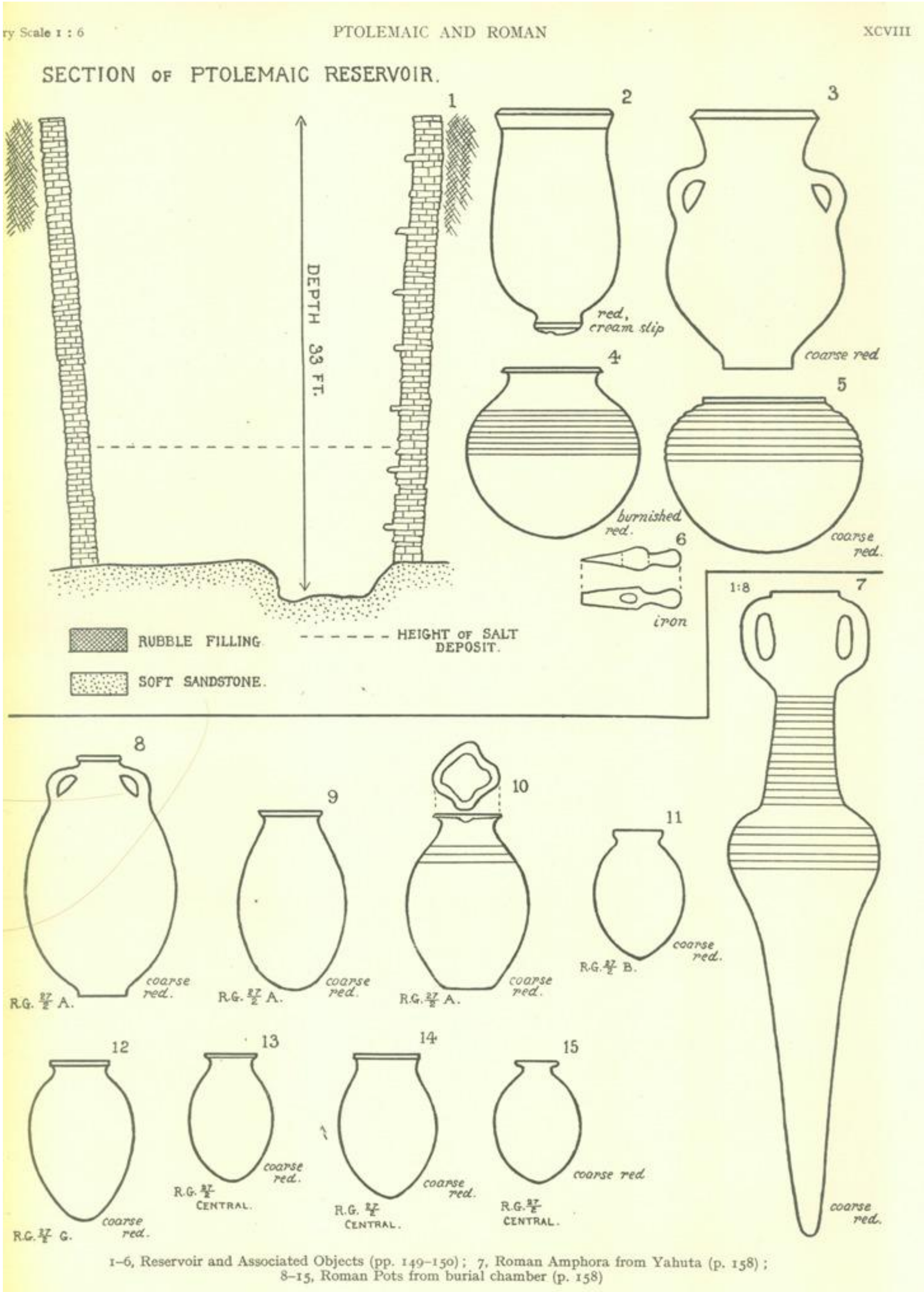


Figure 16: Caton-Thompson and Gardner 1934: plate xcviii. Above, section of reservoir excavated in the K-Basin and artifacts recovered from the site. Not reproduced to scale. Reprinted with the kind permission of the Royal Anthropological Institute.

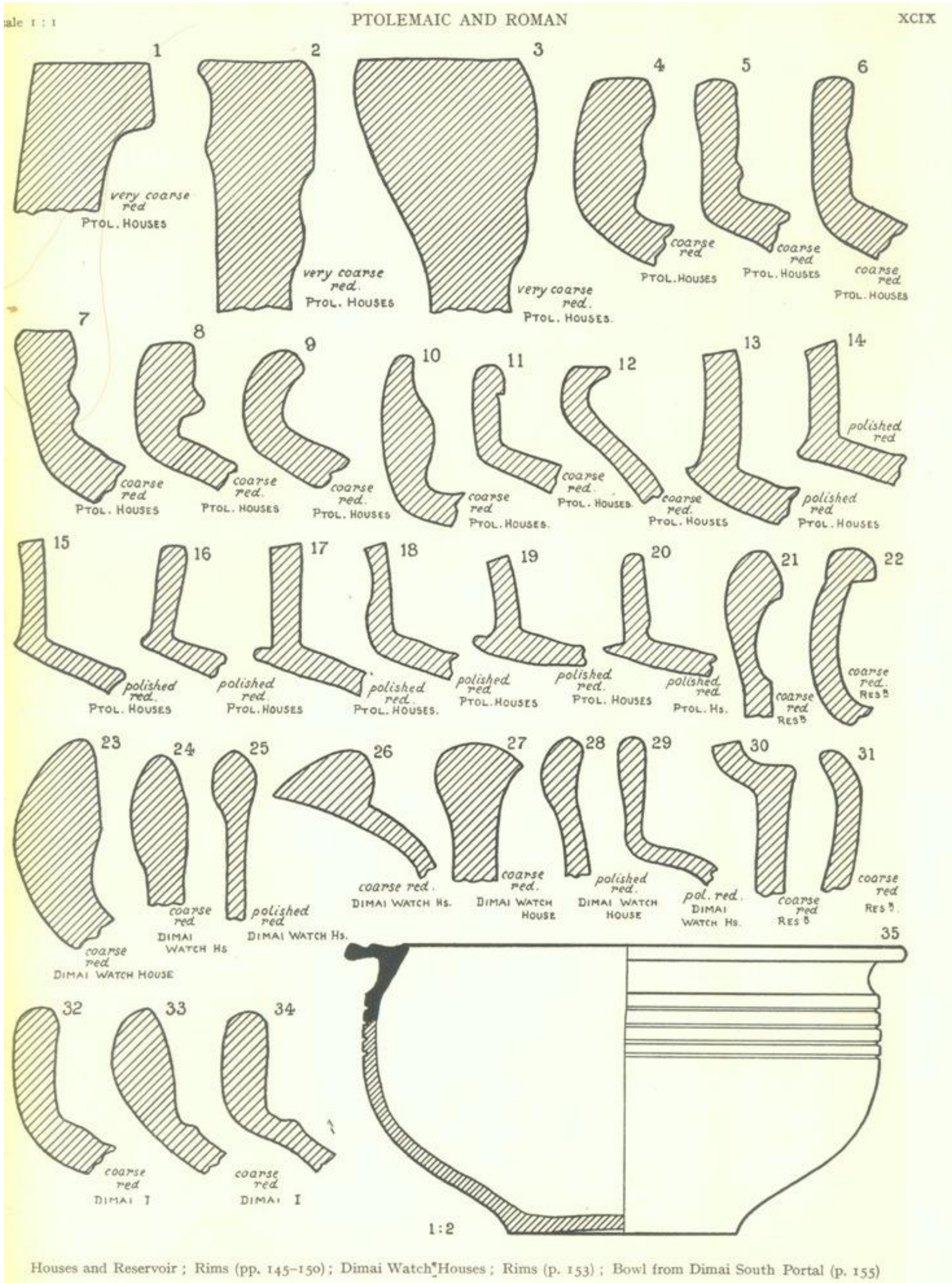


Figure 17: Caton-Thompson and Gardner 1934: plate xcix. Drawing of vessel rims recovered from the houses along the Canal G alignment and the reservoir. Not reproduced to scale. Reprinted with the kind permission of the Royal Anthropological Institute.

GRAECO-ROMAN C

Pottery group from irrigation houses (pp. 145–149)

Abu Ballas (p. 158)

Ptolemaic Net-sinker and Quern (p. 148)

Dimai—Roman grave (p. 158)

Dimai—Roman burial chamber (p. 157)

Figure 18: Caton-Thompson and Gardner 1934: plate c. Top, photograph of vessels recovered from the houses excavated along the Canal G alignment. Reprinted with the kind permission of the Royal Anthropological Institute.

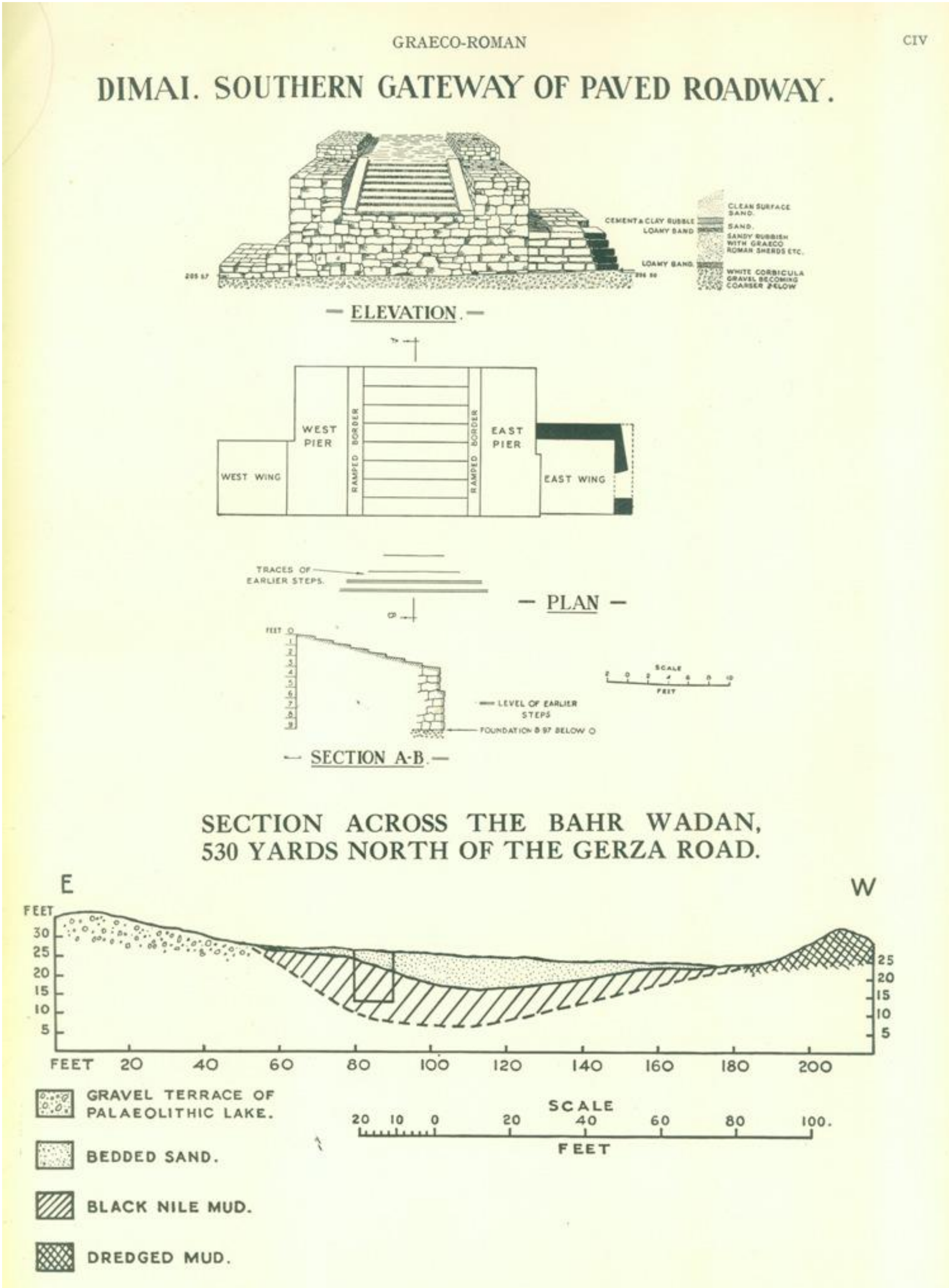


Figure 19: Caton-Thompson and Gardner 1934: plate civ. Bottom, section excavated across the ancient main peripheral canal of the Fayum. Reprinted with the kind permission of the Royal Anthropological Institute.

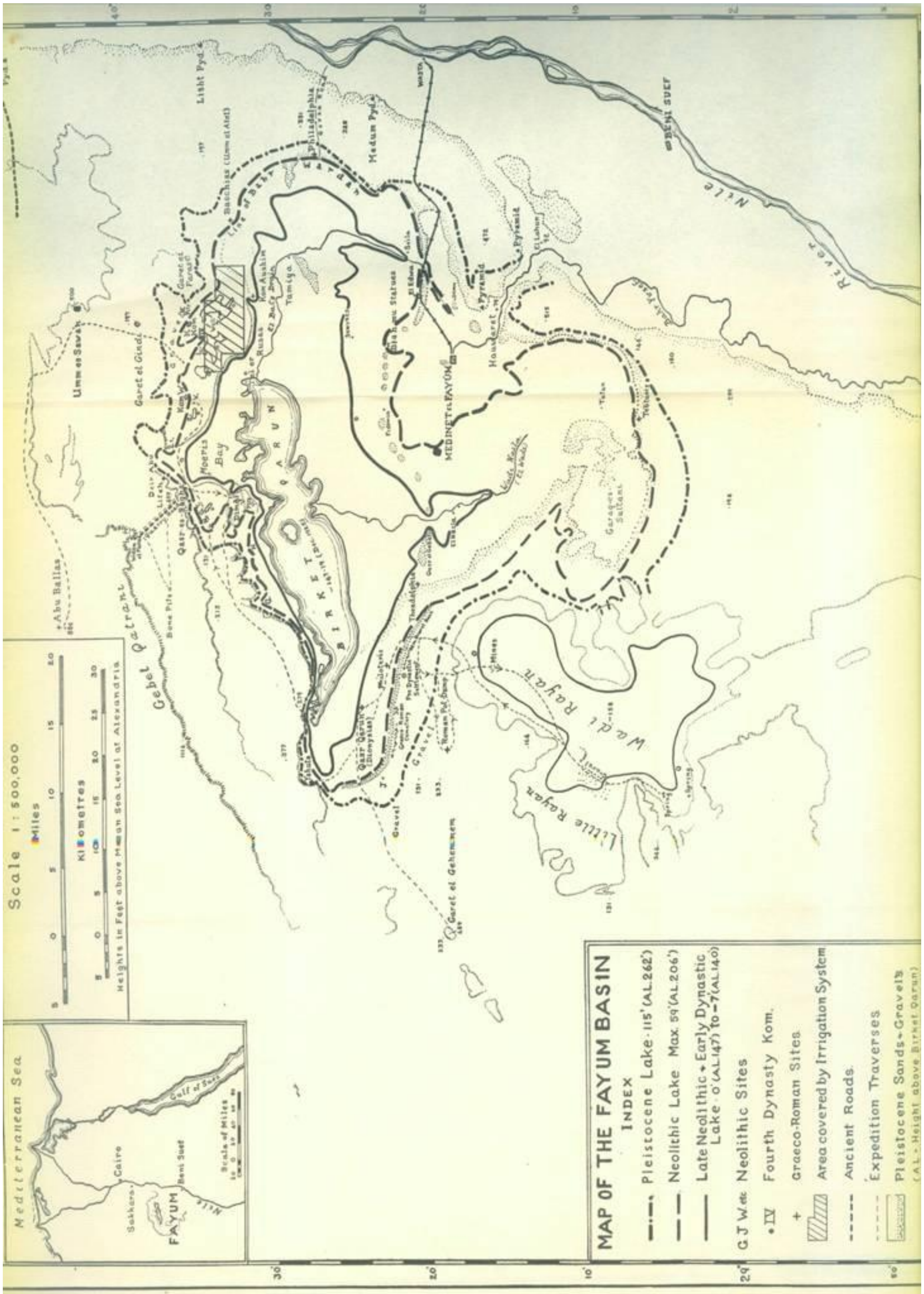


Figure 20: Caton-Thompson and Gardner 1934: plate cviii. Map of the Fayum Basin, 1:500,000. Reprinted with the kind permission of the Royal Anthropological Institute.

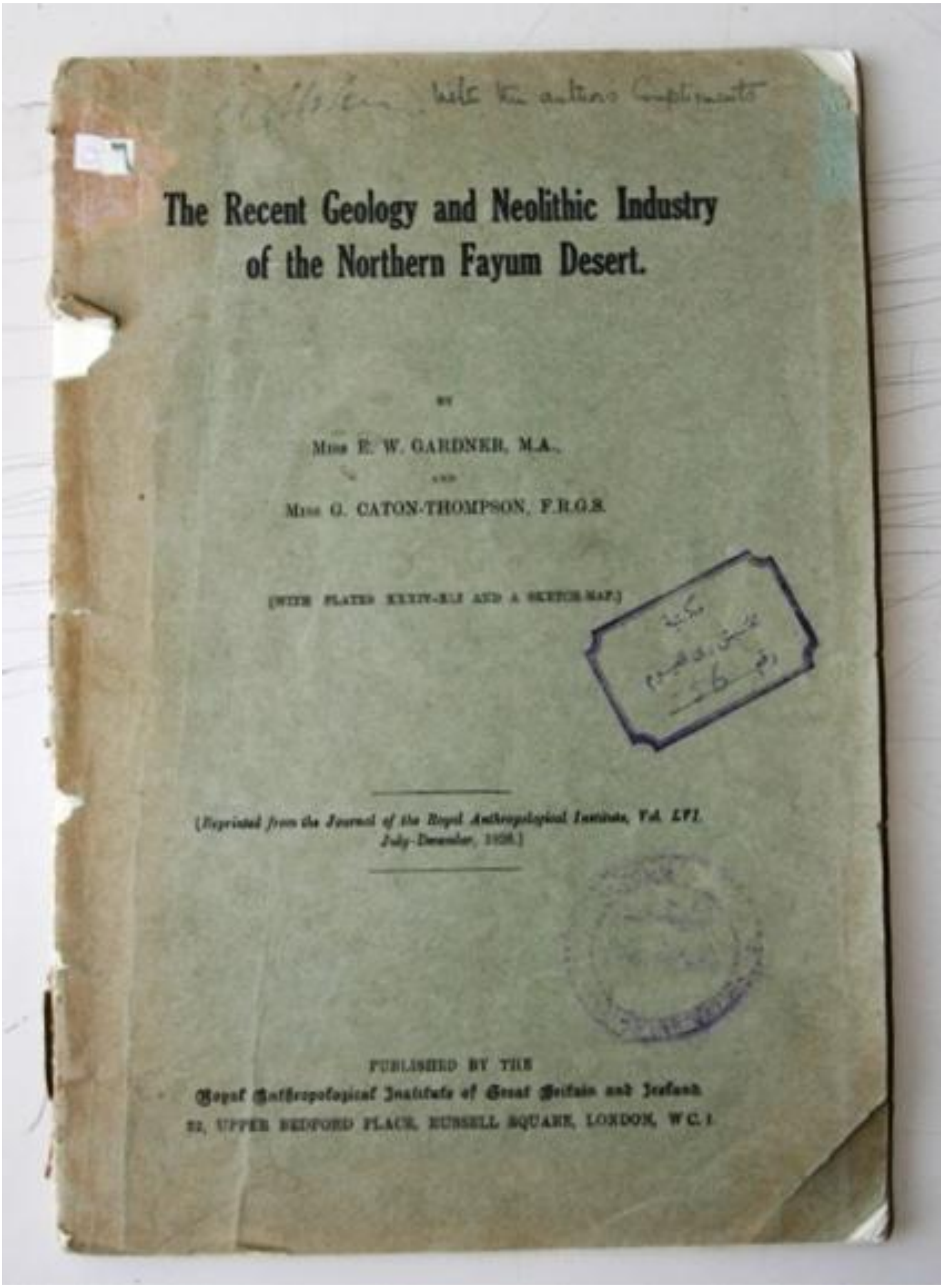


Figure 21: Offprint of a 1926 article by Caton-Thompson and Gardner. Signed by E. Gardner and inscribed, "With the author's compliments". Discovered by the author in the archives of the Fayum Irrigation Authority. Photo by author.

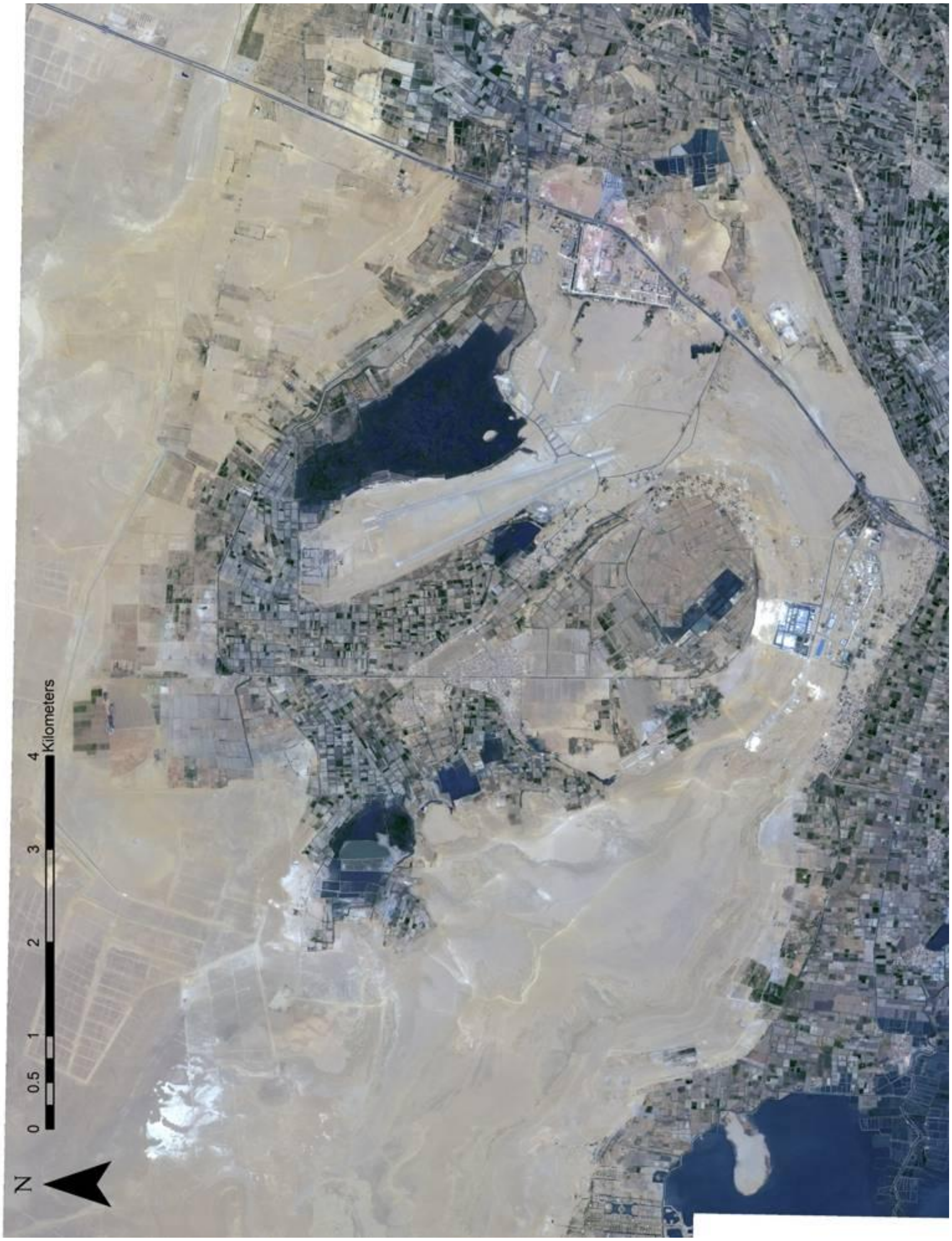


Figure 22: Quickbird image of the survey zone. The K- and L-Basins are filled with dark water, while the diatomaceous pan of the X-Basin appears as a white mark to the northwest. Karanis is located to the east of the highway beside the cultivated area. Data from Digital Globe 2007.

Figure 23: The lake and high desert plateau from Qarit Rusas, facing north. Photo by author.

Figure 24: Typical desert pavement near FD 013, facing south. Photo by author.

Figure 25: Decimation of the landscape by quarrying. East of Karanis, facing south. Photo by author.

Figure 26: Some quarries reach depths of ca. 20 m. West of Karanis, facing east. Photo by author.

Figure 27: A robbed shaft grave on the ridge west of Karanis. Photo by author.

Figure 28: A robbed mastaba tomb in the Karanis cemetery. The police post is in the trees at rear. Photo by author.

Figure 29: A section of the Canal G alignment noticeable by its light interior surface and low, rocky berms, facing east. Photo by author.

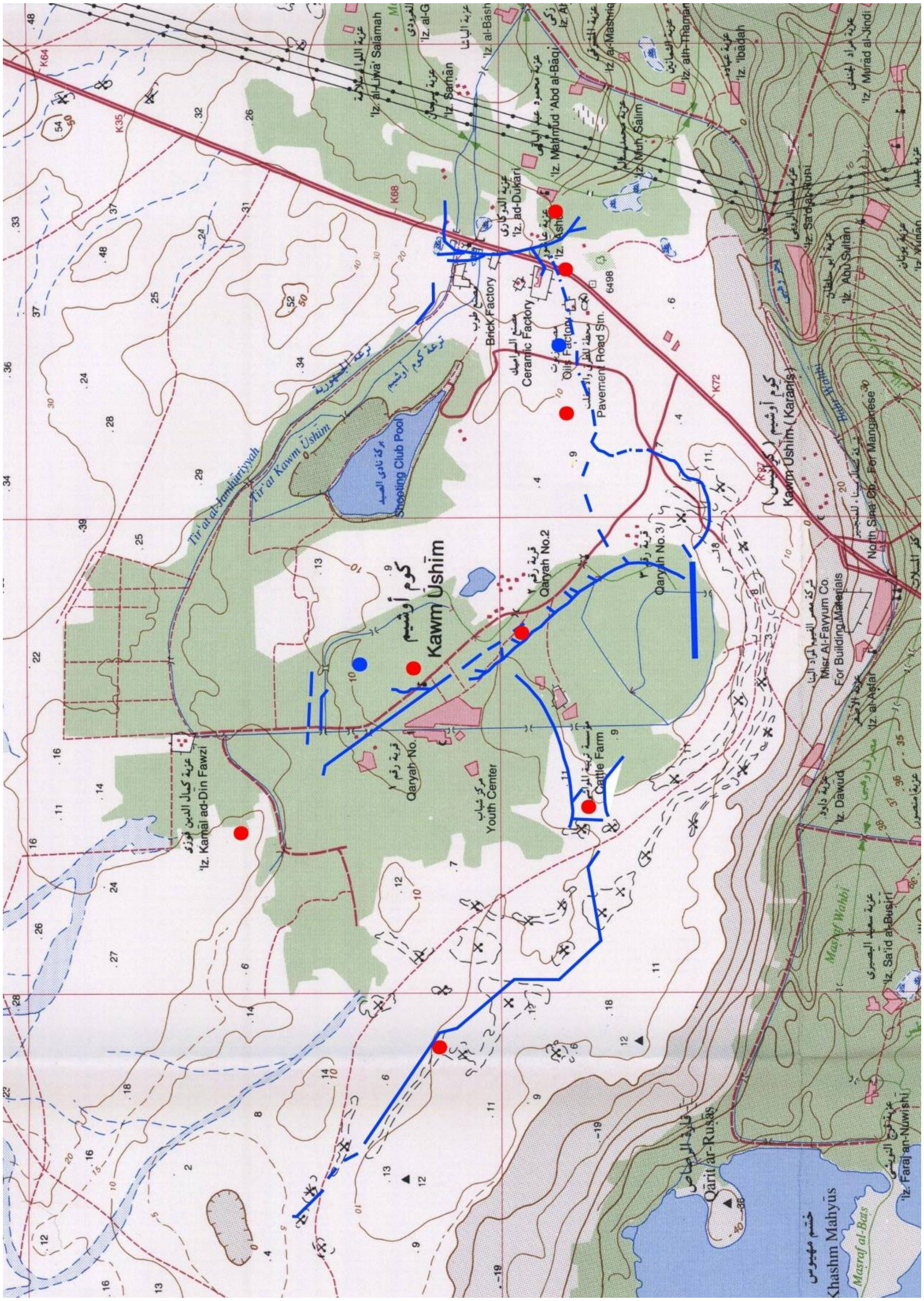


Figure 30: Sites and canals from Caton-Thompson and Gardner's map (above, Figure 3) superimposed on the 1:50,000 series *Kawm Ūshīm* topographic map sheet.

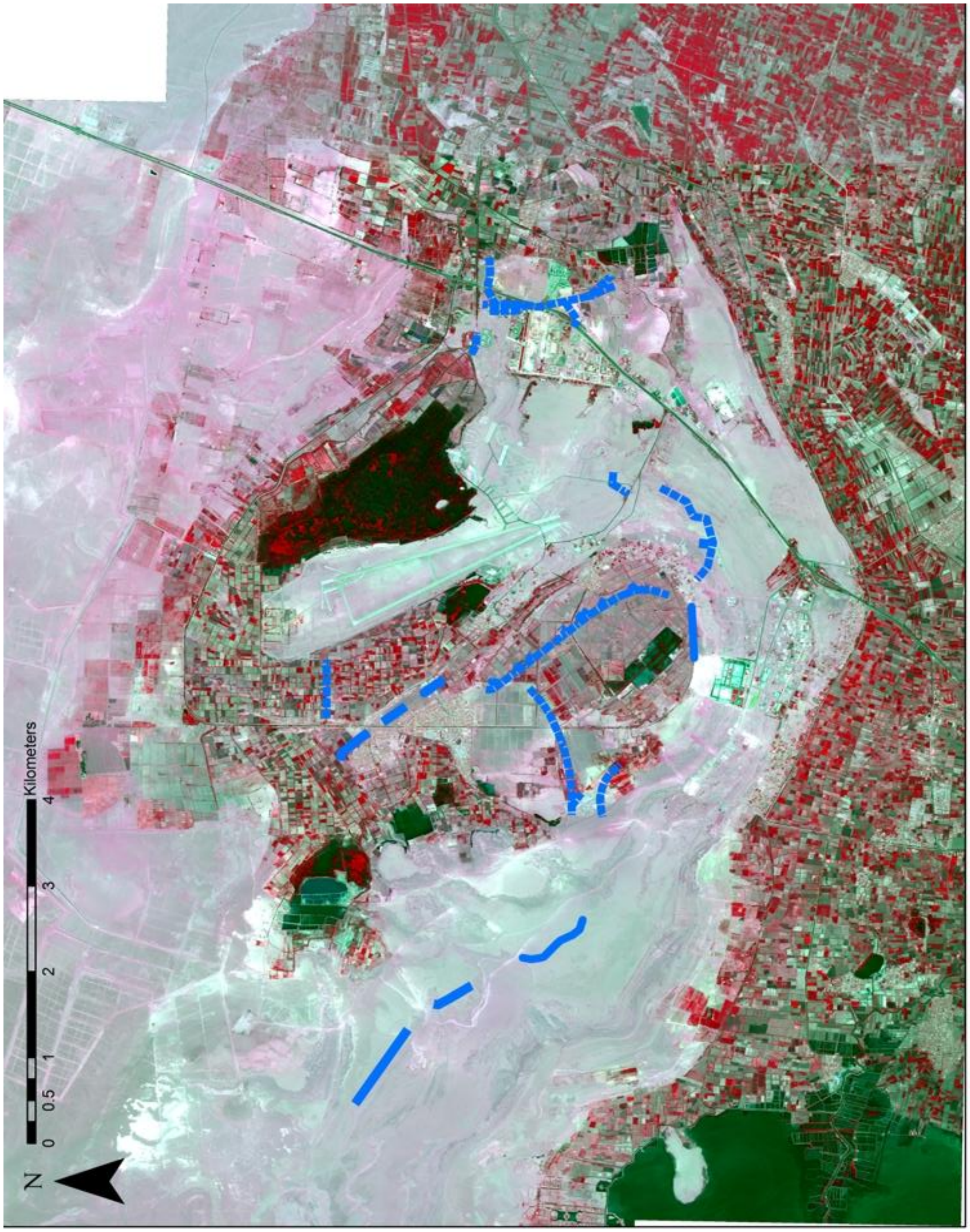


Figure 31: Pan-sharpened False-Color Near-Infrared Quickbird image showing the rectified location of the canals (blue) from Caton-Thompson and Gardner's map (above, Figure 5). Data from Digital Globe 2007.

Figure 32: Pan-Sharpened False-Color Near-Infrared Quickbird Image of Canal E. The channel (indicated by black arrows) can be easily discerned running SE-NW through a series of fields and a large empty lot beside the village of Qarya Ula. Data from Digital Globe 2007.

Figure 33: Ground view of the feature visible in Figure 28. Taken from the northern end of the empty lot, facing south. Photo by author.

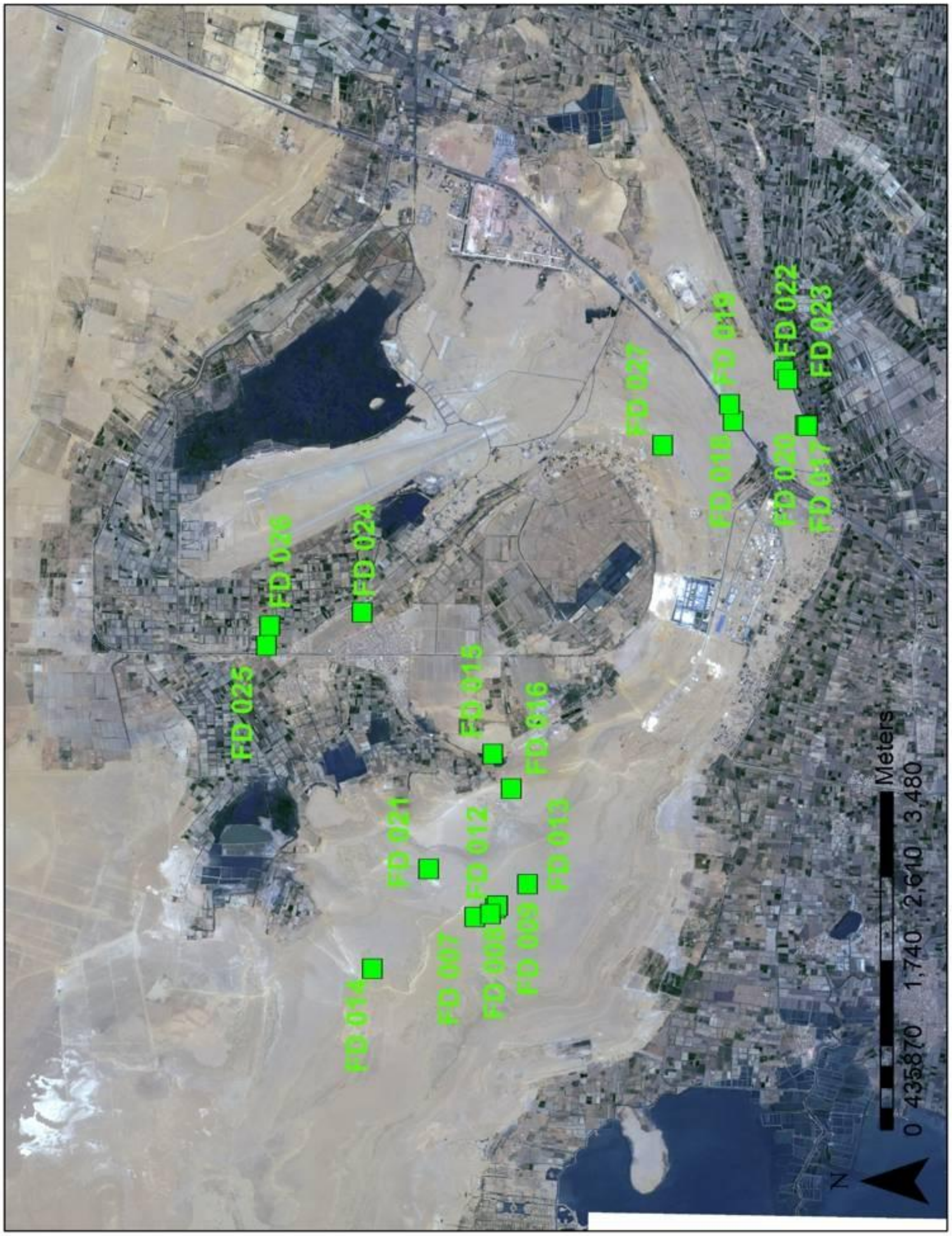


Figure 34: Pan-sharpened Quickbird image showing the location of all trenches excavated in 2007-8. Data from Digital Globe 2007.

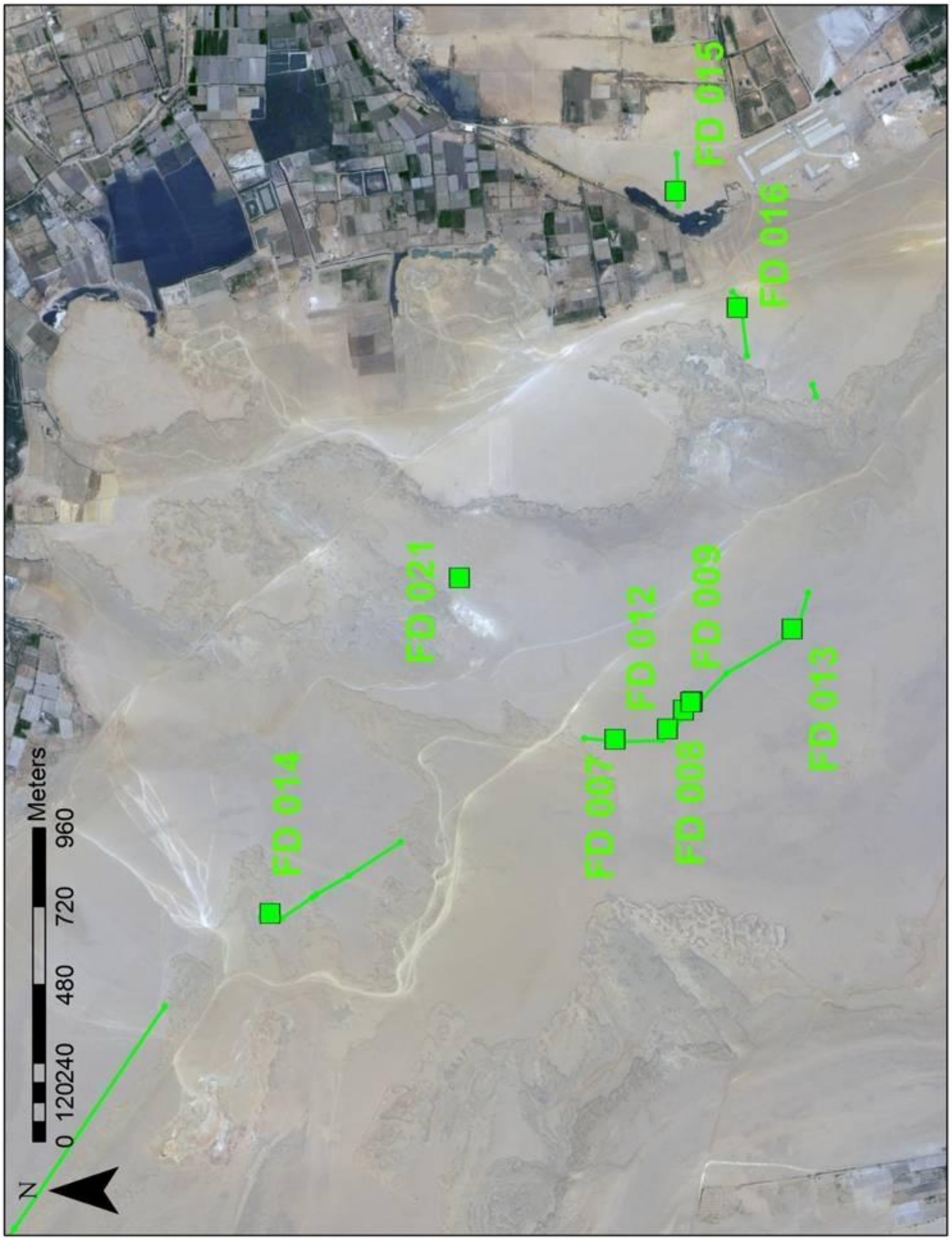


Figure 35: Pan-sharpened Quickbird image showing the location of trenches excavated west of Karanis along the Canal G, H, and K alignments in 2007-8. Data from Digital Globe 2007.

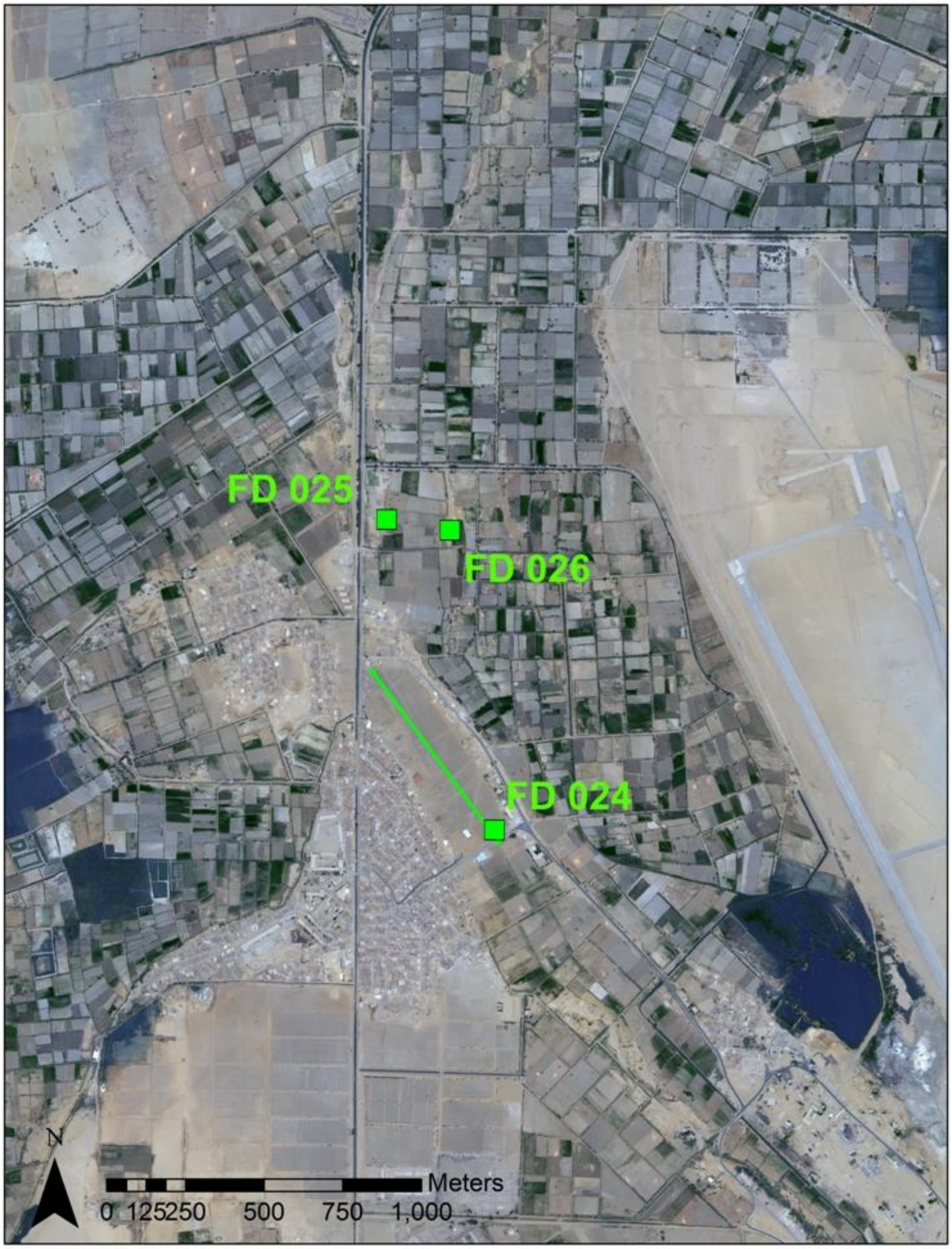


Figure 36: Pan-sharpened Quickbird image showing the location of trenches excavated north of Karanis in the vicinity of Qarya Ula along the Canal E and F alignments in 2007-8. Data from Digital Globe 2007.

Figure 37: The large dune at Izbet Ashur is the probable site of a "Roman House" indicated by Caton-Thompson and Gardner (Above, Figure 3). The Canal A alignment should run from right to left in the foreground, but the landscape has been levelled by plowing. Photo by author.

Figure 38: Pan-sharpened Quickbird image of the area east of Karanis. The relocated "Roman Houses" near Izbet Ashūr are visible as a kidney-shaped dune (indicated) amid the fields in lower left. The modern Masraf Azzam runs vertically through the image, turning to the east at Izbet Darouri/Izbet Sarhān. Data from Digital Globe 2007.

Figure 39: The “great cut” of the Canal B alignment, facing northwest. The channel has been reused for the course of the modern Tira’at Kamw Aushim. Photo by author.

Figure 40: Landscape damage near the probable course of Canal C. Photo taken from the southern end of Qarya Thalatha, facing northeast. Quarrying damage is visible at right. The white features to the left are stone blocks loosely laid as foundation courses for settlement expansion. The area will become private property unless the government removes the blocks.

Figure 41: A modern track near the probable location of Canal C, facing south. The track turns suddenly to the west for no apparent reason, as does the canal alignment on Caton-Thompson and Gardner's map (Above, Figure 3). Photo by author.

Figure 42: FD 027 Pre-excavation Canal C channel, facing west. Photo by author.

Figure 43: Post excavation photo of Canal C channel in FD 027, facing north. The channel slopes steeply to left. Photo by author.

Figure 44: Post excavation photo of Canal C channel in FD 027, facing south. The channel slopes steeply to right. Photo by author.

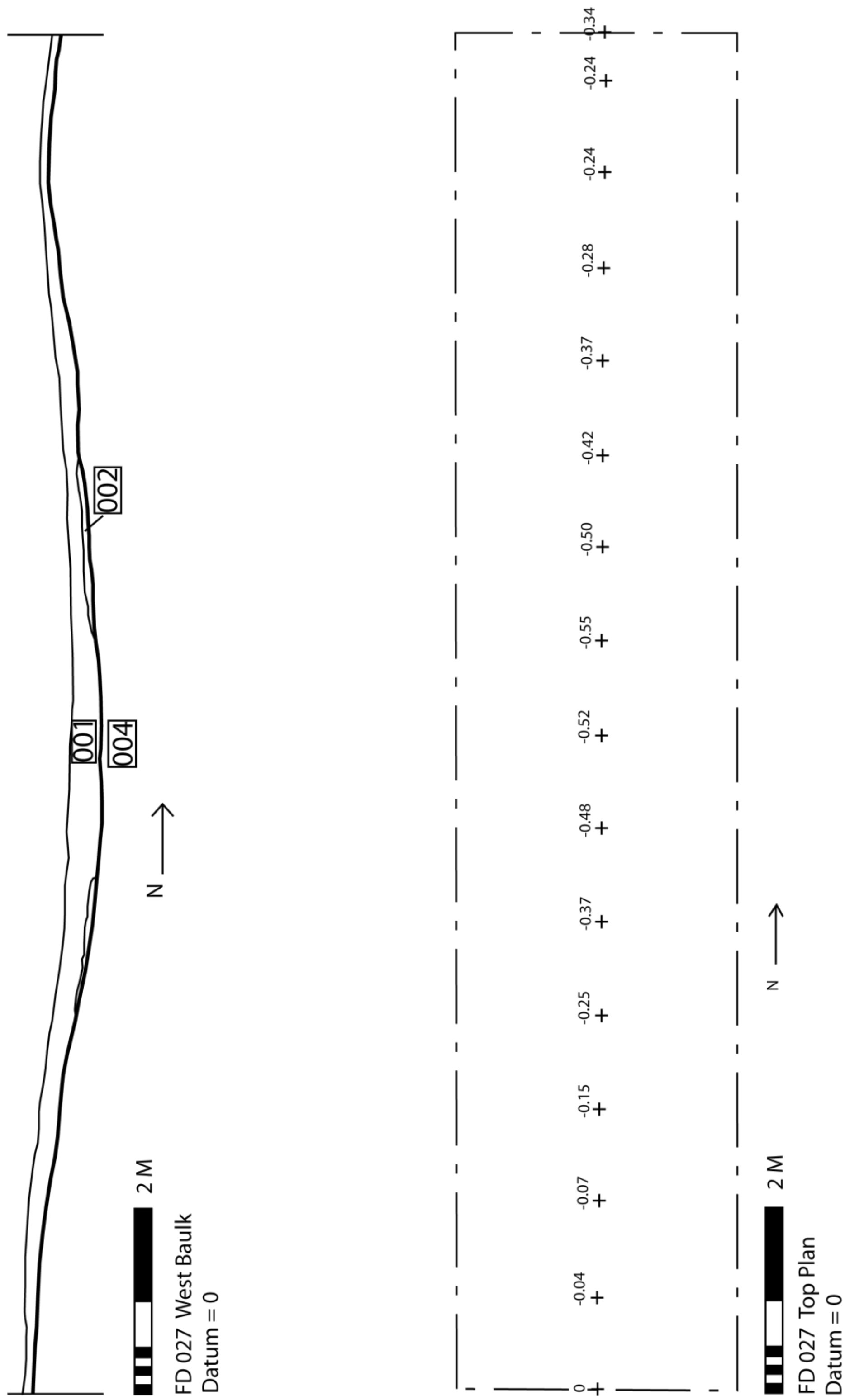


Figure 45: FD 027 Final top plan and final section of west baulk. Drawings by author.

Figure 46: Probable profile of Canal C identified in a quarry cut near Qarya Thalatha, facing northwest. The land above is "private property". Photo by author.

Figure 47: The southern terminus of the modern Tira'at al-Jamhurriyah at the southern end of the L-Basin, facing west. The canal follows the line of the "Embankment" indicated on Caton-Thompson and Gardner's map of the irrigation system and may reuse it for one or both berms. Photo by author.

Figure 48: Modern canal to the west of Qarya Ithnayn which flows through a rock-cut channel following the approximate line of Canal D, facing northeast. Photo by author.

Figure 49: Modern canal to the west of Qarya Ithnayn which flows through a rock-cut channel following the approximate line of Canal D, facing southeast. Photo by author.

Figure 50: Vegetation growing in parallel lines along the Canal E alignment at the northern end of an empty lot in Qarya Ula, facing northwest. Photo by author.

Figure 51: Post excavation photo of Canal E channel in FD 024, facing northeast. Photo by author.

Figure 52: Post excavation photo of Canal E channel in FD 024, facing southwest. Photo by author.

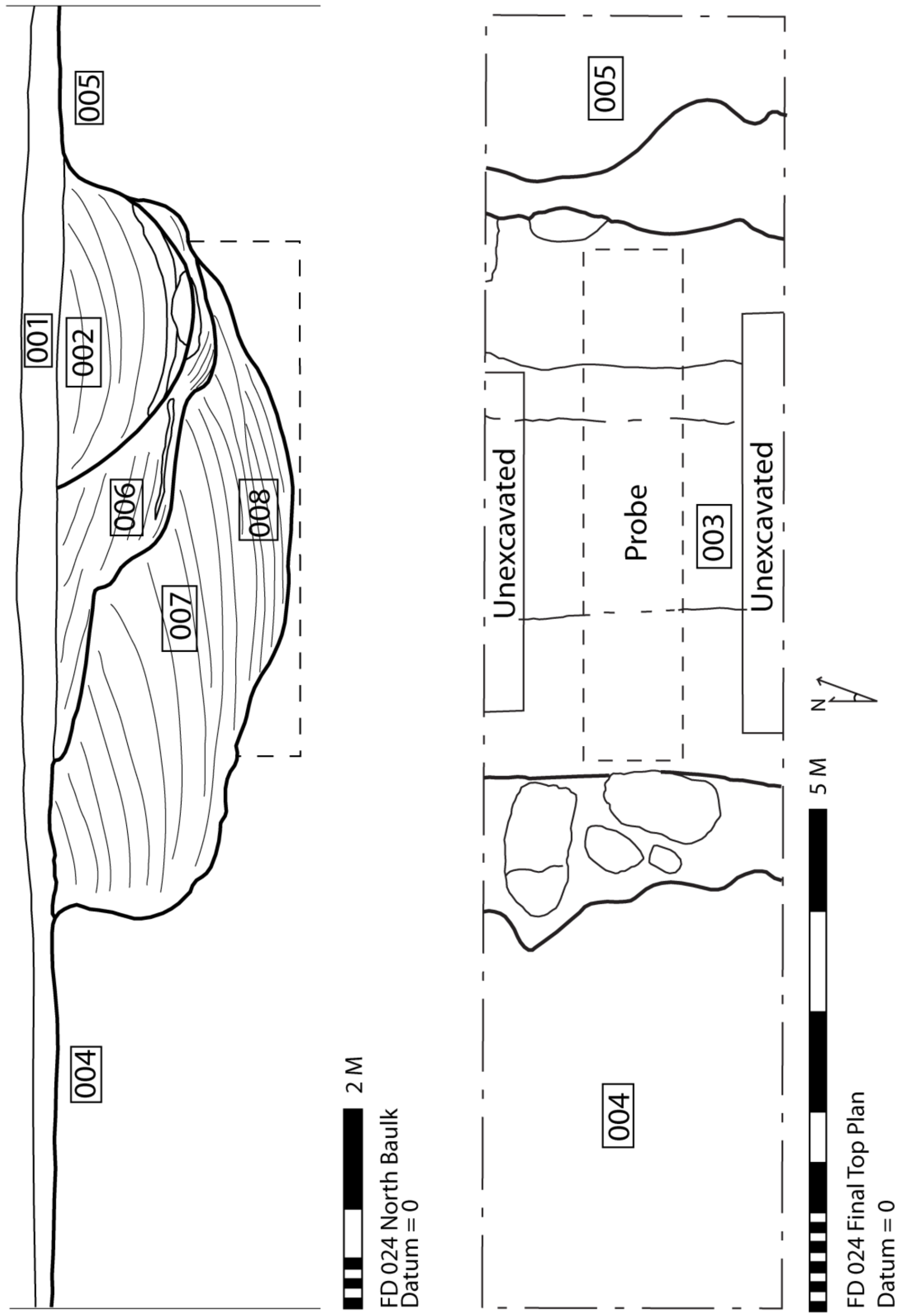


Figure 53: FD 024 Final top plan and drawing of north baulk. Drawings by author.

Figure 54: Broken bedrock aligned on either side of the roofed tunnel in Canal F, facing east. Photo by author.

Figure 55: FD 025 Pre-excavation. The entrance to the tunnel in Canal F, facing west. Photo by author.

Figure 56: FD 025. Interior of the tunnel in Canal F after removal of debris, facing west. Photo by author.

Figure 57: FD 025 post-excavation, facing north. High local groundwater levels have filled the trench. Tunnel entrance at left. Photo by author.

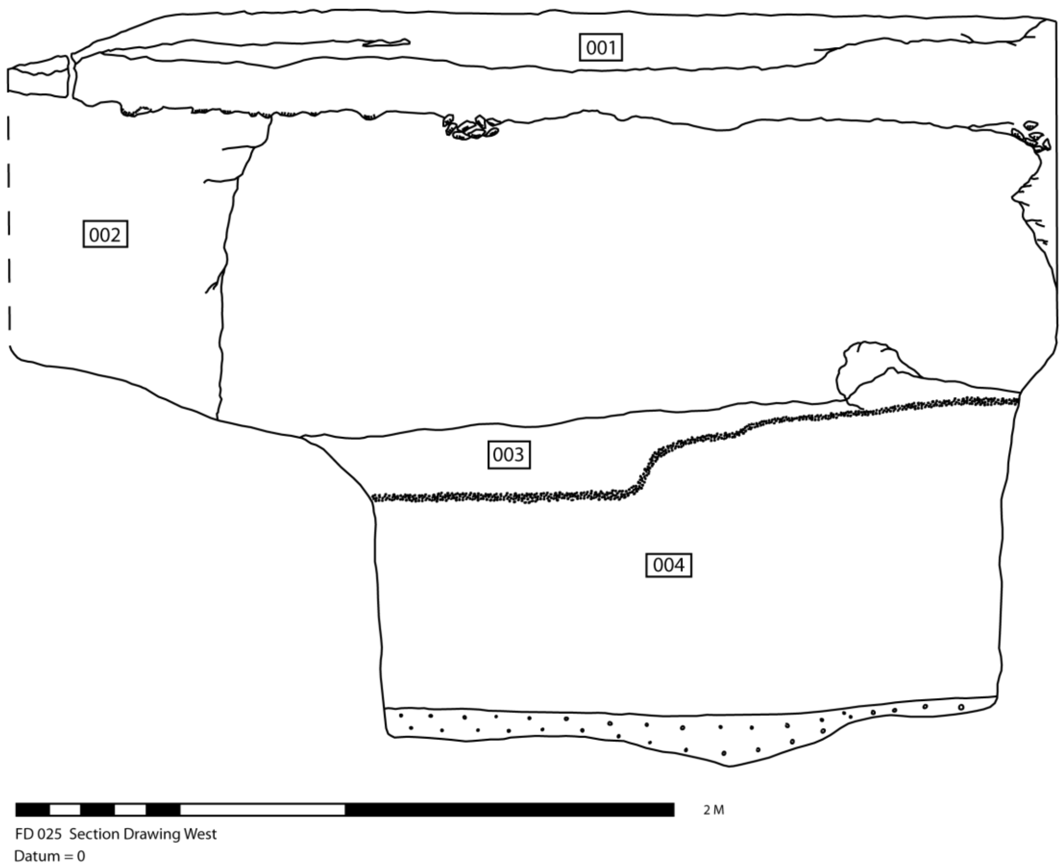


Figure 58: FD 025 Final drawing of west baulk. Drawing undertaken on behalf of the project by J. Van Oostenrijk.

Figure 59: FD 026 pre-cleaning, facing west. The rock-cut bend in the Canal F alignment turns towards FD 025 in the background. Photo by author.

Figure 60: FD 026 post-cleaning, facing west. The rock-cut channel of Canal F has vertical sides and level floor, but is very shallow. Photo by author.

Figure 61: Trench FD 007 pre-excavation of Canal G alignment, facing northwest. Photo by author.

Figure 62: Trench FD 007 post-excavation of Canal G alignment, facing northwest. Photo by author.

Figure 63: Trench FD 007. Detail of Canal G channel, facing northwest. Photo by author.

Figure 64: Trench FD 007 post-excavation of Canal G alignment, facing southeast. Photo by author.

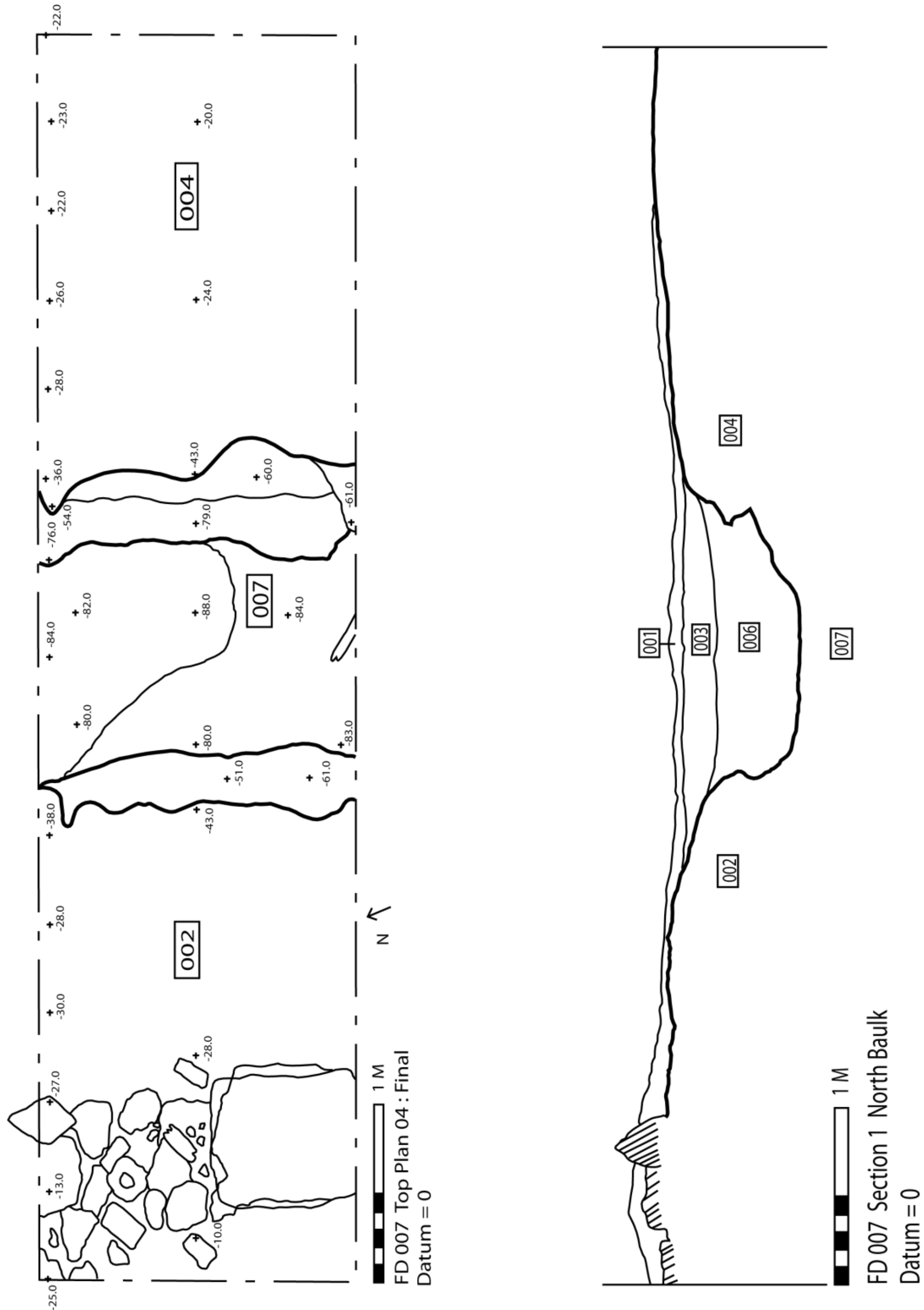


Figure 65: FD 007 Final top plan and final section of north baulk. Drawings by author.

Figure 66: Trench FD 008 pre-excavation of Canal G alignment, facing west. The berms are ca. 12 m apart. Photo by author.

Figure 67: Trench FD 008 post-excavation of Canal G alignment, facing west. Photo by author.

Figure 68: Trench FD 008 detail of Canal G channel, facing west. Photo by author.

Figure 69: Trench FD 008 post-excavation of Canal G alignment, facing southwest. Photo by author.

Figure 70: Trench FD 008 post-excavation of Canal G alignment, facing south. Cracking is visible in the bedrock to the south. Photo by author.

Figure 71: Trench FD 008 post-excavation of Canal G alignment, facing north. Ceramics [Unit 017] are visible in center, against face of berm. Photo by author. See also Figure 69.

Figure 72: Trench FD 008 Detail of north bank after removal of berm, facing west. Ceramics *in situ* on bedrock surface. See Figure 74 for a detail of the berm. Photo by author.

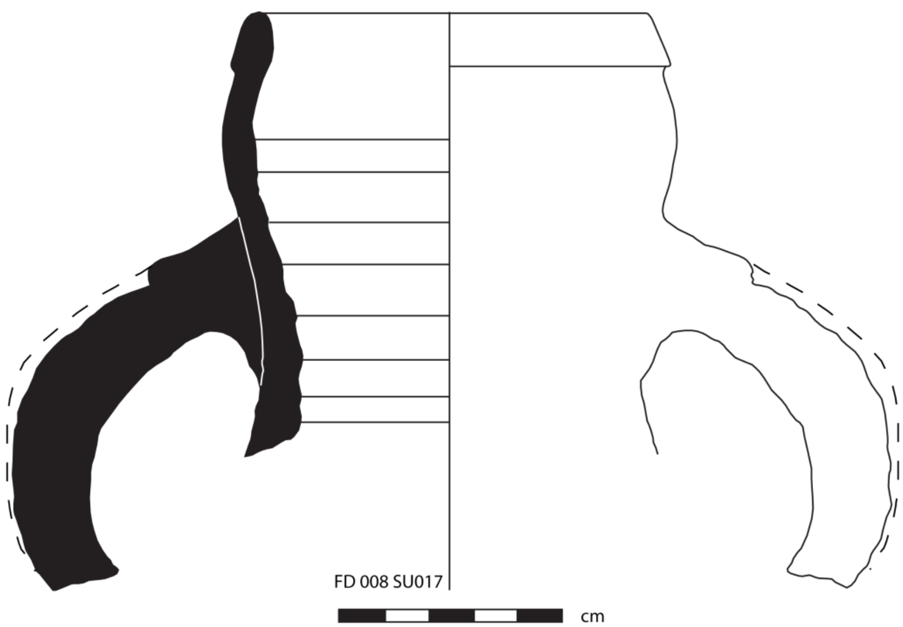


Figure 73: Drawing of restored amphora neck and handles [Unit 017] recovered from the north bank of FD 008. Exterior 10R 4/4 Weak Red; Interior 10R 5/4 Weak Red. The fabric is soft and brittle with some 1 x 3-5 mm voids and very rare 1-3 mm diameter white stone inclusions. The surface has been badly damaged where it contacted the bedrock, but may have had a white slip. Drawing by author.

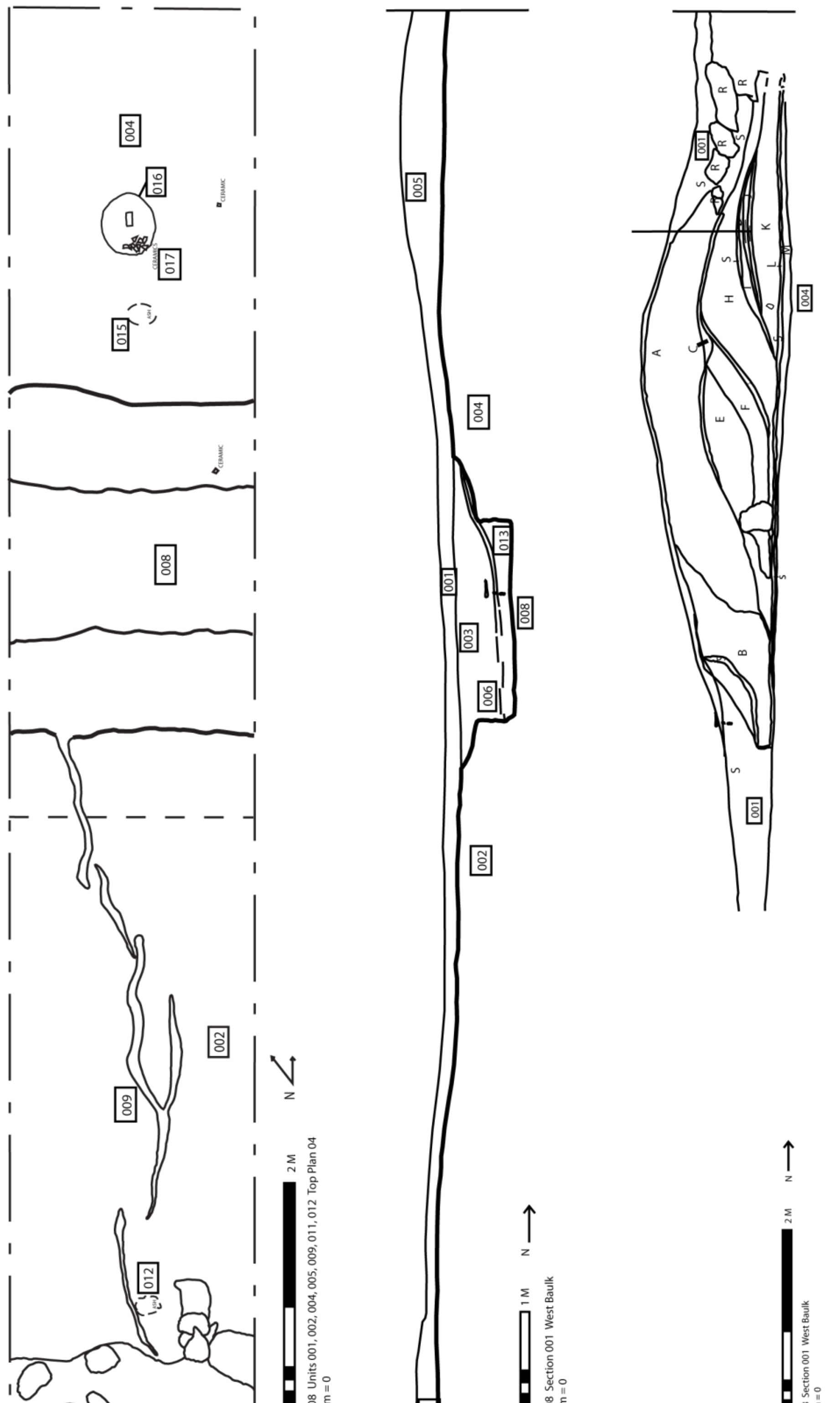


Figure 74: FD 008 Final top plan, final section of west baulk and detail of berm. Drawings by author.

Figure 75: Trench FD 009-010-011 pre-excavation of Canal G alignment, facing west. A modern quarry road is visible running parallel to the canal at right. FD 008 spoil heap is visible in rear. Photo by author.

Figure 76: Trench FD 009 post-excavation of Canal G alignment, facing west. The lower elevation of the north bank is visible at right. Photo by author.

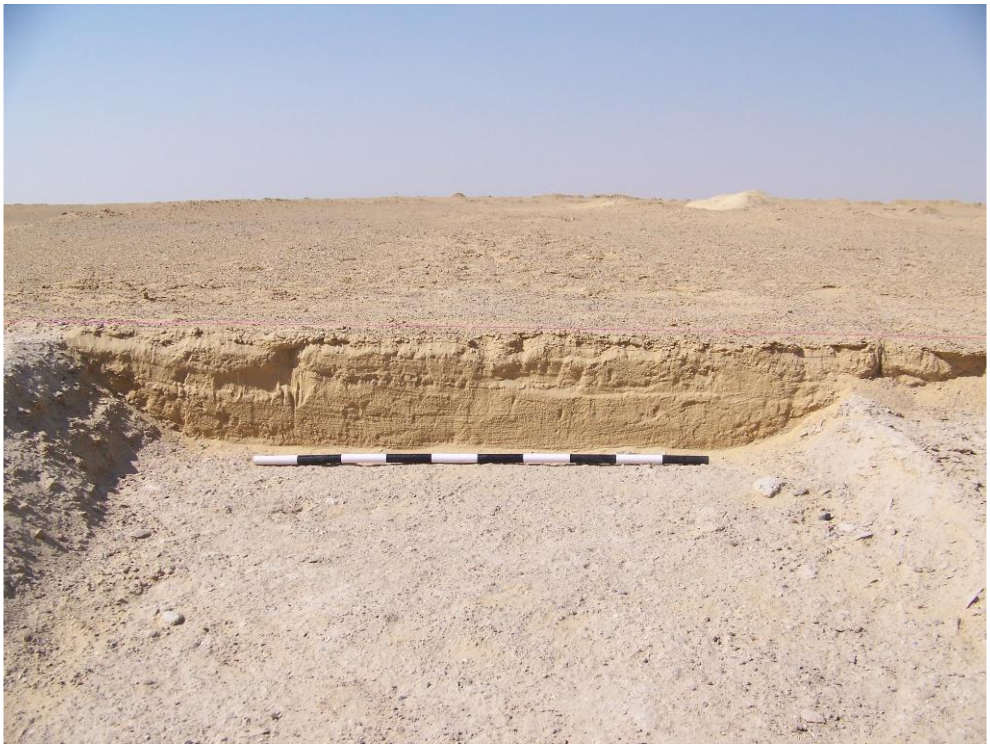


Figure 77: Trench FD 009 post-excavation detail of Canal G channel, facing west. Photo by author.

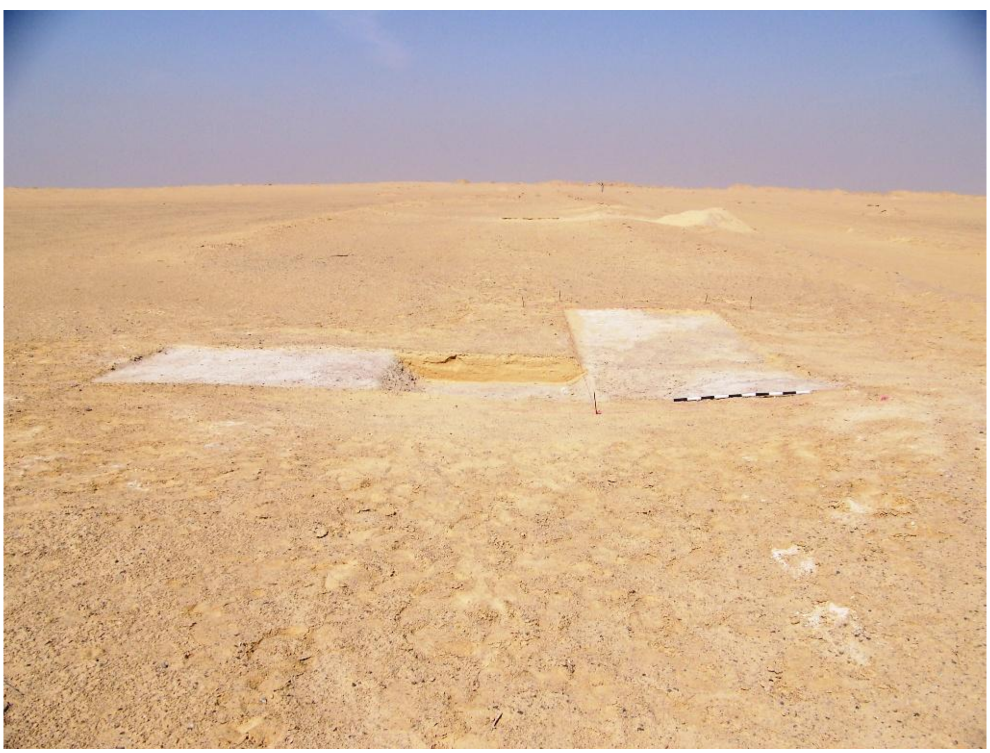


Figure 78: Trench FD 009 post-excavation of Canal G alignment and Trench FD 010 extension to west, facing west. Photo by author.

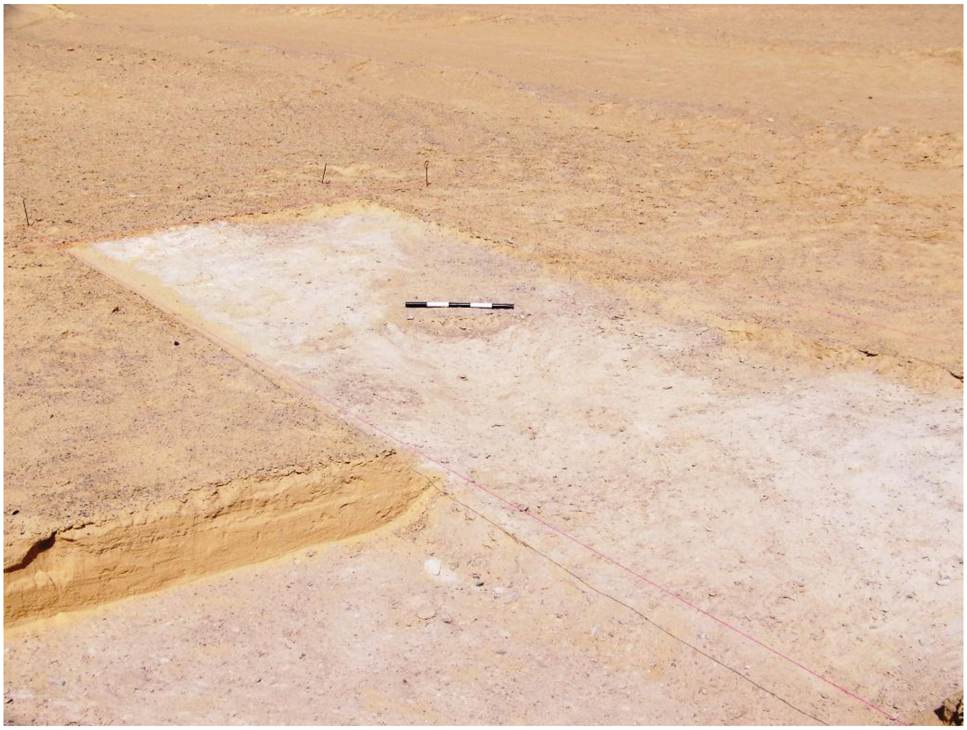


Figure 79: Trench FD 010 post-excavation of feeder channels [Unit 003], [Unit 004], and [Unit 007] running northwest from the Canal G alignment, facing northwest. The smaller channels ([Unit 003], left; [Unit 008], right) have been sectioned to illustrate their fills. Photo by author.

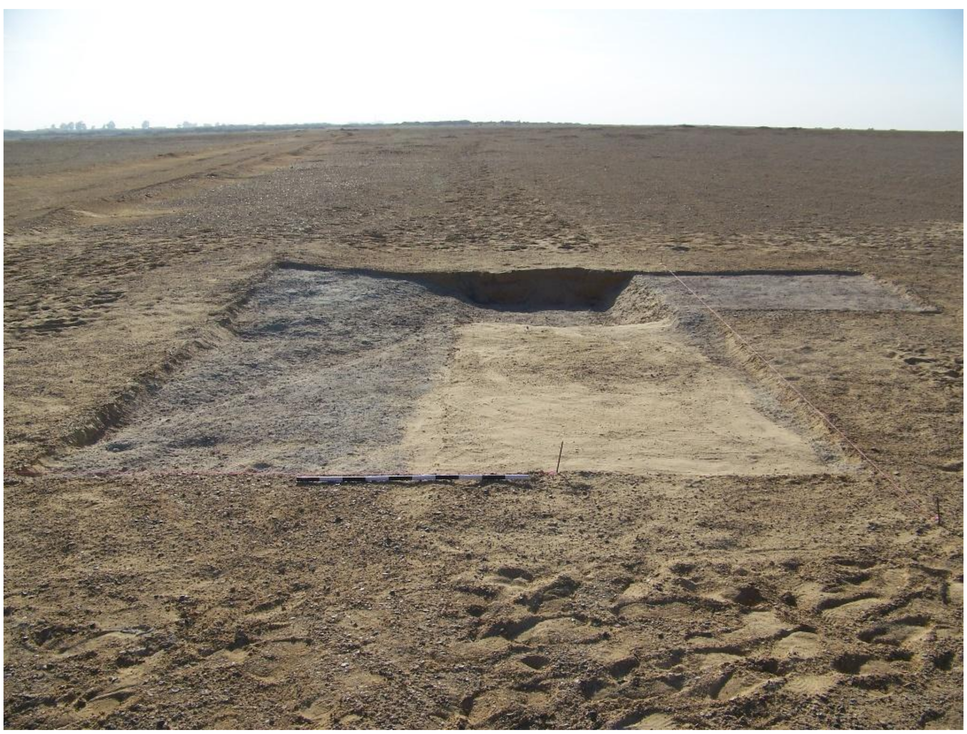


Figure 80: Trenches FD 009-010 post-excavation of feeder channels running northwest from the Canal G alignment, facing east. The smaller channels may be seen at left ([Unit 003]/[Unit 007], foreground; [Unit 008], background). Photo by author.

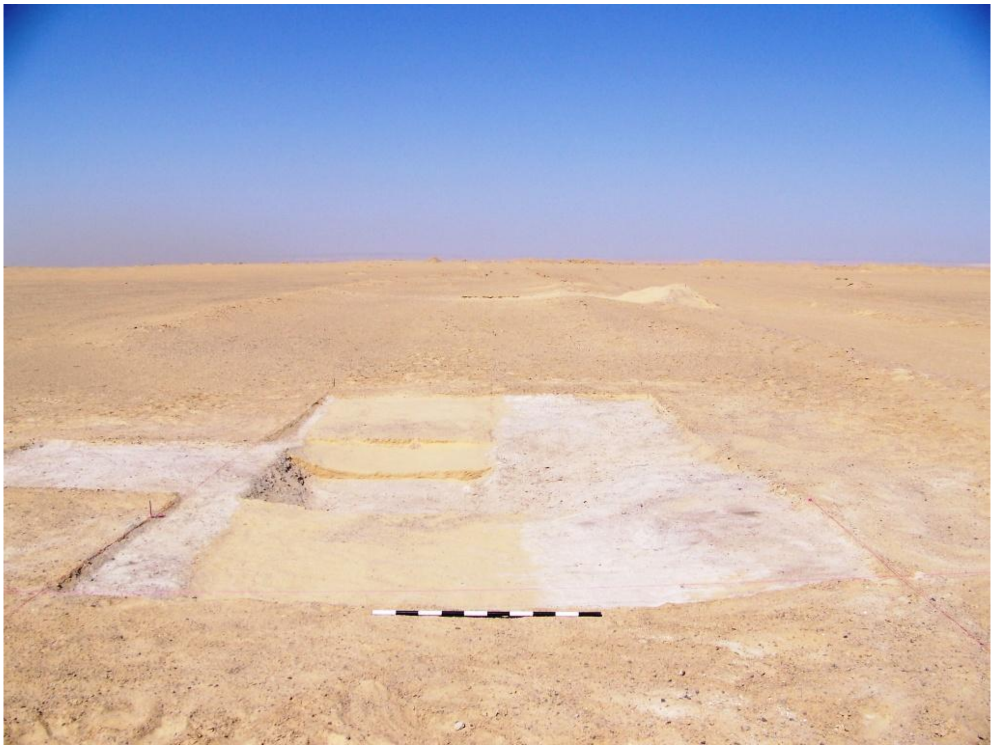


Figure 81: FD 009-010-011 Post-excavation of Canal G channel and feeder channels to right, facing west. Photo by author.

Figure 82: Modern use of a mud barrier to prevent flow into the *khaliga* on the left. North of Qarya Ula. Photo by author.

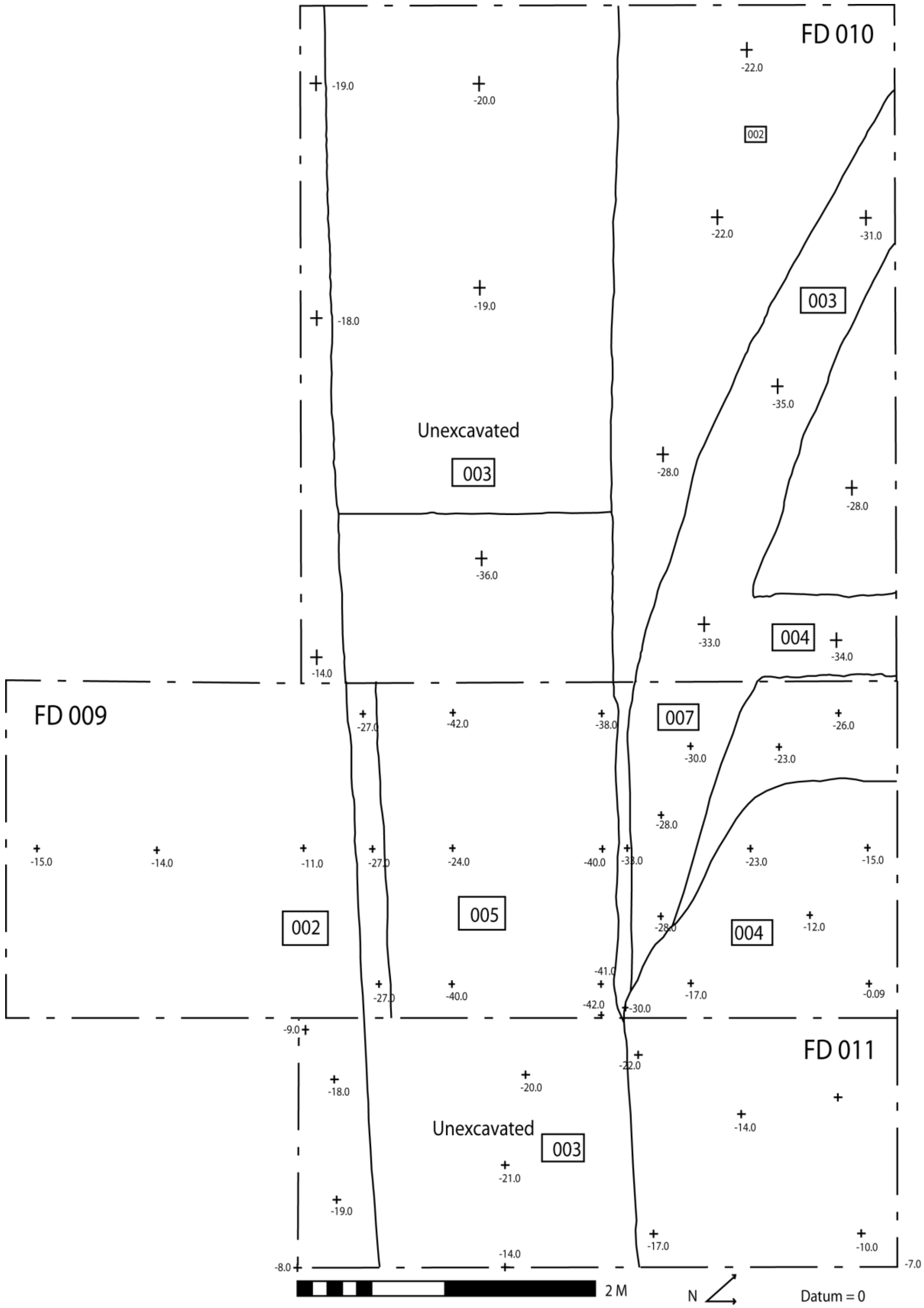


Figure 83: FD 009-010-011 Final top plans. Drawing by author.

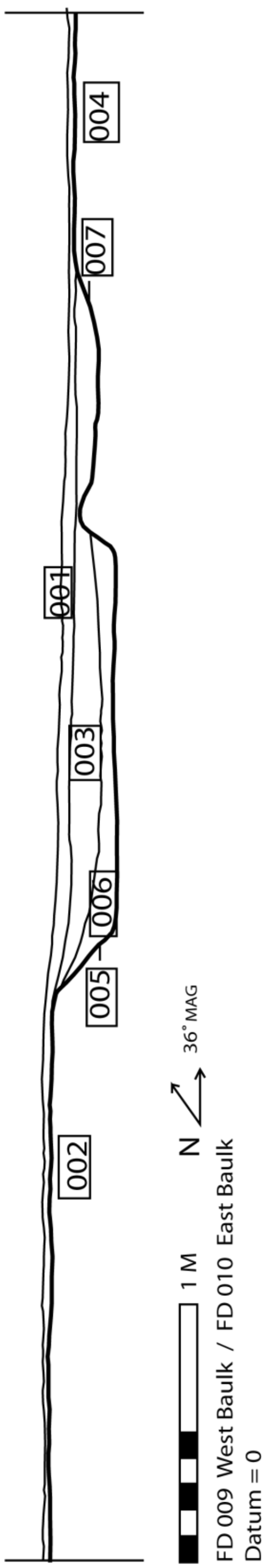


Figure 84: FD 009 best baulk and FD 010 east baulk. Final drawings. Drawing by author.

Figure 85: Trench FD 012 pre-excavation of Canal G alignment, facing west. Photo by author.

Figure 86: Trench FD 012 pre-excavation of Canal G alignment, facing east. The southern berm (right) decreases the distance between the berms from ca. 12 to ca. 6 m. Photo by author.

Figure 87: Trench FD 012 after partial-excavation of Canal G alignment, facing east. The southern berm (right) suddenly diverts to the north, decreasing the distance between the berms from ca. 12 to ca. 6 m. Photo by author.

Figure 88: Trench FD 012 post-excavation of Canal G alignment, facing west. Note the highly irregular channel sides. Photo by author.

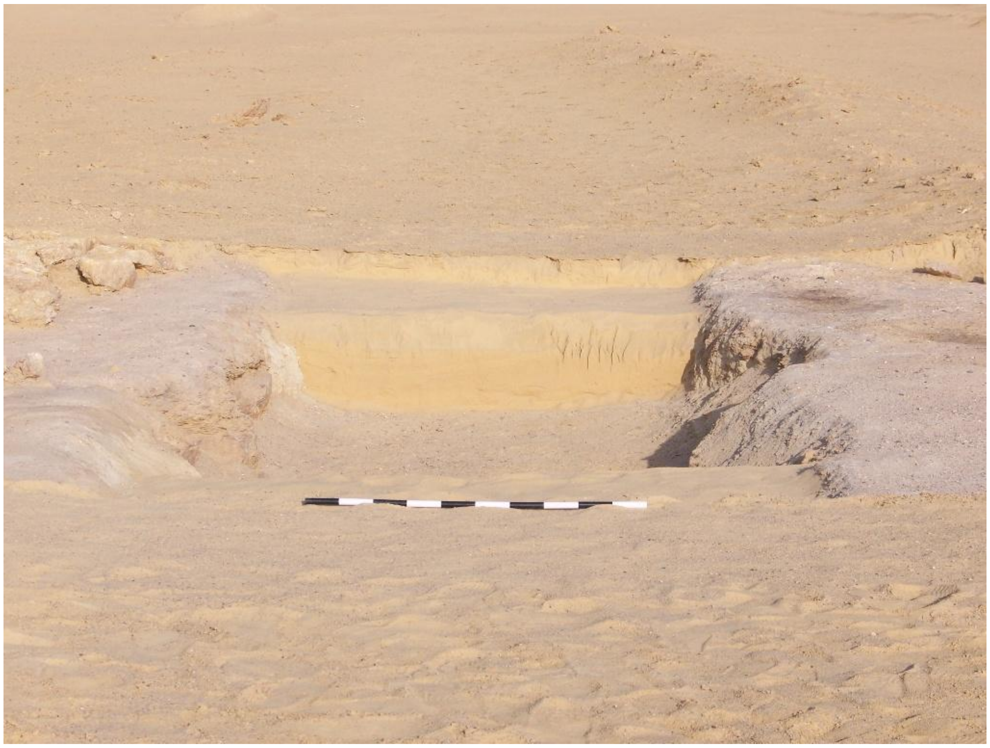


Figure 89: Trench FD 012 post-excavation detail of Canal G channel, facing west. Note the highly irregular channel sides. Photo by author.

Figure 90: Trench FD 012 post-excavation detail of Canal G channel, facing south. The channel sides are coarse and vertical to west, but carefully tapered to east. Photo by author.

Figure 91: Trench FD 012 post-excavation detail of Canal G channel, facing north. The channel sides are coarse and vertical to west, but carefully tapered to east. Photo by author.

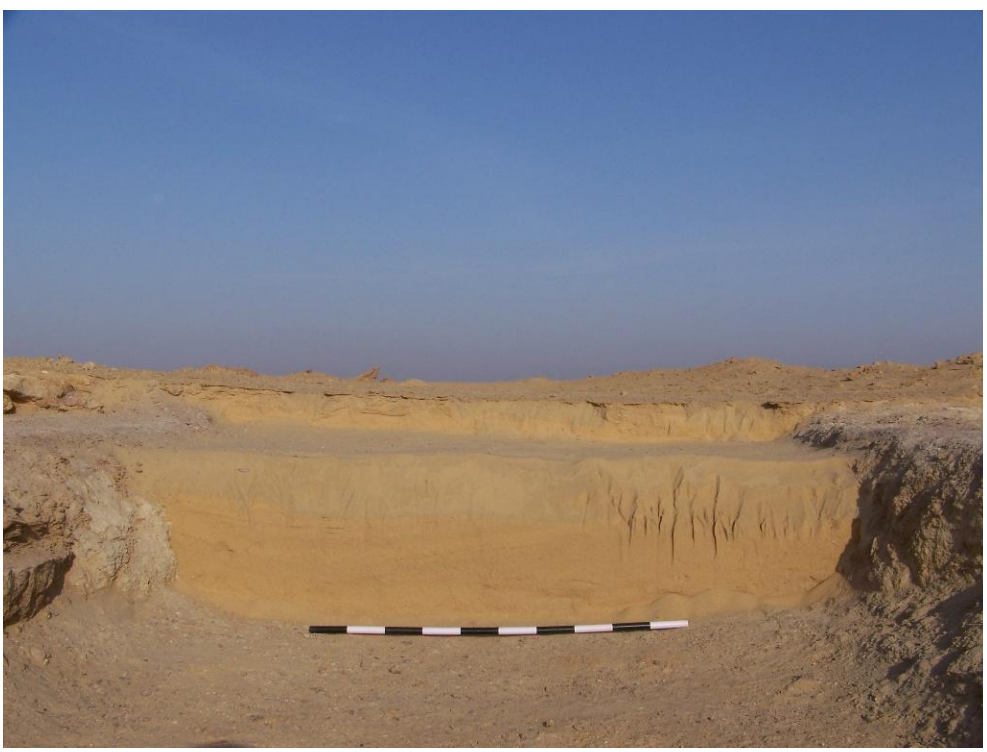


Figure 92: Trench FD 012 post-excavation detail of Canal G channel, facing west. Note the white concretion of diatomaceous material against the southern side of the channel. Photo by author.

Figure 93: Trench FD 012 post-excavation detail of linear feature [Unit 014] formed from broken bedrock fragments, facing south. The open side of the rectangle faces the canal and the prevailing wind. Photo by author.

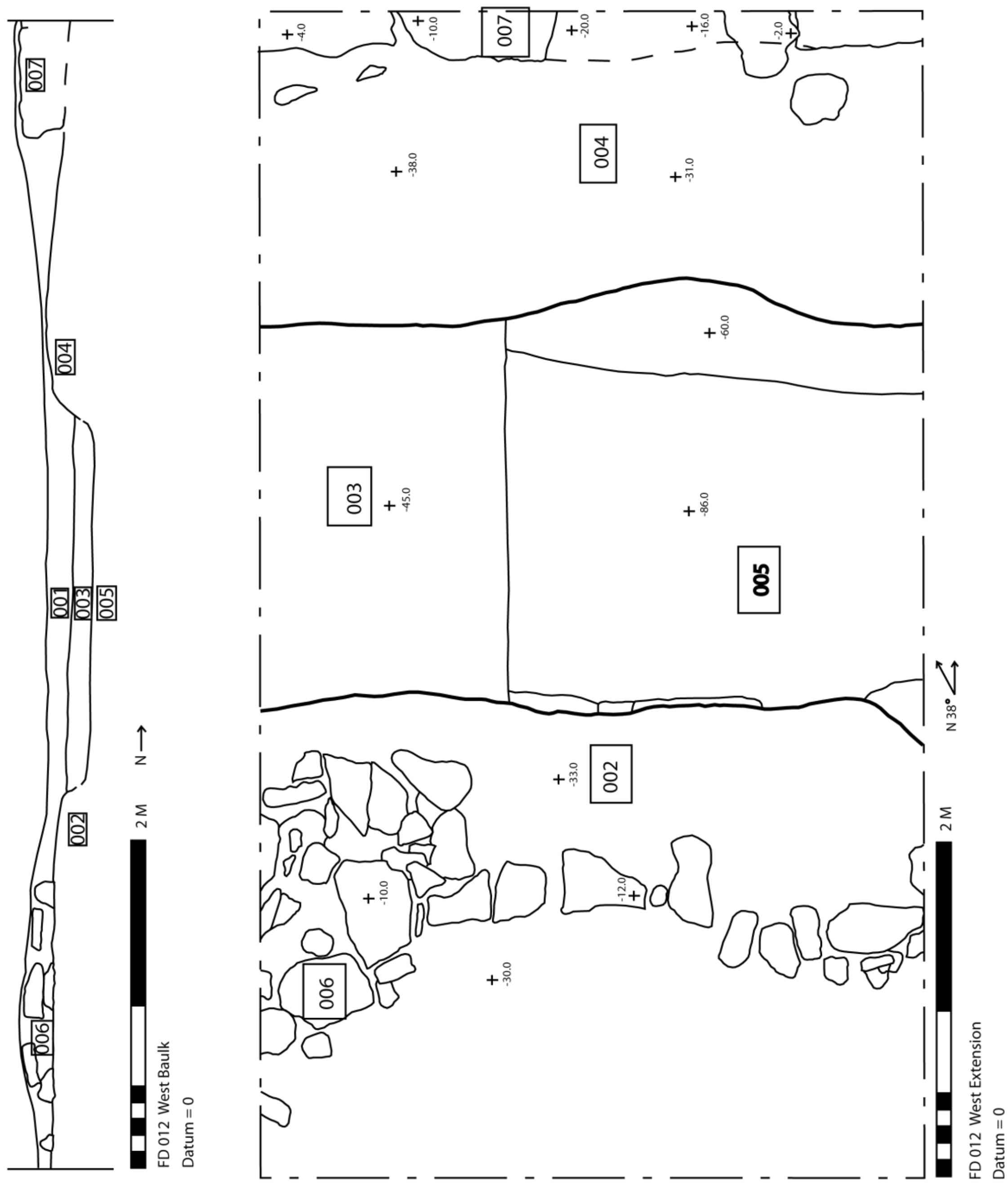


Figure 94: FD 012 Final top plan and west baulk. Drawings by author.

Figure 95: Trench FD 013 pre-excavation of Canal G alignment, facing southeast. The channel turns to the west (right). Photo by author.

Figure 96: Trench FD 013 after partial excavation of Canal G alignment, facing southeast. The sandy fill of the channel can be seen turning to the west (right). Photo by author.

Figure 97: Trench FD 013 post-excavation of Canal G alignment, facing southeast. The outside of the bend in the channel appears somewhat irregular and abraded. Photo by author.

Figure 98: Trench FD 013 post-excavation detail of the Canal G channel, facing southeast. Photo by author.

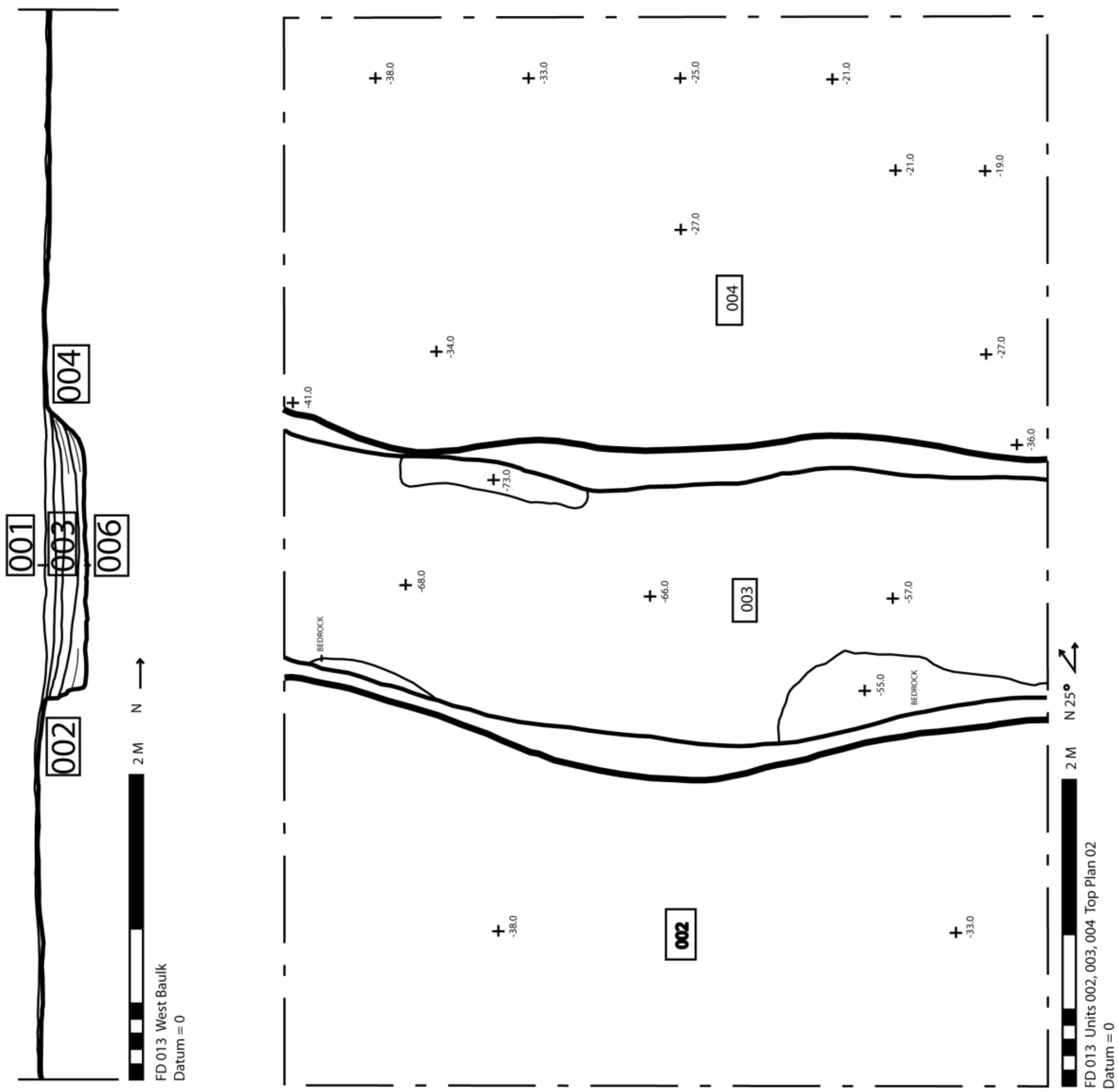


Figure 99: FD 013 Final top plan and west baulk. Drawings by author.

Figure 100: Trench FD 014 pre-excavation of Canal G alignment, facing southeast. Quarrying has destroyed both ends of this segment. Photo by author.

Figure 101: Trench FD 014 post-excavation of Canal G alignment, facing northwest. The fragments of a cooking pot [Unit 001] are visible *in situ* at the center of the trench. A smaller, deeper channel [Unit 008] has been cut into the earlier channel [Unit 005]. Photo by author.

Figure 102: Trench FD 014 post-excavation detail of Canal G channels, facing southeast. Symmetrical triangular cuts in the smaller channel may have served for the installation of a gate or other hydraulic feature. Photo by author.

Figure 103: Trench FD 014 post-excavation detail of ash deposits ([Unit 009] and [Unit 010], top; [Unit 011], bottom) along southwest bank of Canal G channel, facing southwest. Photo by author.

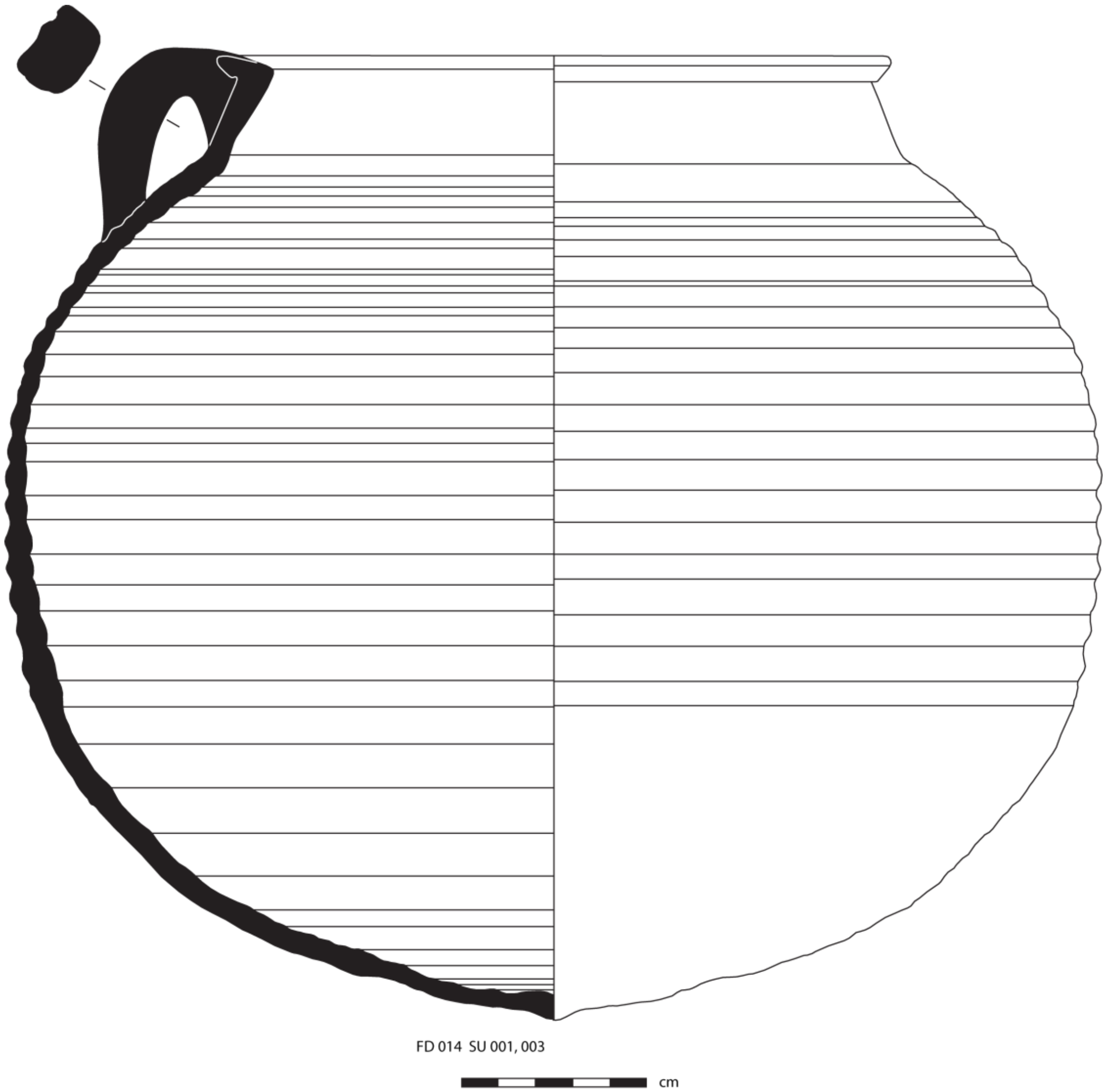


Figure 104: Restored cooking vessel [Unit 015] recovered from the channel bottom of FD 014. Rim diameter 18 cm. Exterior 5YR 5/4 Reddish Brown, but blackened by fire; Interior 2.5YR 5/6 Red. Fabric is very hard and micaceous, with many 3-5mm voids from organic temper. There are rare sand paticle inclusions and very rare ≥ 1 mm white (calcium carbonate?) inclusions. Drawing by author.

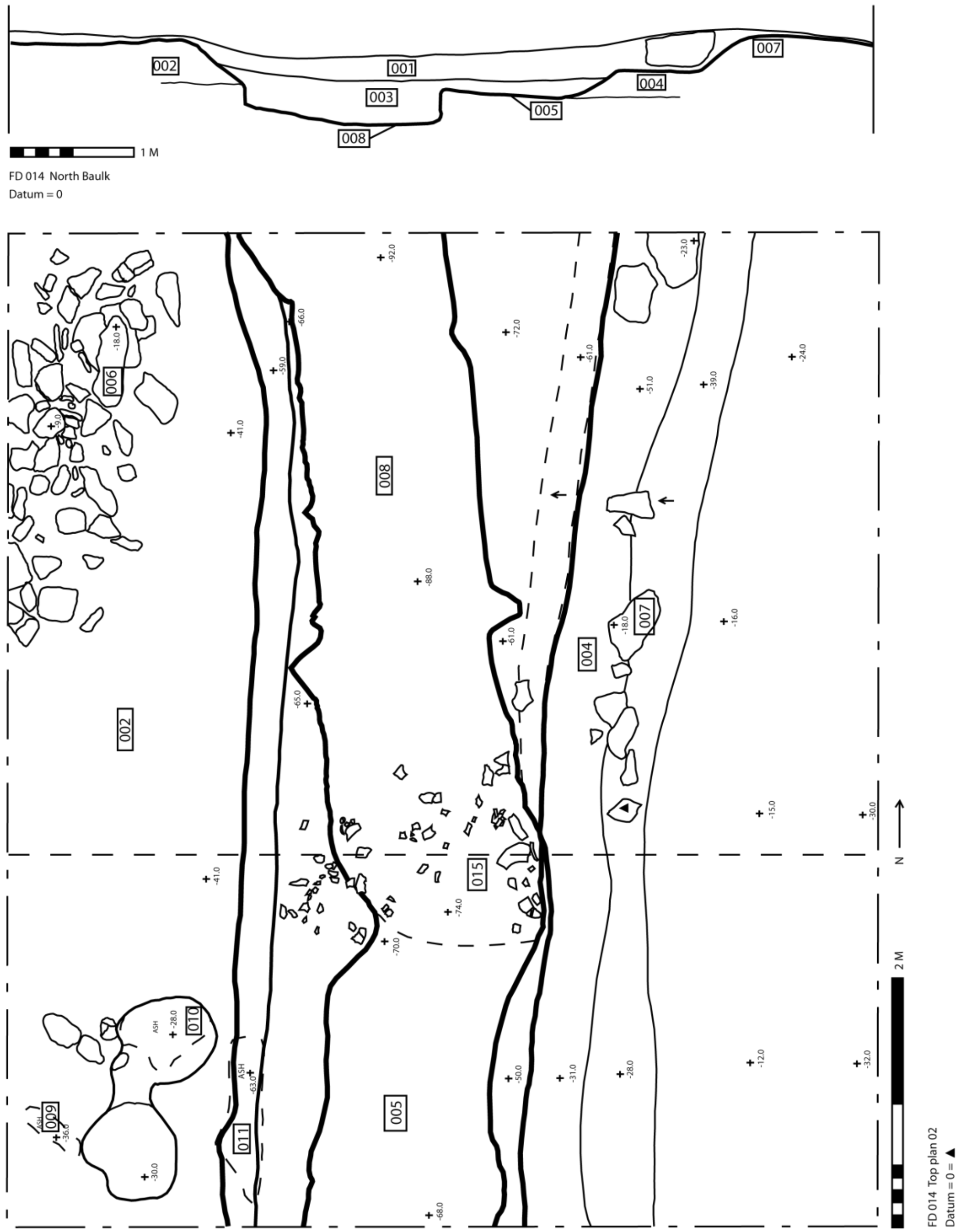


Figure 105: FD 014 final top plan and north baulk. Drawings by author.

Figure 106: Trench FD 015 pre-excavation of Canal G alignment, facing southwest. Quarrying (rear) has destroyed the alignment and resulted in a steep drop. Photo by author.

Figure 107: Trench FD 015 post-excavation of possible Canal H alignment, facing southwest. Photo by author.

Figure 108: Trench FD 015 post-excavation of possible Canal H alignment, facing northeast. The alignment is interrupted by fields to the northeast. Photo by author.

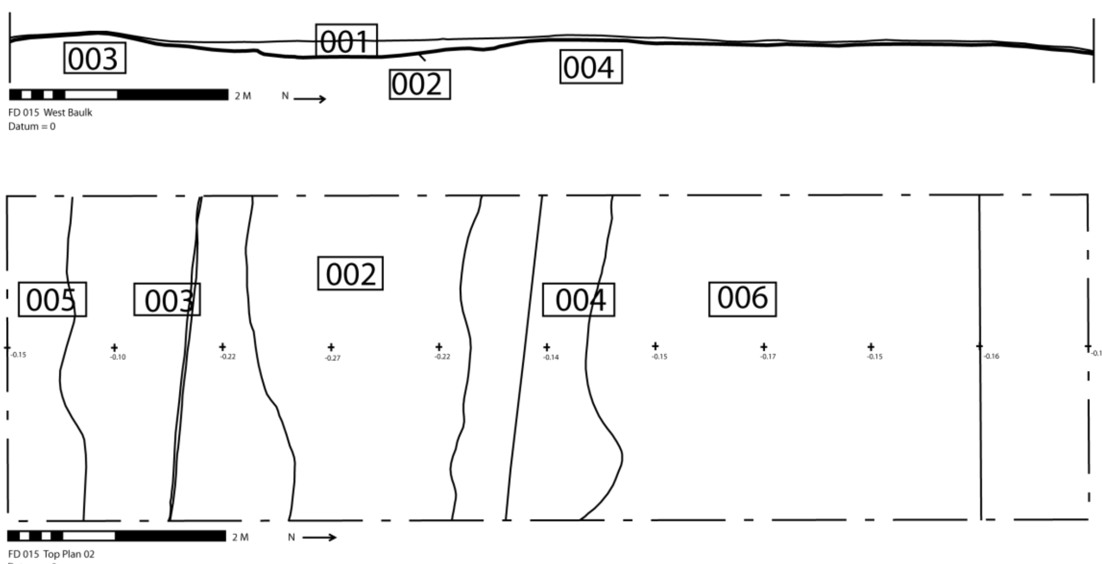


Figure 109: FD 015 final top plan and west baulk. Drawing by author.

Figure 110: Trench FD 016 pre-excavation of possible Canal H alignment, facing southwest. A gradual turn in the channel is visible in the distance. Photo by author.

Figure 111: Trench FD 016 pre-excavation of possible Canal H alignment, facing northeast. Trench FD 015 and another possible Canal H alignment are preserved on the elevation at rear. Photo by author.

Figure 112: Trench FD 016 post-excavation of possible Canal H alignment, facing northeast. Photo by author.

Figure 113: Trench FD 016 post-excavation of possible Canal H alignment, facing southwest. Photo by author.

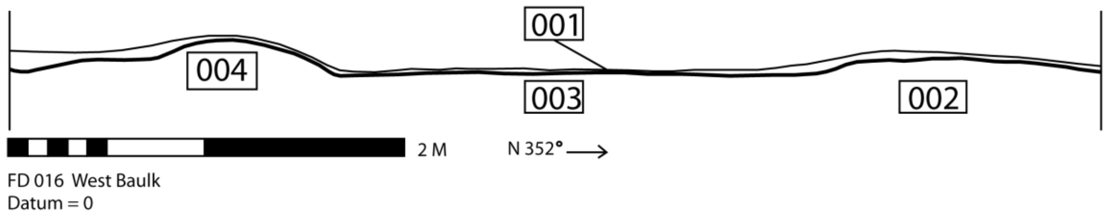


Figure 114: FD 016 final west baulk. Drawing by author.

Figure 115: Possible location of reused Canal I alignment beside the main road north of Qarya Ula, facing east. Photo by author.

Figure 116: A newly discovered narrow alignment, designated Canal K, to the north of Canal G, facing northwest. The berms are only ca. 1.25 m apart. Photo by author.

Figure 117: A newly discovered alignment, designated Canal K, to the north of Canal G, facing southeast. The berms have been interrupted by a series of parallel bulldozer tracks at the eastern end of the alignment. Photo by author.

Figure 118: Trench FD 021 post-excavation of the Canal K channel. The channel is only ca. 0.50 m wide. Photo by author.

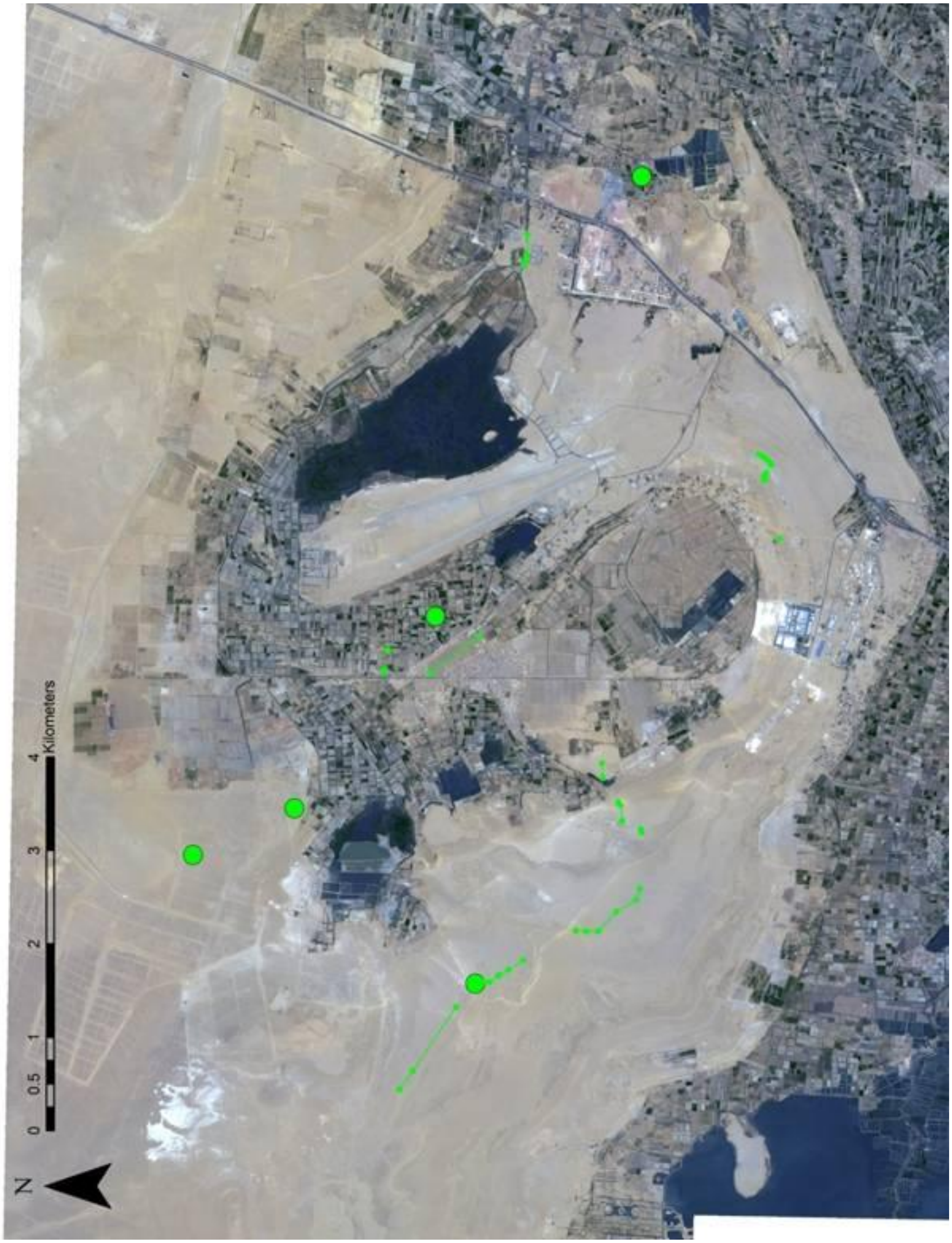


Figure 119: Pan-sharpened Quickbird image showing habitation sites and canal alignments relocated in the Karanis hinterland 2007-8. Data from Digital Globe 2007.

Figure 120: Pan-sharpened Quickbird image of Kom Aushim (ancient Karanis) and its cemetery. Data from Digital Globe 2007.

Figure 121: Pan-sharpened Quickbird image showing the location trenches excavated west of Karanis along the Canal G, H, and K alignments in 2007-8. Data from Digital Globe 2007.

Figure 122: Trench FD 018 Pre-excavation showing a linear berm on the northwest side of the highway at Karanis, facing southeast. Photo by author.

Figure 123: Trench FD 018 post-excavation, facing southeast. Photo by author.

Figure 124: Trench FD 018 post-excavation detail of berm, facing northeast. A backhoe cut is visible running parallel to the berm on the northwest (left) side. Photo by author.

Figure 125: Trench FD 019 Pre-excavation showing parallel berms on the southeast side of the highway at Karanis, facing northeast. Photo by author.

Figure 126: FD 019 post excavation, facing southwest. Photo by author.

Figure 127: Trench FD 018 post-excavation detail of backhoe cut, facing southwest. Photo by author.

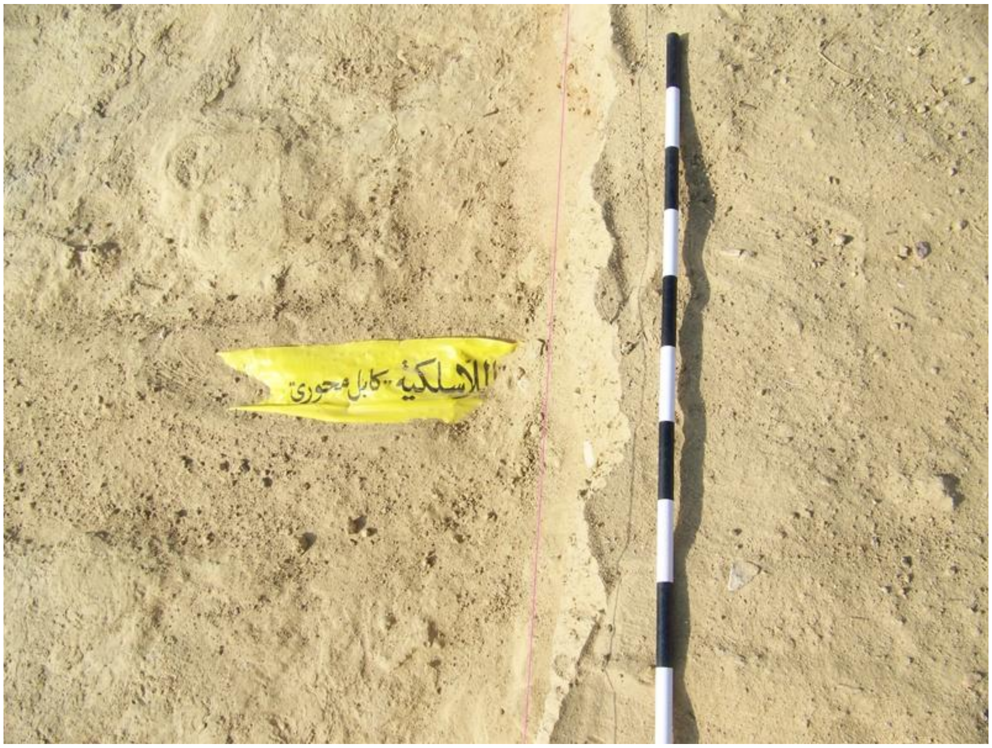


Figure 128: Trench FD 019 post-excavation detail of warning tape in backhoe cut, facing northwest. Photo by author.

Figure 129: Well known concave depression at the bottom of the kom at Karanis, facing northeast. Photo by author.

Figure 130: The modern Bahr Wahbi canal at Karanis, facing west. The Kom is visible at right. A 3 m high retaining wall supports the road, which is built on the southern berm, at left.

Figure 131: Trench FD 017 pre-excavation, facing east. Photo by author.

Figure 132: Trench FD 017 after removal of topsoil, facing south. Bedrock is visible in the foreground, clay in the mid-ground and a relict berm in the distance. Photo by author.

Figure 133: Trench FD 017 after sectioning of the relict berm, facing south. Compare the relatively smooth exterior face of the berm with the interior (below). Photo by author.

Figure 134: Trench FD 017 after sectioning of the relict berm, facing south. The surface of the berm is cracked and infiltrated by salts. Photo by author.

Figure 135: Trench FD 017 detail of east baulk, facing east. The superimposed berms are visible but are cut to left. The uppermost berm disappears into the south baulk. Photo by author.

Figure 136: Trench FD 017 post-excavation detail of probe into geological clay. The surface of the clay served as a channel and has been infiltrated by salts. Photo by author.

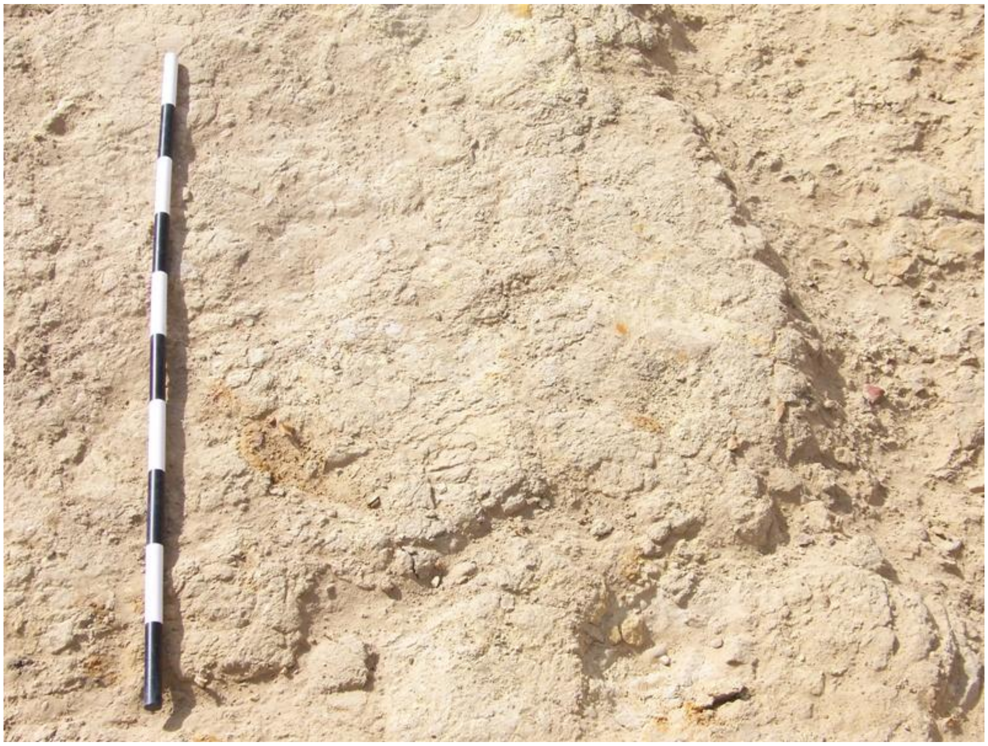


Figure 137: Trench FD 017 detail of yellow mineral stains on the bedrock. Spectrometry identified the mineral as jarosite, but could not determine if it was naturally occurring in the bedrock. Photo by author.

Figure 138: Trench FD 017 post-excavation, facing south. Photo by author.

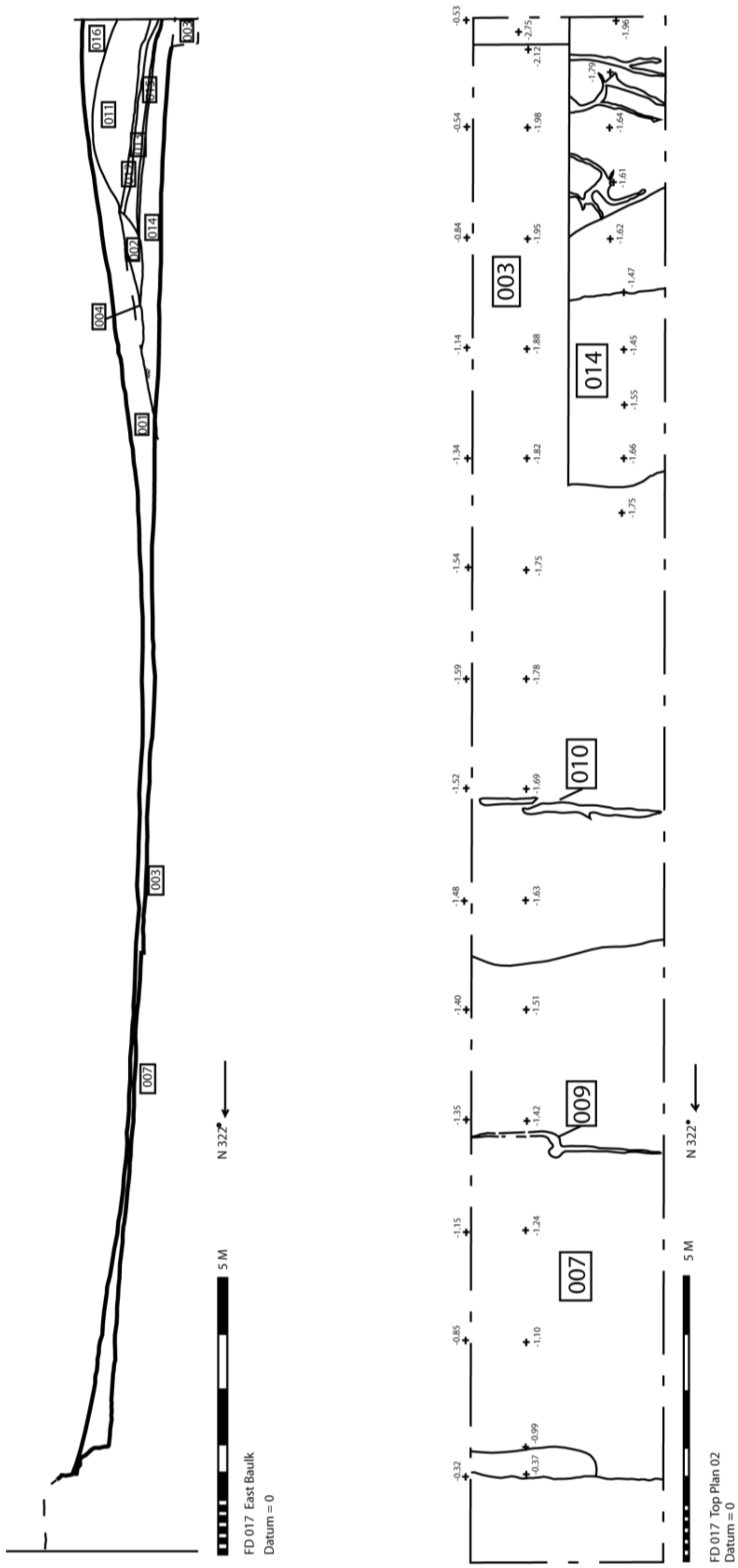


Figure 139: FD 017 Final top plan and east baulk. Drawings by author.

Figure 140: Dried sediment cleaned out of the modern Bahr Wahbi canal near trench FD 017. The numerous small bivalves are indicative of perennial irrigation. Photo by author.

Figure 141: Trench FD 20 post excavation, facing south. The two upper channels have been sectioned in order to expose the final channel below. The recent robbing cut is seen running left to right in the foreground. Photo by author.

Figure 142: Trench FD 020 post-excavation detail of east baulk, facing east. All three channels descend beneath the modern Bahr Wahbi, visible to right. Photo by author.

Figure 143: Trench FD 020 post-excavation detail of sectioned channel profiles. Both of the upper channels show roughened surfaces consistent with erosion at the waterline. Photo by author.

Figure 144: Trench FD 020 post-excavation detail of sediments resting on geological clay in the east baulk, facing east. The natural clay has been accumulated a thick white salt deposit as a result of its use as a channel. The alternating fine gray and coarse red sediments preserved in the channel are indicative of alternating reducing and oxidizing environments in the flow. Photo by author.

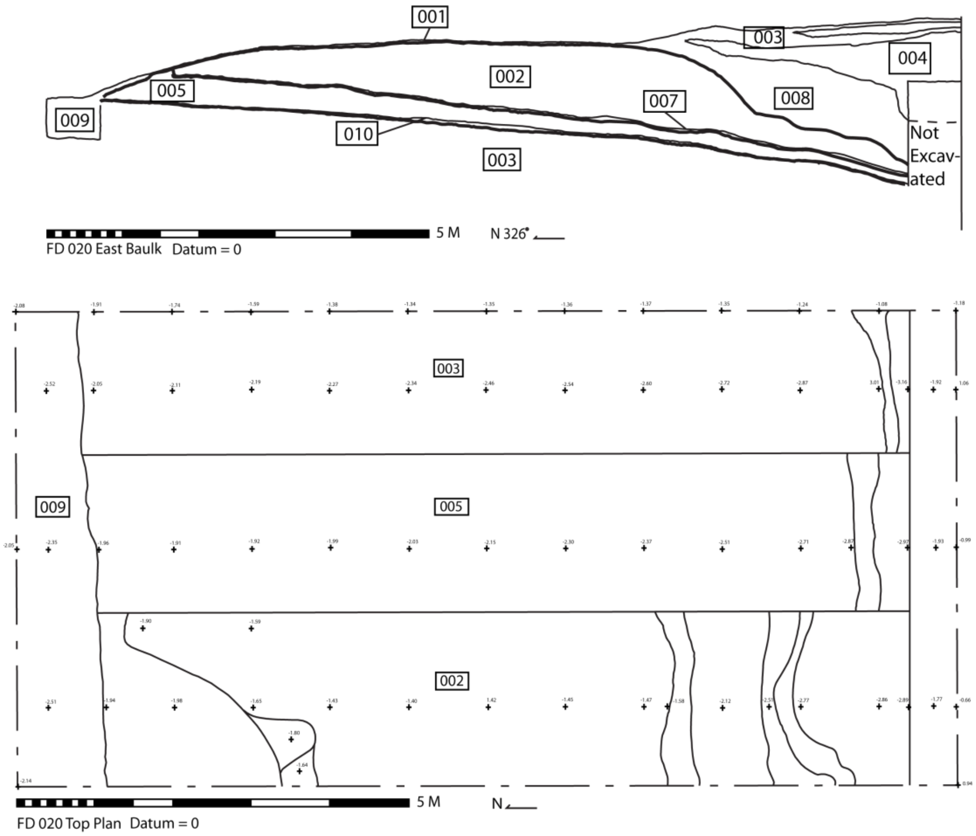


Figure 145: FD 020 Final top plan and east baulk. Drawings by author.

Figure 146: Trench FD 17 (left) and FD 20 (right) post-excavation. There is remarkable variation between the trenches over a distance of only ca. 10 m, demonstrating sinuosity in the channels. Photo by author.

Figure 147: The foot of the kom (right) at Karanis, facing west. The bushes (left) in the background diverge from the line of the modern canal. Photo by author.

Figure 148: Trench FD 022 pre-excavation, facing west. The bushes typically found along the berm of the modern Bahr Wahbi canal have inexplicably diverged from its path. Photo by author.

Figure 149: Trench FD 022 pre-excavation after clearance of surface vegetation, facing south. Photo by author.

Figure 150: Trench FD 022 after excavation of topsoil, facing south. Two distinct berms are visible in the foreground with a channel running between them. The main channel is at the south end of the trench and runs east to west. Photo by author.

Figure 151: Trench FD 022 after removal of topsoil, facing west. Detail of late channel [Unit 003] between the berms. Photo by author.

Figure 152: Trench FD 022 after removal of late berm and channel. The fill of the main channel is still *in situ*. Photo by author.

Figure 153: Trench FD 022 after removal of topsoil and channel fill in the western half of the square, facing south. Photo by author.

Figure 154: Trench FD 022 detail of the southwest corner, facing southwest. The geological clay layer at bottom rises point from the north and east indicating bifurcation. One channel runs into the east baulk, while another runs into the south baulk. Photo by author.

Figure 155: Trench FD 022 post-excavation west baulk, facing west. Photo by author.

Figure 156: Trench FD 022 post-excavation east baulk, facing east. Photo by author.

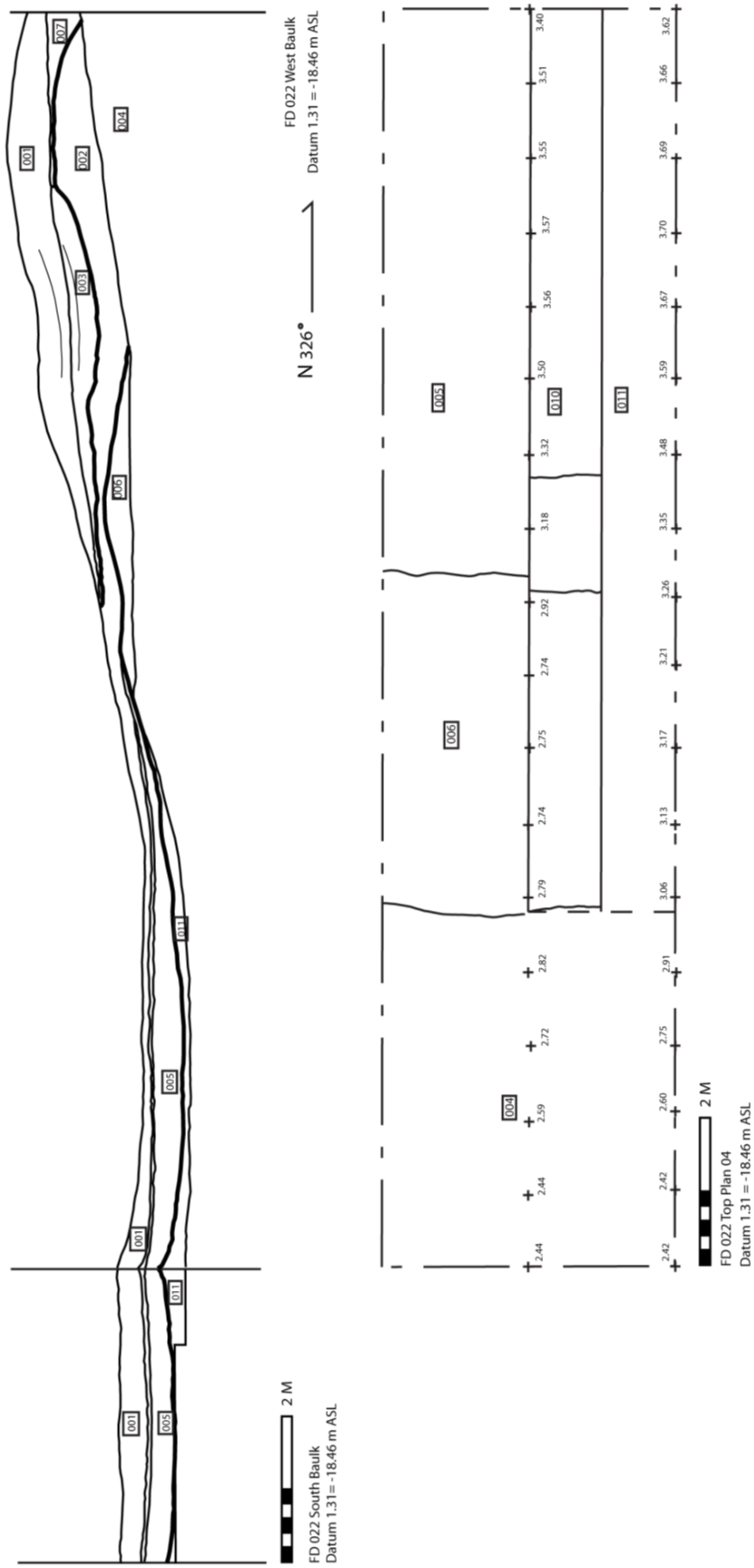


Figure 157: FD 022 Final top plan, west baulk and south baulk. Drawings by author.

Figure 158: Modern water drop structure on the Bahr Wahbī near FD 22, facing west. Photo by author.

Figure 159: Detail of water level measurement device on the east face of the drop structure shown above. Photo by author.

Figure 160: High energy flow behind the water-drop shown above. A number of brick retaining walls have been built to limit erosion. The rocks in the bottom of the channel are known as *rip-rap* and are intended to dissipate energy. Photo by author.

Figure 161: Trench FD 023 pre-excavation, facing south. Photo by author.

Figure 162: Trench FD 023 after removal of topsoil showing damaged bedrock throughout, facing south. Photo by author.

Figure 163: Trench FD 023 after removal of topsoil showing terraced and pitted bedrock, facing north. Photo by author.

Figure 164: Trench FD 023 post-excavation detail of west baulk, facing west. Photo by author.

Figure 165: Trench FD 023 post-excavation detail of west baulk, facing west. Photo by author.

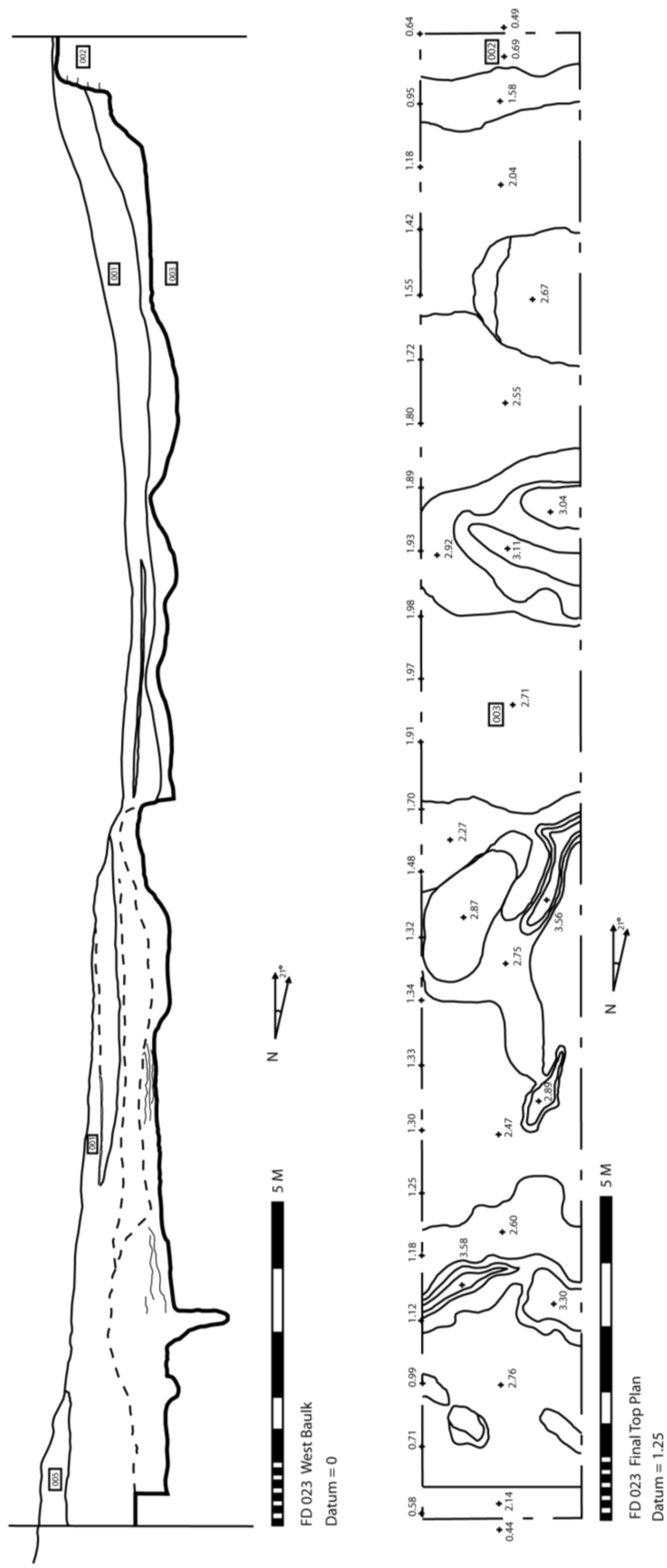


Figure 166: FD 023 final top plan and west baulk. Drawings by author.

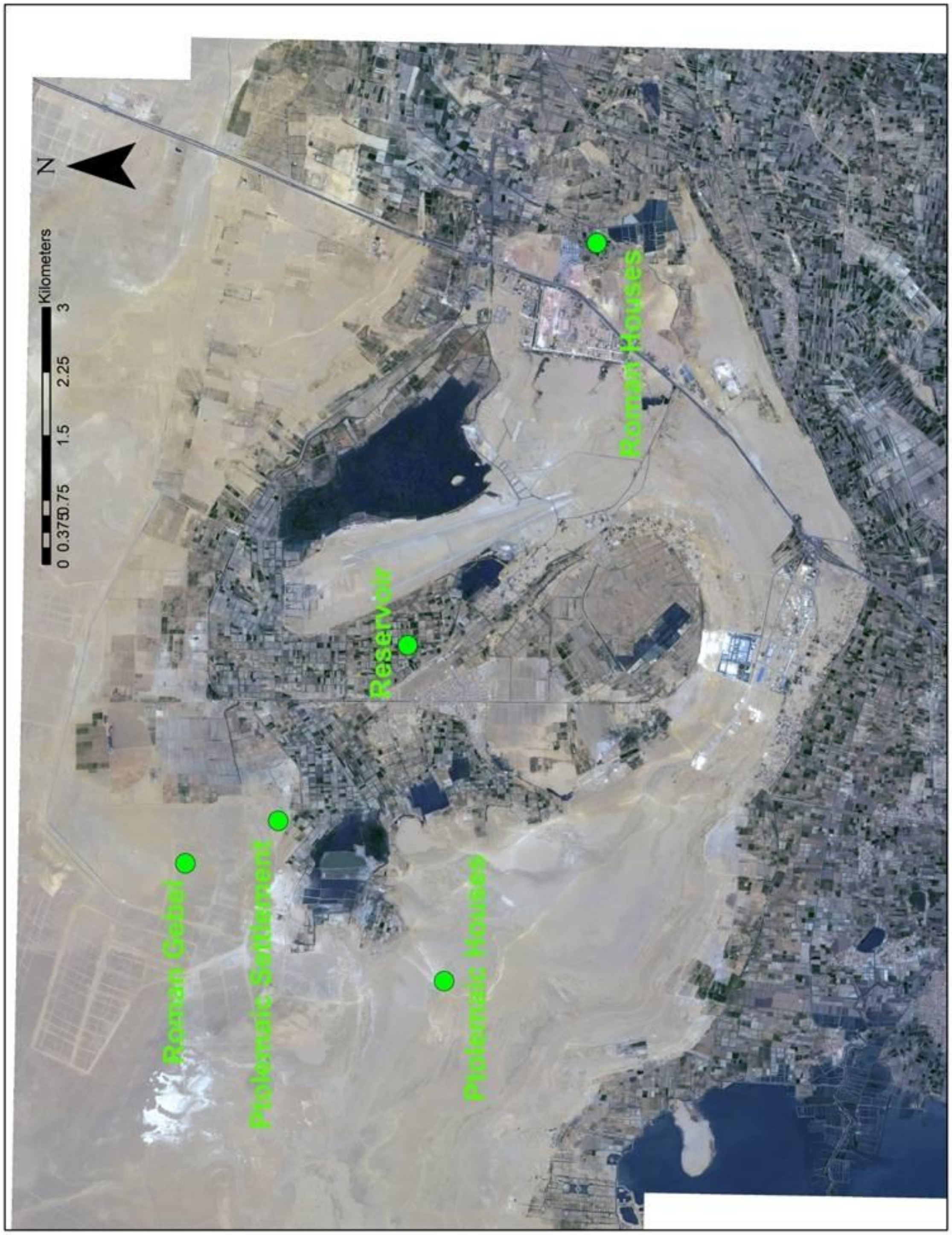


Figure 167: Pan-sharpened Quickbird image showing the location of Habitation sites re-located by the author in 2007-8. Data from Digital Globe 2007.

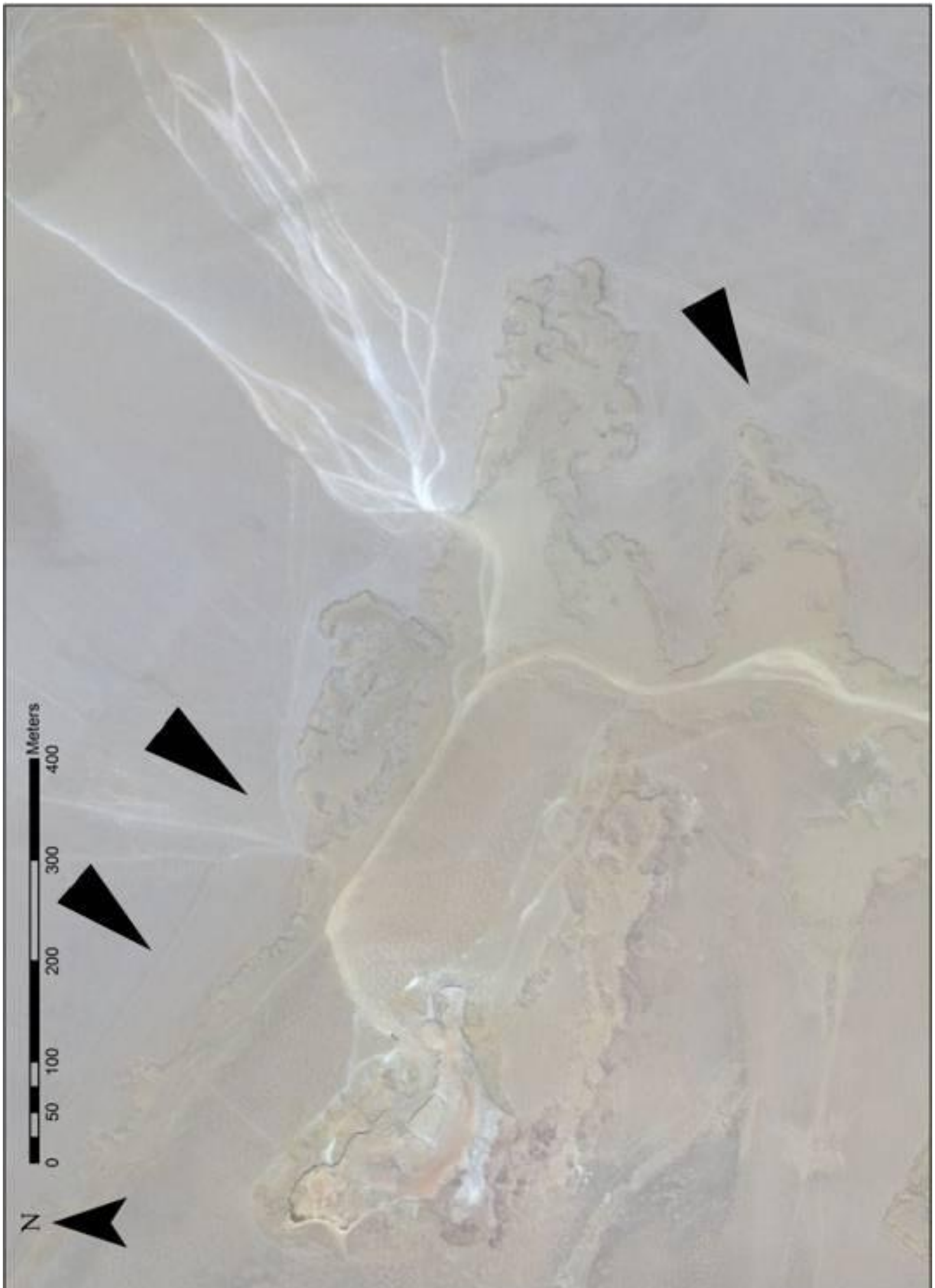


Figure 168: Pan-sharpened Quickbird image of the vicinity of the "Ptolemaic Houses" excavated by Caton-Thompson and Gardner along Canal G alignment (the latter indicated by black arrows). Ceramics were recovered from debris to the east of the quarry cut. Data from Digital Globe 2007.

Figure 169: Piles of surface material bulldozed during quarrying to the south of the Canal G channel, facing south. Many of the debris piles contain ceramic and stone artifacts from the now destroyed houses. Photo by author.

Figure 170: Ceramics recovered from the debris piles near Canal G. Photo by author.

Figure 171: Ceramics recovered from the debris piles near Canal G. Photo by author.

Figure 172: Stone artifacts identified on the debris piles near Canal G. Photo by author.

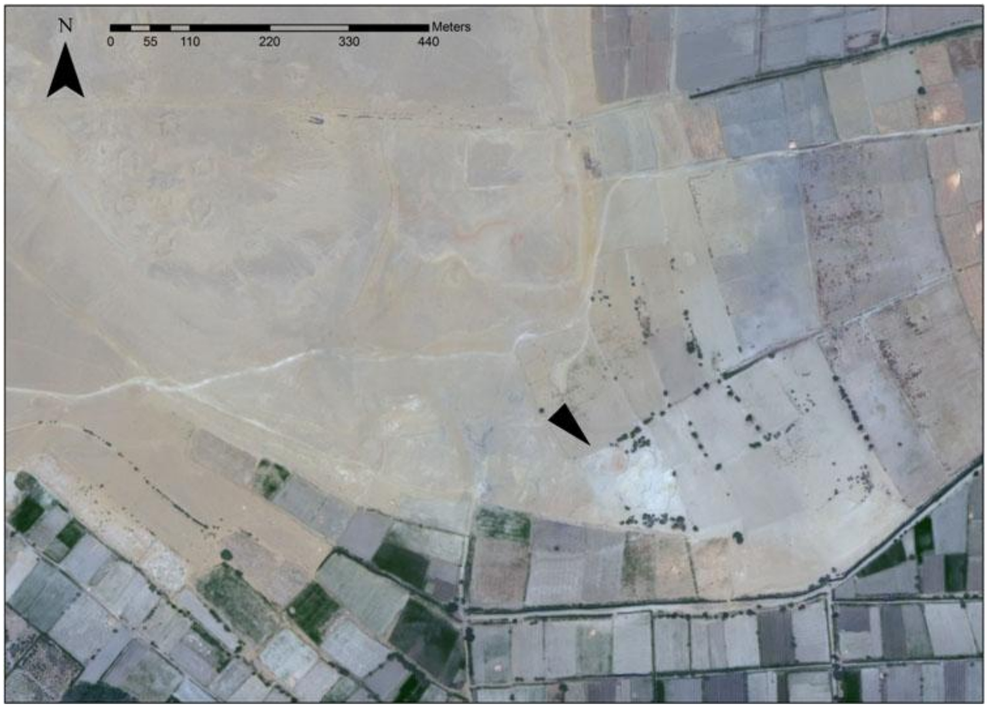


Figure 173: Pan-sharpened Quickbird image showing the probable location of the "Ptolemaic Settlement" (indicated). Remains of an abandoned military base are visible to the northwest. Data from Digital Globe 2007.

Figure 174: A quarry cut through the site of the "Ptolemaic Settlement" located by Caton-Thompson and Gardner on the northern side of the L-Basin. Remains of the settlement are visible as a gray layer in the quarry cut. Photo by author.

Figure 175: Detail of the gray layer preserved below modern debris at the "Ptolemaic Settlement".

Figure 176: Detail of ash and bone in the layer at the Ptolemaic settlement. Photo by author.

Figure 177: Detail of stratified deposits in the preserved layer at the “Ptolemaic Settlement”. A fish vertebra and ceramic fragments are visible. Photo by author.

Figure 178: Disturbed desert surface to the west of the quarry cut at the "Ptolemaic Settlement". The black and gray stain indicates ash and decomposed mudbrick beneath. Photo by author.

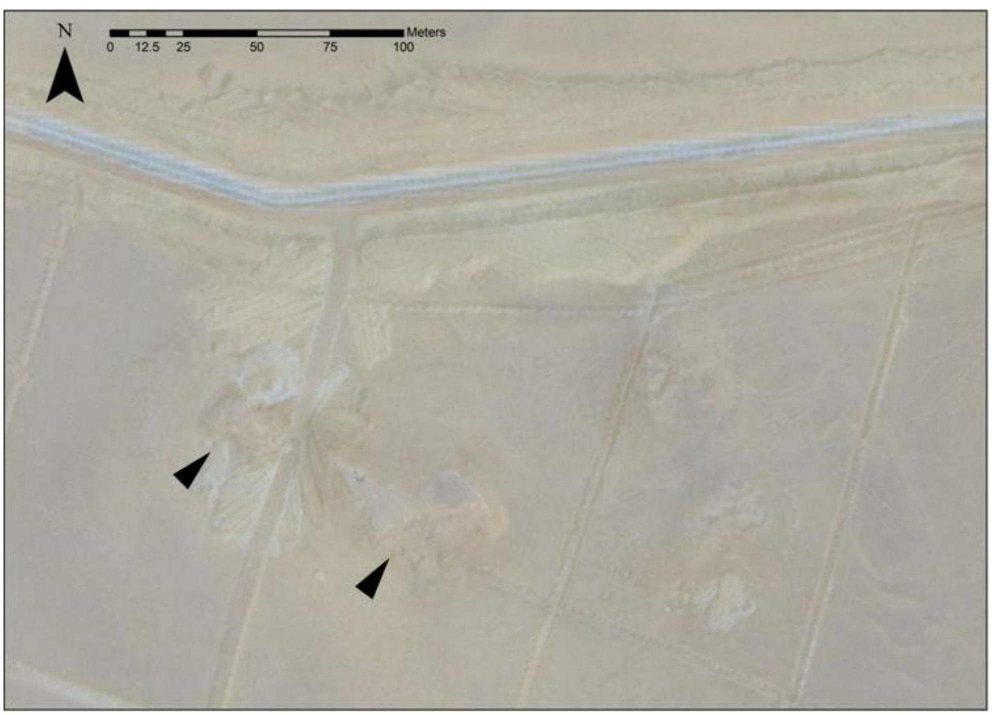


Figure 179: Pan-sharpened Quickbird image showing the location of the "Roman Gebel" (indicated). A new irrigation system has been laid out in the area and a road has cut through the site. Data from Digital Globe 2007.

Figure 180: The "Roman Gebel" identified by Caton-Thompson and Gardner. Robbed burials are visible in the gebel face at right. A modern access road runs between the peaks of the gebel. Photo by author.

Figure 181: Detail of robbed burials at the "Roman Gebel" identified by Caton-Thompson and Gardner. Human bone, but very little pottery, litters the surface of the site.

Figure 182: Pan-sharpened Quickbird image showing the probable location of the " Houses" or "Reservoir" (green dot) excavated to the northeast of Canal E. Canal E is indicated running southeast-northwest in the empty lot at left. Data from Digital Globe 2007.

Figure 183: A modern irrigation ditch in the K-Basin northwest of Qarya Ula. A mudbrick and stone feature has been cut by the ditch and is exposed at left. This may be the site of the "Reservoir" excavated by Caton-Thompson and Gardner to the east of Canal E. Photo by author.

Figure 184: A sandy dune southeast of Izbet Ashur which is littered with mudbrick and pottery. It is the probable site of one set of "Roman Houses" identified by Caton-Thompson and Gardner near Canal A, facing north. Photo by author.

Figure 185: Southwest side of the sandy dune at Izbet Ashur, facing northwest. Photo by author.

Figure 186: Detail of the southwest side of the dune southwest of Izbet Ashur showing a late pit cut into the kom, facing northwest. Photo by author.

Figure 187: The top of the dune southwest of Izbet Ashur, showing a dense scatter of mudbrick and ceramics, facing south. Photo by author.

Appendix 1: Relict Canal Alignments Excavated Near Karanis, Egypt, 2007-8

The author undertook survey and selected excavation of relict canal alignments in the vicinity of ancient Karanis (modern Kom Aushim) during two field seasons: September to December 2007 and September to December 2008. As a result, several canals identified by Caton-Thompson and Gardner were relocated and a series of previously unidentified main distribution canal alignments were examined near Karanis. Sections across the alignments revealed detailed information regarding their construction, function, use, and abandonment. A synthetic interpretation of the re-located and excavated alignments is presented above (Chapter Five).

Catalogue of Excavated Canal Alignments

The preliminary results of the excavations are presented below in sequential order by trench designation. The following format is used in the catalogue:

Trench Designation: Excavation trenches were named according to the conventions of the UCLA/RÜG Fayum Project. Each trench was prefixed with FD (= Fayum Desert) and a three digit trench number beginning with 007.

Canal Name: Each previously identified relict canal alignment was assigned the same letter of the alphabet (A-I) as used by Caton-Thompson and Gardner in their pioneering study of the hydraulic system (1935: 140-53 and Fig. lxxxvii; reproduced here as Figure 5). Newly identified alignments were assigned subsequent letters of the alphabet (J-K).

UTM Coordinates: Universal Transverse Mercator (UTM) coordinates were obtained at the surface in the middle of each trench using a Garmin 76sx handheld Geographical Positioning System (GPS). Current accuracy of the device is estimated at ± 4m, but clear desert visibility and the removal of Selective Availability restrictions by the United States Government have made greater accuracy possible. Readings are given in standard UTM order of Geographical Zone identifier, followed by a seven digit northing and a seven digit easting (e.g. 36R 1234567, 8901234). All locations presented below are visible on the Egyptian Series 1:50,000 *Kawm Ūshīm* (NH36-E5b) map sheet published in 1995 by the Irrigation Management Systems Project, Surveying and Mapping Component, in conjunction with the Egyptian General Survey Authority. Unfortunately, the 1:50,000 map series provides 1 m contour lines in cultivated areas, but only 10 m contour intervals in the desert, limiting its usefulness in certain locations.

Elevation: Absolute elevation is recorded in meters (m) Above Sea Level (ASL) or Below Sea Level (BSL). While elevation is the least accurate of the three spatial measurements recorded by handheld GPS units, the unobstructed satellite visibility provided by desert conditions and the use of "averaging" (the automated calculation and averaging of dozens of readings over several minutes) brought elevations to within a few metres accuracy for selected locations. Each elevation is presented with the accuracy reported by the unit (e.g. 45.0 ± 3.0 m ASL). All trench elevations were recorded at the surface in the centre of the square before excavation.

References: Citations of previously published commentary on each alignment are given in standard bibliographical format. In general, this relates only to the discussions of Caton-Thompson and Gardner in *The Desert Fayum* (1934).

Figures: References are made to relevant Figures accompanying this report, including the plates reproduced from Caton-Thompson and Gardner's original publication (Figures 5-20).[1]

Location and Description: Each entry includes a discussion of the size, location, orientation, and preservation of the canal alignment as well as information about the means used to locate the relict canal. The reasons for selecting each excavation area are given in the text.

Excavation: Trenches were excavated across several of the canal alignments in order to obtain cross-sections of the hydraulic channels and to obtain datable artifacts

[1] With the kind permission of the Royal Anthropological Institute.

and sediment samples. The stratigraphic sequence of each trench is presented below and reference is made to the relevant Figures.

Interpretation: Interpretation of the excavated remains, their function, and their probable date are recorded, where appropriate, and integrated into a critical re-evaluation of the interpretation provided by Caton-Thompson and Gardner.

Fayum Desert 007

UTM Coordinates: 36R N29.54427, E030.84617
Elevation: 8.0 ± 2.9 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 61-65

Location and Description:

FD 007 was selected for excavation because of its intact appearance and location in an area as yet undisturbed by quarrying activity. This segment of Canal G and the desert surrounding it appeared to be typical of the canal alignment before modern disturbance. Situated on the north side of a hilltop which overlooks the Fayum Lake, Canal G proceeds in a generally northwesterly direction towards the X-Basin, but with minor deviations to avoid local topography.

The desert pan in the vicinity of FD 007 is a typically dense scatter of surface pebbles on top of the underlying surface apart from the disturbance caused by the canal. The surface of the canal is lighter in color than the surrounding desert and lacks the heavy surface scatter of pebbles deposited by the process of deflation elsewhere

(Figure 61). The channel is filled with windblown sand and is concave and slightly lower than the surrounding desert pavement. There are traces of broken bedrock visible on both sides of the channel.

The distance between the berms is ca. 5.0 m with the berms rising 0.10 - 0.15 m above the desert and ca. 0.20 – 0.30 m above the concave channel. The remains of desert plants are visible in the channel and outside of it to the west (a local topographic low which may collect moisture).

Excavation:

A formal trench 7.0 m SW-NE x 2.0 m SE-NW was laid out perpendicular to the channel. The objective was to clear this section of the canal, expose the channel, and examine its profile, construction, and fills. Topsoil, a sandy matrix with some large pebbles and many small pebbles [Unit 001], was removed throughout the square revealing a linear but slightly irregular channel [Unit 005] ca. 2.25 - 2.50 m wide running N-S which cut the bedrock to the west [Unit 002] and east [Unit 004]. The bedrock was a mottled, dark gray fossiliferous limestone with high gypsum content, highly friable at the surface but becoming more indurated below.

The fill of the channel, composed of numerous microlaminae of windblown sand bedded from the north or northwest was removed in arbitrary layers [Unit 003 and Unit 006] to reveal the bottom of the channel [Unit 007]. The preserved width of the gently U – shaped channel ranged from ca. 1.30 – 1.35 m to ca. 2.00 – 2.10 m. The maximum preserved depth of the channel was ca. 0.55 m (Figure 62-65).

Interpretation:

Excavation of FD 007 provided several insights into the nature of Canal G. First, there is no direct relationship between the width of the berms and the width of the canal channel. Second, the berms themselves appear to be composed of bedrock boulders and cobbles thrown up during the original excavation of the channel and subsequently covered by windblown sand. No silt was preserved in the berms. This may suggest that water never overtopped the channel itself, that the berms never served to contain the flow, or that cleaning operations were minimal in the vicinity. It is also possible that the small particle size of any silt allowed it to be completely eroded by wind action, but it would be remarkable if none remained even in the sheltered areas between the bedrock fragments.

Third, the channel itself was completely filled with windblown sand. While the absence of bedded silt or clay might suggest that the channel was never used, it is also possible that the channel had been scoured by wind action or that all of the particulate matter had fallen out of suspension earlier in the system, as suggested by Caton-Thompson and Gardner.[2] Additional trenches were necessary to establish that the channel had been used (see below, FD 009 and FD 014).

[2] Caton-Thompson and Gardner 1934: 142.

Fayum Desert 008

UTM Coordinates: 36R N29.54237 E030.84712
Elevation: 11.0 ± 2.5 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 66-74

Location and Description:

FD 008 was selected for excavation owing to its visible differences in width between the berms despite its relative proximity a few hundred meters to the east of FD 007. Here the berms appeared to be preserved at a distance of ca. 12.0 m apart. The presence of a modern desert track following the line of the canal on the north side raised the possibility of modern disturbance to the placement of the berms. However, the desert surface was identical to that found in FD 007 with dense desert pavement to either side of the berms and with the remains of desert plants inside the channel (Figure 66).

Excavation:

A trench 7.0 m N-S x 2.0 m E-W was laid out perpendicular to the preserved channel and was later extended to the south by an additional 5.0 m. Removal of the topsoil [Unit 001 = Unit 007] revealed wide sections of the local bedrock between the berms and the channel. To the south, the bedrock [Unit 002] was the same friable fossiliferous stone found in FD 007. However, the surface was scored by numerous large and irregular cracks. One crack [Unit 009] up to 0.10 m wide may have been the result of rapid desiccation (less likely) or geological movement (Figures 69-70). The fill of the cracks [Unit 010] was identical in color to the bedrock [Unit 002] but was slightly sandier. At the southern edge of the trench near the broken bedrock [Unit 011] composing the berm was a small concentration of dark-colored bone fragments [Unit 012]. These fragments were collected and submitted for examination but were ultimately interpreted as fossils weathered out of the bedrock.

To the north, the bedrock [Unit 004] sloped gently away from the channel and up to large bedrock fragments composing the berm [Unit 005]. The northern berm appeared to have been built up over time both with windblown sand and with finer, silty deposits which may have come from the channel but could also have eroded from the bedrock (Figures 72, 74). Resting on the bank on the north side [Unit 004] and abutting the berm [Unit 005] were numerous ceramic fragments which were later restored as the rim, neck, and handles of an amphora [Unit 017] which had suffered from spalling as a result of the abundant salts in the bedrock (Figure 73).[3] There appeared to be some ephemeral ashy sand, bone, and wood(?) [Unit 015] in a small shallow depression or pit [Unit 016] associated with the ceramics, but it may have been a geological remnant of the low-oxygen marine environment in which the bedrock was laid down. The north berm [Unit 005] was removed to determine if the sherd scatter extended beneath but no additional ceramics were recovered (Figure 72). The berm was composed entirely of small lenses of material cut from the original channel, including fossiliferous limestone, fossiliferous clay/shale, sand, and pebbles (Figures 72, 74). Notable, however, was the fact that a thin layer of sandy topsoil [Unit 001] ca. 0.01 m thick extended beneath the

[3] A similar vessel from Elephantine has been dated to the fourth or early third century BCE, see Aston 1999: 260, and pl. 83 #2261.

berm [Unit 005] (see below). The superimposed layers in the berm were labelled [Unit 018 A-M] and sampled for analysis.

The fill of the channel was composed entirely of windblown sand bedded from the north or northwest and was removed in arbitrary layers [Units 003, 006, and 013]. A very thin, powdery lens [Unit 014] at the bottom of the channel appeared to be composed of sediment weathered from the surrounding bedrock (but see FD 013, below). The channel itself [Unit 008] was revealed to be ca. 1.40 m wide by 0.30 m deep (Figure 68).

Interpretation:

Most notable is the fact that the channel in FD 008 (ca. 1.40 m) is not as wide as the channel in FD 007 (1.30-2.40 m) despite the fact that it lies to the east and, therefore, upstream. This suggests that the precise width of the channel may not have been of critical importance to those constructing it, perhaps because the channel was never filled to capacity and only the width at some particular level within the channel was of importance. Alternatively, fracturing of the bedrock using hand tools may have led to irregular widths along the alignment, particularly in areas where greater depth of excavation was required to maintain the slope. However, the lack of attention paid to the precise channel width is not commensurate with the effort taken to transport the excavated bedrock fragments away from the channel in order to form the linear berms.

Great effort seems to have been expended in spacing the berms quite widely to either side of the canal channel. As the distance between the berms narrows ca. 20.0 m to the west, it seems plausible that the wide spacing served a specific purpose. One possibility is that a water control device was installed at or near the narrowing of the berms to the west; by restricting the flow of water at that point, it would have been possible to raise the hydraulic head and flood the canal banks to either side of the channel where the berms were widely placed. This type of irrigation would have been particularly effective for small garden-type plots immediately next to the channel which could be irrigated initially with flood water and subsequently by hand.[4]

The numerous superimposed lenses of bedrock debris in the north berm [Unit 018 A-M] were occasionally separated by lenses of windblown sand. It is tempting to suggest that there was more than one phase of channel cutting in the vicinity, but this could not be established beyond a doubt. All of the individual lenses were examined for palaeobotanical and faunal evidence, but were completely sterile apart from fossilized shell and bone fragments.

The cracking visible in the bedrock surface to the south is intriguing (Figure 70). If the berms were placed farther apart in the vicinity of FD 008 in order to flood the banks for the purpose of cultivation, then the cracking may be due to rapid desiccation of the sediments as the water evaporated. However, the bedrock on the north side of the channel is at a slightly lower elevation and should also have been subject to flooding, but no equivalent cracking of the surface was visible on that side. While it might be possible to attribute the cracking to seismic activity, there is very little in the area and

[4] For the long history of the practice in Egypt, see Eyre 1994.

no cracks of this type were visible in other trenches along the Canal G alignment (but see FD 017 below).

One of the most significant results obtained from trench FD 008 was the identification of the original desert surface dating to the time of canal excavation. A sandy layer of surface sand ca. 0.01 m thick was preserved beneath the northern berm [Unit 005]. As the layer was capped by the berm in antiquity, the ancient landscape in the area must have been very similar to that found today and Canal G represents an ancient attempt to bring an arid, desert environment under cultivation. Local informants report that the friable and weathered bedrock found just below the desert surface in the area is relatively fertile, given sufficient irrigation, and that it is often collected and used as an admixture in neighbouring fields.

Fayum Desert 009-010-011

UTM Coordinates: 36R N29.54213, E030.84740
Elevation: 11.0 ± 2.1 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 75-84

Location and Description:

Trench FD 009 is located ca. 40 m southeast of trench FD 008. It was selected for excavation in order to explore an area where only very low, if any, berms were preserved on the surface for some distance. Despite the lack of substantial berms, the location of the canal channel could be discerned as a slightly concave (ca. 0.02 – 0.05 m deep) path of sandier topsoil running through the desert pavement heading towards FD 008 (Figure 75). The absence of berms suggested either a different type of localized ancient activity or more recent activity, perhaps the trenching activity of Caton-Thompson and Gardner.

Excavation:

Trench FD 009 was laid out 6.0 m N-S by 2.0 m E-W perpendicular to the presumed line of the channel. The ends of higher and wider berms were preserved in the eastern half of the trench. Preliminary results led to the expansion of the trench to the west (FD 010) and to the east (FD 011); for the purposes of this report all three trenches are considered together.

Removal of the topsoil [Unit 001] revealed the sandy fill [Unit 003] of the channel [Unit 005] with weathered bedrock exposed to the north [Unit 004] and to the south [Unit 002]. Removal of the loose sandy fill [Unit 003 and Unit 006] revealed the bottom of the channel [Unit 005]. Some bone and shell fragments were collected from the fill but they appeared to be petrified deposits which had eroded out of the weathered bedrock. The channel was slightly concave, ca. 1.5 - 1.8 m wide, with a depth of between 0.15 – 0.30 m (Figure 77).

While drawing the western baulk of FD 009, it became obvious that the northern (i.e. downhill) side of the channel was substantially lower than the southern side (Figures 76-7). As this would have led to the loss of half the water in the channel, a new trench FD 010 was opened to ascertain whether the lower elevation was intentional or the result of more recent disturbance.

FD 010 was laid out on the western side of FD 009 and perpendicular to its northern end (Figure 78). It was originally 4.0 m E-W x 2.0 m N-S, but was extended an additional 2.0 m N-S to include the Canal G alignment. Removal of the topsoil [Unit 001] revealed a roughly concave off-take channel [Unit 007] ca. 0.80 m wide which leaves the main canal channel in a northwesterly direction and diverges into two smaller channels [Units 003 and 008] after ca. 0.50 m (Figures 78-80, 83). One of the smaller channels [Unit 003] is ca. 0.50 – 0.60 m wide, semicircular, with gently sloping sides and a gradual break at the top. It extends across the square to the northwest, continuing the line of the main off-take channel [Unit 007] and disappears into the north baulk. The second channel [Unit 008] is similarly constructed but only 0.35 – 0.4 m wide and turns abruptly to the north before disappearing into the north baulk. Examination of the desert surface to the north of the trench revealed shallow depressions indicating the probable continuation of the smaller channels in that direction. All three of the subsidiary off-take channels were filled with a loose mixture of the surrounding friable bedrock and sand [Units 005 and 006] (Figure 79).

Trench FD 011 was laid out to the east of FD 009 in order to clarify the relationship between the off-take channel (FD009 Unit 007) and the main channel. Removal of topsoil [Unit 001] exposed the point of intersection and revealed a small hump of decomposed bedrock ca. 0.10 m high and 0.20 m wide running along the main channel, separating it from the off-take [Unit 007]. This material had presumably been built up by hand in order to control the flow of water into neighboring fields (Figures 81, 83).

Interpretation:

The low berms in the vicinity of FD 009 – FD 010 – FD 011 were undoubtedly the result of a man-made feature designed to lead water into a field system to the north of Canal G. Similar constructions, referred to as field turn-outs by archaeologists, are used in modern fields in the area today and are known in Arabic as *khaliga* (Figure 82).[5] They are simple and easy to maintain and the flow of water can be regulated by building up or removing a small amount of soil across their entrance. Given the well preserved features located in the trenches and the apparently undisturbed nature of the desert surface to the north, it is very likely that an entire ancient field system is preserved in the immediate vicinity and that it could be excavated with relatively little effort.

Fayum Desert 012

UTM Coordinates: 36R N29.54281 E030.84656
Elevation: 10.0 ± 2.7 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 85-94

Location and Description:

Trench FD 012 was opened ca. 40.0 m to the west of FD 008. The trench was laid out over a transitional area where berms visible on the surface could be seen to diverge

[5] For the term, see Foster, Woodson, and Huckleberry 2002: 112; Howard 1990; Doolittle 1990.

from a distance of ca. 12.0 m to a distance of ca. 6.0 m apart. The objective was to test the hypothesis that the berms were spaced more widely in FD 008 in order to facilitate cultivation or other activity along the banks and that some sort of water control feature may have been constructed in FD 012 in order to raise the hydraulic head and flood the banks beside the canal upstream.

The pre-excavation surface of FD 012 was similar to that seen along the course of Canal G. The most obvious difference was the relatively rapid constriction of the berms which turned inwards towards the canal to transition from a distance apart of ca. 12.0 m to ca. 6.0 m over a distance of only ca. 5.0 m (Figures 85-6). As in other trenches excavated along Canal G, the path of the channel was easily identifiable by its sandy appearance when compared to the surrounding desert pavement.

Excavation:

Trench FD 012 was originally laid out perpendicular to the channel and covering an area 7.0 m N-S x 4.0 m E-W. A later extension of 3.0 m to the west created a single trench of 7.0 m x 7.0 m. Removal of the surface sand [Unit 001] revealed the fill of the canal channel [Unit 005] ca. 2.65 m wide dividing the bedrock on the north [Unit 004] from the bedrock on the south [Unit 002]. It was immediately striking that, although the berms narrowed at this point, the channel maintained a width similar to that found in the upstream trenches (Figure 87).

The berm to the north [Unit 007] of the channel was composed of broken bedrock boulders and cobbles which had been formed into a rough linear feature later covered by windblown sand. The berm to the south [Unit 006] was of similar construction, but appeared to have been modified after its construction. Only the southern berm deviated from its course in order to effect the change in width between the berms (Figures 87, 94). Built into the southern berm were three large slabs of broken bedrock [Unit 014] which had been placed in a rectilinear U-shaped feature (ca. 1.15 m E-W x ca. 0.80 m N-S) facing the channel (Figure 93). Small stone features of this type could be used as a windbreak to protect a fire, but no ash was preserved and the feature had its open side to the north (i.e. facing the predominant regional wind). No specific function could be ascribed to the feature, but its presence demonstrated more than casual human activity in the area.

As in the other trenches along Canal G, the channel [Unit 005] was filled with laminated windblown sand [Units 003 and 008]. Removal of the sand revealed a layer [Unit 009] of decomposed bedrock varying between ca. 0.02 – 0.05 m thick. Removal of this “false bottom” revealed another layer of sand [Unit 013] ca. 0.01 - 0.03 cm thick which rested upon the channel bottom (Figure 92).

The channel [Unit 005] was extremely irregular in trench FD 012. In the eastern portion of the trench, the sides of the channel sloped gradually inwards while to the west they were almost uniformly vertical. These two differing construction techniques intersected at a slight angle (Figures 89-91). Fragments of decomposed bedrock which appeared to have been piled-up or otherwise formed against the sides of the channel at this intersection both on the north [Unit 011] and south [Unit 012] appeared to be an attempt to make the channel smoother and more hydrodynamic. On both sides of the channel, but particularly on the south, there were some traces of a white chalky substance [Unit 013] which appeared to be the local diatomaceous clay which can be seen in the bottom of the X-Basin only a few kilometres away. In the one location where the substance was preserved in any quantity, there was a ca. 0.20 x 0.20 x 0.10 m chunk adhering to the bedrock on the south side of the channel (Figure 92).

Interpretation:

No evidence of a water control device or other feature was found in the channel of Canal G in FD 012. It seems instead that the narrowing of the berms at that point was the result of construction in two phases or by two teams. The fact that the channel sides differed in their profiles to the east and west and that there was a disjunction in the line of the channel at the same point suggests that either Canal G was constructed up to this point with an addition to the west at a later time, or that two teams were each responsible for excavating a section of the channel and that they did not meet precisely. Differences in horizontal alignment in the canal at this point required patching on the sides of the channel. It is worth noting that Caton-Thompson and Gardner reported the use of diatomaceous clay to patch the sides of canals in areas of probable leakage (e.g. Canal E), although they did not report its use along Canal G.

The “false bottom” of the channel is more difficult to interpret. While it might be tempting to suggest a brief period of abandonment of the canal during which a small amount of sand accumulated in the bottom of the channel and upon which slump from the banks accumulated, the overall effect suggested an intentional attempt to smooth over differences in vertical alignment between the independently constructed section and re-level the bottom of the canal. Some confirmation for this interpretation was provided by the smoothing of both sides of the channel at mid-trench.

A group of houses excavated by Caton-Thompson and Gardner along Canal G to the west of FD 012 (i.e. downstream) were dated by several bronze coins of Ptolemy II (Appendix 2: “Ptolemaic Houses”). As the houses would not have had access to water until the construction of the canal, the entire canal alignment must have been in place quite early in the Ptolemaic period. This fact strongly suggests that the entire Canal G alignment was constructed in a single phase by multiple teams or in multiple, but rapidly progressing, sequential phases and that its construction was centrally organized in a manner consistent with the state-sponsored irrigation scheme described in the archive of Kleon and Theodoros (Chapter 3). However, it remains possible that the extension of the alignment was left to the initiative of individual landholders. If the latter, it may be that the section of the alignment which begins in FD 012 and runs to the west was commissioned or constructed independently by the inhabitants of the houses located along its banks and that the intersecting segments of the alignment reflect these differences.

Fayum Desert 013

UTM Coordinates: 36R N29.53941 E 030.84976
Elevation: 13.0 ± 4.3 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 95-9

Location and Description:

Trench FD 013 was located ca. 150 m to the east of FD 009. The objective of the trench was to examine a bend in the canal alignment where it turned from a southwesterly direction to a westerly direction. Once again, the location of the channel could be identified by its sandy path through the surrounding desert pavement and by the presence of a low berm on its north/northwest side. No berm was identifiable to the south/southwest where the abutting hillside rises gradually but appreciably (Figure 87).

Excavation:

Trench FD 013 was laid out perpendicular to the line of the canal at its bend. Removal of the surface sand [Unit 001] revealed a relatively sharp angular bend in the channel [Unit 005] ca. 1.90 m wide dividing the bedrock to the south [Unit 002] from the bedrock to the north [Unit 004] (Figure 96). The sandy fill [Unit 003] of the channel was heavily laminated and obviously windblown, but quite shallow compared to the channel further west. As in trench FD 012, removal of the channel fill [Unit 003] revealed a "false bottom" [Unit 007] composed of crushed bedrock. However, this disturbed bedrock did not contain any of the larger inclusions of shell or stone which occur in the geological layer. There was a thin layer of sand [Unit 008] ca. 0.01 – 0.02 cm thick below the "false bottom" which rested on the true channel bottom ca. 0.30 m deep (Figures 97-8).

While the inside of the bend appeared somewhat angular, the outside appeared to follow a more circular path and the channel side appeared to be much more rounded and worn (Figures 98-9). Degradation of the outside of canal channels, where water velocity is higher, is a well-known phenomenon. However, it is difficult to believe that such a shallow channel could generate sufficient energy to erode the bedrock except over a relatively long period of time. In addition, if there were sufficient energy in the flow to scour the side of the bedrock channel, one might not expect that the powdery crushed bedrock used to line and level the channel bottom would have remained intact.

Interpretation:

It is reasonable to conclude that the downstream flow in Canal G never exceeded the maximum depth of the channel in FD 013 (ca. 0.30 m); the deeper channels to the west were simply the result of attempting to maintain the slope in an area of higher bedrock, as suspected by Caton-Thompson and Gardner. While the total cross-sectional area of the channel is extremely small, it seems that this was sufficient to irrigate a relatively large area downslope from the canal to the west of FD 009. If so, the flow may have persisted over a considerable period each season or water may have been released into the alignment in small quantities but at frequent intervals. In FD 013, the shallow channel resulted in less available raw material for berm construction and this was put to use only on the north/northwest side, either because of the greater ease in placing the debris on the down-slope side or as part of the construction to prevent spillage. No such construction was strictly necessary to the south/southeast, as the grade of the hillside was already was substantial enough to contain any overflow.

Fayum Desert 014

UTM Coordinates: 36R N29.55370 E 030.84045
Elevation: 5.0 ± 2.9 m ASL
Canal Name: Canal G
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 100-5

Location and Description:

Trench FD 014 was laid out along the Canal G alignment ca. 1.5 km along its course to the west of FD 007. The desert surface in the immediate vicinity of the trench appeared to be relatively intact but significant portions of the alignment had been destroyed by modern quarrying activity to the north and south of the trench (Figure 100). Once again the channel was visible on the surface as a sandy path through the desert pavement as it followed along the hillside rising to the west. Significant berms ca. 0.3 m – 0.5 m high were well preserved on both sides of the channel particularly at the northern end of the square where the channel was presumed to be correspondingly deep.

The primary objective of the trench was to examine a preserved portion of the Canal G alignment in proximity to the large group of houses excavated by Caton-Thompson and Gardner slightly to the west and northwest of the trench and, if possible, to obtain datable ceramic samples attesting to its periods of use. Examination of the large piles of debris heaped up on the surface beside the modern quarry area to the north of the trench yielded numerous ceramic and stone artifacts which must have come from the now utterly destroyed houses (see Appendix 2: "Ptolemaic Houses"). While Caton-Thompson and Gardner believed that they had cleared the houses completely, the presence of several virtually intact vessels in the debris suggests that an additional portion of the habitation site was untouched until very recent times.

Excavation:

Trench FD 014 was laid out 5.0 m N-S x 7.0 m E-W perpendicular to the line of the channel. It was later expanded 3.0 m to the south in order to expose additional artifacts (Figures 101, 105). Removal of the topsoil [Unit 001] exposed the bedrock banks to the west [Unit 002] and the east [Unit 004] separated by the channel cut [Unit 005] filled with the laminated windblown sand fill [Unit 003] typical of other trenches.

Broken bedrock on the west side [Unit 006] had been piled in the northwest corner of the trench rather than in a linear feature, as elsewhere, and seemed to indicate deeper excavation of the bed rock in the immediate vicinity. To the east, broken debris from the channel cutting [Unit 007] had been piled into a linear berm on the downhill slope, but the quantity seemed relatively minor compared to that found in other trenches. A single blackened sherd of a ribbed cooking pot was recovered from the eastern bank at the southern end of the square. At the southern end of the west bank, two small and ephemeral ashy lenses [Unit 009] and [Unit 010] were visible on the surface.

The removal of the sandy channel fill [Unit 003] exposed the channel cut into the bedrock [Unit 005] which varied between 2.0 - 2.5 m wide with gently tapering sides. However, it was immediately obvious that a second channel [Unit 008] had been cut into the bottom of [Unit 005] in a later phase (Figures 101-2). This channel was ca. 1.35

– 1.45 m wide and its bottom sloped rapidly downwards (ca. 0.30 m over a distance of 5.0 m) deviating to the west of the main canal alignment by 16°. Just before the north baulk, the western side of the later channel appeared to widen sharply or turn to the west (Figures 101, 105). Expansion of the square would have been necessary in order to establish its further course. Near the center of the trench, two triangular, symmetrical cuts had been made into the sides of the smaller channel [Unit 008] directly opposite each other (Figure 102). Each cut was ca. 0.55 m long x .28 m wide x 0.26 m deep.

Substantiation for dating the two channels [Unit 005 and Unit 008] to separate periods was provided by a small probe in the southeastern corner of the square where the berm was sectioned in order to examine its internal structure. Below topsoil [Unit 001], the berm was composed of a thin layer of crushed bedrock [Unit 012] resting upon a thin layer of sand [Unit 013] which in turn lay upon a central core of crushed bedrock [Unit 014]. The separation of two distinct layers of excavation debris by a layer of windblown sand implies a delay between two excavation phases, although it is not possible to determine the chronological length of the interval.

Resting on the bottom of the channel in the central portion of the trench was a large scatter of 22 additional sherds, including the partial rim and handles of a blackened and ribbed cooking pot [Unit 015] of the late first century BCE or early first century CE. Despite significant spalling on the surfaces which had been in contact with the channel bottom, the vessel was restorable and joined with the fragment found on the east bank above (Figure 104).[6] Scattered down the west side of the channel and across part of its bottom in the southern extension of the trench was a large ash deposit [Unit 011] which contained carbonized threshing remains visible to the naked eye (Figure 103). C^{14} analysis of the sample reported a date between 70 BCE and 40 CE. Preliminary paleobotanical analysis indicated that the crop was bread wheat and that this may be the earliest archaeological attestation of the species in Egypt.[7]

Interpretation:

Trench FD 014 preserved some of the most important evidence for the occupation history of the Canal G alignment. While Caton-Thompson and Gardner dated Canal G to the early Ptolemaic period on the basis of coins of Ptolemy II (ruled 283-246 BCE) recovered from the houses excavated to the immediate west and northwest of trench FD 014, they concluded that this portion of the irrigation system was in use for only a short time. The presence of both an ash deposit and the remains of a cooking pot dating to the first century BCE or first century CE indicates either continuous use from the Ptolemaic to the early Roman period or a period of reuse at that time (which might be associated with the re-cutting of the canal visible in the trench). Re-examination of the ceramics excavated from the houses by Caton-Thompson and Gardner might clarify the issue.[8]

[6] The marl clay cooking vessel is broadly similar in form to Gempeler 1999: 168, K407, Abh. 101.2. He gives a date between the early Augustan period and the early 2nd century CE.
[7] Drs. Willeke Wendrich and René Cappers, pers. comm. 2008. The crop is attested at an earlier date in documentary sources.
[8] The finds from the irrigation system are now scattered in various museums in the UK. See Chapter 4 and Appendix 2: “Ptolemaic Houses”.

While Canal G appears to have been in use in the late first century BCE or the early first century CE, it was abandoned at that time. The major ash deposit [Unit 011] recovered from the west side and bottom of the channel would have been partially washed away by any significant flow in the channel. In addition, the sherds recovered in the trench displayed no rounding or other alteration caused by water and many were still covered with carbonized residue from cooking which could easily be brushed away by hand. Taken together, this evidence suggests that the chaff from a previous threshing was burned and disposed of in the canal channel but that water did not arrive at this point in the system during the following irrigation season or the ash would have been washed away.

It is worthy of note that the sides of the original channel [Unit 005] slope gently inwards in FD 014, just as they do in the western half of FD 012 (see above). If FD 012 preserves the join between two separately-excavated sections of the alignment, as proposed above, then it is possible that the entire segment from FD 012 to FD 014, a distance of ca. 1.4 km, was constructed as a single unit.

The symmetrical triangular cuts on either side of the smaller channel [Unit 008] were clearly designed for the installation of the water control feature, probably a gate or fence made of wood or woven rushes. A feature of this type, referred to as a *tapon* by archaeologists, would have impeded the flow in the channel sufficiently to raise the hydraulic head on the upstream side and would have permitted irrigation of the landscape on the downhill side.[9] Temporary and removable water control features of this type are commonly found in irrigation societies around the world and are still used in Egypt today, but evidence for them is rarely found in soil-lined channels; the preservation of an installation for one here is a by-product of the original excavation of Canal G into the geological layers of the area.

The relatively large amount of broken bedrock in the northwest corner of the square and the apparent deviation of the smaller channel [Unit 008] to the west just before the north baulk, may indicate the presence of a reservoir or cistern in immediate proximity to the channel. Certainly, once the original channel [Unit 005] had been modified by the cut for the smaller channel [Unit 008], it would have been virtually impossible to maintain flow to additional portions of the Canal G alignment further to the northwest.

Fayum Desert 015

UTM Coordinates: 36R N29.54286 E030.86353
Elevation: 9.0 ± 2.0 m ASL
Canal Name: Canal H(?)
References: Caton-Thompson and Gardner 1934: 142-5 Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 106-9

Location and Description:

Trench FD 015 was excavated to investigate a linear feature, preserved for a length of only ca. 200 m, which was visible in the satellite imagery on a topographic rise ca. 1.0 km to the west of Canal G in the approximate vicinity of Caton-Thompson's and

[9] For the term, see Foster, Woodson, and Huckleberry 2002: 112; Howard 1990: 21-2.

Gardner's Canal H. The entire area had been disturbed by quarrying and modern agricultural activity. To the east, the potential Canal H alignment had been completely removed to a depth of ca. 6.0 m by mechanical excavators, while to the west, modern fields had been established along the banks of the L-Basin. Ca. 150 m to the north, at the approximate location of another group of ancient houses located by Caton-Thompson and Gardner lies an abandoned(?) co-operative farm with its substantial walled compound. No traces of the houses could be located near the farm or in the modern quarrying debris.

The surface in the immediate vicinity of the trench appeared to be undisturbed and intact desert pavement could be seen on both sides of the channel (Figure 96). The very low berms were ca. 0.10 m high and ca. 3.80 m apart. No broken bedrock was visible in the berms.

Excavation:

FD 015 was 9.0 m N-S x 3.0 m E-W and laid out perpendicular to the visible remains of the channel. Removal of the sandy topsoil [Unit 001], revealed a slightly concave channel [Unit 002] which only descended ca. 0.11 m into the soft, white limestone bedrock [Unit 006]. The channel was ca. 3.20 m wide at the banks and ca. 2.40 m wide at the bottom. The berms to south [Unit 003] and north [Unit 004] were ca. 0.08 m high and were composed of compacted limestone debris (Figures 107-8).

Interpretation:

Given the amount of disturbance to the topography of the area (a significant topographic high shown a few hundred meters to the north on Caton-Thompson's and Gardner's plan has been completely removed), it was not possible to establish that the feature excavated in FD 015 was Canal H. No datable material was recovered from the square and the alignment does not correspond well with the map (Figure 5) published in *The Desert Fayum*. However, as the channel runs into the desert where there has been only quarrying activity in recent times, it is difficult to determine what modern purpose the shallow channel could have served were it modern (but see FD 016, below).

Fayum Desert 016

UTM Coordinates: 36R N29.54108 E 030.85988
Elevation: 6.0 ± 4.2 m ASL
Canal Name: Canal H(?)
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix.
Figures: 5, 7, 34-5, 110-14

Location and Description:

FD 016 was excavated to investigate a narrow linear feature which had been identified in the satellite imagery. The feature ran E-W for ca. 600 m in a straight line in an area of desert lying between the Canal G and Canal H alignments before turning east at its southern end, but had been disrupted at both ends by quarrying activity (Figures 110-11). The desert pavement in the area was visible but, apart from the presence of two low berms ca. 0.35 m high, the purported channel could not be easily distinguished from the surrounding landscape, as a monthly camel and goat market held in the vicinity had compacted the surface and littered it with coprolites.

Excavation:

Trench FD 016 was laid out 5.5 m N-S x 1.0 m E-W perpendicular to the visible remains of the channel. Removal of the topsoil [Unit 001] revealed a shallow, concave channel [Unit 003] ca. 2.4 m wide and 0.10 m deep excavated into the white limestone bedrock [Unit 005]. The berms to the north [Unit 002] and south [Unit 004] were composed of crushed, powdery bedrock debris from the channel (Figures 113-14).

Interpretation:

The feature in FD 016 may be modern. No ancient artifacts were recovered but the channel and its berms were remarkably similar to those revealed in FD 015. No physical connection between the channels is extant and it seems unlikely that one could ever have existed given their relative elevations but disturbance to the landscape precludes certainty. Further, there is no obvious reason why such a feature would be constructed in the midst of a modern quarry. Desert tracks in the area are un-modified and simply follow the topography of the desert surface. All of the modern roads in the quarry were formed by bulldozing and have debris piled up only in selected areas; where the bulldozers did leave debris on both sides of a road, the material is much more heterogeneous and is not symmetrically distributed.

Fayum Desert 017

UTM Coordinates: 36R N29.51434 E030.89910
Elevation: -18.0 ± 2.3 m BSL
Canal Name: Canal J
References: Caton-Thompson and Gardner 1934: 142-5
Figures: 34, 120-1, 131-9, 146

Location and Description:

Caton-Thompson and Gardner were unable to investigate the immediate vicinity of Karanis as it lay within the boundaries of the University of Michigan's archaeological concession. However, numerous scholars since that time have assumed that the ancient high-level distribution canal which followed the northern desert boundary of the Fayum in the Graeco-Roman period, the *Dioryx Kleonis*, could be seen running NW-SE at the base of the kom (Figures 129, 131). The objective of trench FD 017 was to establish the presence or absence of an ancient canal in that location.

The landscape has been badly disturbed on the south side of the kom at Karanis. The greatest disturbance is associated with the organized looting of the site by the *sebbakhin* during the late 19th and early 20th centuries; at that time vast quantities of decayed organic matter were quarried from the site for use as agricultural fertilizer. As a result the central portion of the site has been almost completely lost and resembles and eerie moonscape. Most of the *sebbakh* was removed through a gap in the south side of the kom and was then transported on a light rail line, the remains of which are visible running southwest from the kom (Figures 120-1). The process of removal seems to have spread ceramics and other artifacts across a relatively wide area between the kom and the modern canal, the Bahr Wahbī. The effect has been compounded by spoil heaps from the University of Michigan excavations and natural erosive processes which have transported large quantities of sand and artifacts down to the southern slopes.

Today the kom is preserved to a height of approximately sea level. To the south, it drops off in a series of steep steps covered with mud brick walls and other features until it begins to level off at ca. -15.0 m BSL. There the surface is much sandier and is more reminiscent of the deflated desert landscape visible to the North of the site. After a few meters, the surface drops off sharply at a low, vertical bedrock face which projects from beneath the kom. Between the bedrock and the berm of the modern canal is a long concave depression ca. 25.0 - 30.0 m wide running NW-SE along the south side of the kom for ca. 1 km. The depression is filled with windblown sand and looks very much like a wide canal channel, an impression which is reinforced by the wide northern berm of the modern canal which is covered with debris from cleaning operations and abundant brush and reeds.

Excavation:

Trench FD 017 (24.0 m N-S x 3.5 m E-W) was laid out from the exposed edge of the bedrock beneath the kom to the berm of the modern canal and perpendicular to the intervening concave depression. The topsoil [Unit 001] was composed entirely of windblown sand which had been badly contaminated by modern garbage. Beneath the topsoil in the northern portion of the trench was a further stretch of mottled sandstone bedrock [Unit 007] which appeared weathered and sloped gently to the south. The sandstone terminated in a rough line exposing another geological layer [Unit 003] approximately 10 m from the north baulk. The latter layer is brittle and powdery when dry with an overall light gray color, mottled with orange and black as a result of its marine origins. The fact that this layer emerges from beneath the sandstone to the north indicates that it should be called shale rather than clay but it is so poorly indurated that it can be molded easily by hand when wet. Large cracks, ca. 0.10 – 0.20 m wide [Unit 009, Unit 010], ran E-W across both the sandstone [Unit 007] and the clay [Unit 003] and appeared to be the result of natural erosive fracturing under the weight of the bedrock where it had been exposed along the edge of the Fayum depression (Figure 132).

At the southern end of the trench was a hard-packed layer of yellow sand [Unit 002] which rested on the clay [Unit 003], but rose relatively sharply to the south and entered the baulk. An extension of the trench revealed a preserved relict berm [Unit 011] below an additional layer of sand [Unit 016]. The berm was a hard packed mound of sand mixed with cobbles of clay and mottled sandstone which sloped to the south and disappeared into the baulk (Figure 133).

Beneath [Unit 011] was a very thin layer of windblown sand [Unit 012] which rested upon a hard layer, ca. 0.15 m thick, of alternating microlaminae of gray and yellow clay each ca. 1 mm thick [Unit 013]. Beneath was another layer of windblown sand [Unit 015]. The sand rested upon a berm [Unit 014] very similar to the local geological clay but which sloped southwards forming the bank of a channel. The berm had perhaps been formed from cutting of the geological layers to the south of the trench. The clay berm [Unit 014] was riddled with desiccation cracks and was encrusted with salts attesting to its submergence (Figure 122). A probe beneath [Unit 14] exposed the natural clay [Unit 003], confirming its geological origins, and revealed that the salts had penetrated ca. 0.10 m into its surface (Figure 124).[10] A late cut [004] running E-W along the northern preserved limit of the berms is probably attributable to late robbing or *sebbakh* hunting. The cut was not recognized immediately and may have contaminated the ceramic sample from some of the units below (Figures 135, 139).

Interpretation:

Trench FD 017 exposed a series of superimposed relict berms belonging to canal channels which now lie beneath the modern canal. It seems that the exposed edge of the geological clay [003] along the rim of the Fayum basin was cut and utilized as the north bank of a channel. Over time, debris from canal maintenance was piled on the north bank forming a berm [Unit 014] (Phase 1; Figures 133, 139). Following a period (Phase 2) of use or abandonment during which windblown sand accumulated [Unit 015], waterborne sediments were deposited above [Unit 013] (Phase 3). The layers continue over the earlier berm to the north, implying a wider channel (with a now missing northern berm) or a displacement of the channel in that direction.

Following another period (Phase 4) of windblown sand deposition [Unit 012] a new berm [Unit 011] was erected on top the earlier berms (Phase 5). That most of the berm is preserved in the trench implies that the channel was not as wide during this period or that it had moved to the south. The matrix contained numerous bedrock

[10] A powdery yellow stain was noted on the surface of [Unit 007]. Spectroscopy identified it as jarosite, which has been associated with biologically "dead" canals, but it may have been a natural occurence, see Hey and Anorov 2006.

cobbles, perhaps suggesting that additional cutting had taken place, either to deepen or widen the channel. Alternatively, the bedrock may have been cut from similar exposed strata to the north and used to erect a new, higher berm over a pre-existing channel. A long period of abandonment ensued with more than 1.0 m of windblown sand accumulation (Phase 6). A late E-W running cut [004] removed the northern part of all of the relict berms and may be associated with robbing seen in FD 020, 022, and 023 (Phase 7). Recently, the modern canal channel was cut and its debris is visible on the surface above the south baulk (Phase 8). It is not possible to establish a relative chronological relationship between Phases 7 and 8 (Figure 135). The fact that the bivalves commonly found in modern canal clean-out debris (Figure 140) are absent from the relict channels is a strong, but circumstantial, affirmation that all of the relict berms pre-date modifications to the irrigation system under Mohammed Ali (ruled 1805-48).

Fayum Desert 018

UTM Coordinates: 36R N29.31274 E30.54064
Elevation: -8.0 m BSL
Canal Name: None
References: None
Figures: 34, 121-4

Location and Description:

Trench FD 018 was excavated in a naturally occurring depression on the northwest side of the Cairo–Fayum highway between the ancient kom to the southeast and its cemetery to the northwest. A long, linear feature was visible in satellite imagery of the area and inspection on the ground revealed a well-defined berm ca. 0.40 m high in that location (Figures 120, 122). As Michigan's archaeological concession included this area, it was not examined by Caton-Thompson and Gardner during their study of the irrigation system, despite the fact that their Canal C was located only ca. 500 m to the north. The modern highway follows a natural depression between the kom and the low hills to the Northwest; as a local topographic low point, the area accumulates moisture today and there are many bushes and small plants lining the highway.

One fundamental question concerning the site of Karanis is the source of potable water. No ancient channel has been located leading directly into the kom, although the population was relatively substantial and a small bathhouse has been excavated on its northwestern slope.[11] A canal situated beside or under the modern highway could have brought water within 50 m of the bathhouse and could easily have been fed from the northeast where many of the canals identified by Caton-Thompson and Gardner must have originated. The objective of trench FD 018 was to explore visible features on that side of the kom in the hopes of identifying a canal serving the village.

Excavation:

Trench FD 018 was 25.0 m N-S x 3.5 m E-W and laid out perpendicular to the berm visible on the surface. A surface collection was made after removal of surface vegetation and garbage, but only diagnostic ceramics were kept. All of the sherds were badly abraded and many were encrusted with salts. Removal of the windblown sand comprising the topsoil [Unit 001] revealed a layer of very poorly indurated shale [Unit

[11] El-Nassery, Wagner, and Castel 1976.

002] which was so plastic that it could be molded by hand when wet. The intact geological bedding of the unit was clearly visible (Figure 123).

Near the midpoint of the trench, an east-west running, linear cut [Unit 003] ca. 0.50 m wide had been made in the clay and filled with windblown sand [Unit 004]. At the southern end of the trench was a second, similar cut [Unit 005] which had also been filled with windblown sand [Unit 006] (Figure 124). Consultation with local informants indicated the presence of one or more buried natural gas lines in the vicinity and excavation was halted.

Interpretation:

While trench FD 018 did not provide any evidence for the presence of an ancient canal, it did confirm that relatively small excavated features could be detected through careful examination of the satellite imagery. Most surprising was the relatively small volume of surface sherds given the proximity of the trench to both the kom and its cemetery. Indeed, the surface scatter surrounding ancient Karanis appears to taper-off within only ca. 50 m to the north and northwest of the ancient site.

Fayum Desert 019

UTM Coordinates: 36R N29.31297 E30.54169
Elevation: -3.0 m BSL
Canal Name: None
References: None
Figures: 34, 121, 125-8

Location and Description:

Like FD 018, trench FD 019 was excavated in order to investigate linear features visible in the desert on the north side of the kom at Karanis which may have served to bring water to that side of the village. Examination of the satellite imagery had revealed a roughly linear but intermittent series of features running roughly NE-SW on the gentle slope between the kom and the modern Cairo – Fayum highway. The vicinity of the trench was typical of the area with a deflated desert pavement on the surface but with a relatively high concentration of sherds and modern garbage. Two very low, parallel berms, ca. 0.30 m high, ran through the square from east to west ca. 10 m apart (Figure 125).

Excavation:

Trench FD 019 was 11.5 m N-S x 7.5 m E-W and laid out perpendicular to the berms visible on the surface. The topsoil [Unit 001] was composed of very loosely-packed sand and contained numerous ceramics, most of which were very abraded and encrusted with salts. Only diagnostic ceramics were kept. Beneath unit 001 was a more densely-packed layer of sand [Unit 002] which was removed only in a 3.0 m wide strip along the eastern edge of the square. Beneath [Unit 002] was a natural geological outcrop of mottled sandstone which rose slightly in elevation towards the south and was undoubtedly a part of the bedrock upon which the kom was initially established and identical to that exposed on the other side of the kom in trench FD 017(Figure 126).

At the southern end of the trench was a modern backhoe cut [Unit 004] ca. 0.50 m wide filled with windblown sand [Unit 005] (Figure 127). The cut was similar to that located in trench FD 018 and brushing of the sandy fill revealed a strip of yellow plastic tape printed with an Arabic message warning of a buried electrical cable (Figure 128). Were the backhoe cut to maintain its course, it would come within only a few meters of the northwestern corner of the site and could easily be breached by researchers investigating the so-called “city wall” or other nearby features. Excavation was halted and the location of the buried electrical cable was communicated to the local SCA inspector.

Interpretation:

No evidence for a canal or other hydraulic feature was identified in trench FD 019. A badly-worn road marker was located *in situ* ca. 15 m to the east of the trench and slightly upslope. It was ca. 0.31 m high x 0.20 m wide x 0.10 m deep and retained a light blue and a light pink horizontal band of paint on its lower surface beneath which were some lines in red paint which may be the traces of now-illegible writing. It seems reasonable to conclude that the marker was associated with the unpaved early-modern road known as the King’s Highway. However, if the berms near FD 019 were projected in a straight line to the east of the square, then the road marker would stand more than 15 m away from its course. For that reason, it seems possible that a series of roads followed slightly divergent paths through the area, but further excavation would be necessary to test this hypothesis.

Fayum Desert 020

UTM Coordinates: 36R N29.30859 E30.54041
Elevation: -19.0 m BSL
Canal Name: Canal J
References: None
Figures: 34, 120-1, 141-6

Location and Description:

Trench FD 020 (36R N29.30859 E30.54041, -19 m BSL) was laid out ca. 10 m to the west of FD 017 in an area where the berm of the modern canal extended far beyond its usual width. It was hoped that the relict berms identified in trench FD 017 would be well-preserved and that the channels could be penetrated to a greater distance (Figures 141-6). Trench FD 020 revealed the same superimposed layers of canal sediments and berms found in FD 017, but with a greater portion of the downward-sloping channel visible at the extreme south (Figures 143, 145).

Excavation:

Beneath the topsoil [Units 001, 003, 008] was another portion of the berm composed of clay-and-sandstone cobbles [Unit 002]. A layer of windblown sand [Unit 007] lay beneath, covering the laminated gray and yellow clay layer [Unit 005] seen in FD017. Here, the layer was ca. 0.25 m thick and depositional details could be discerned (Figure 144). There were three roughly equal alternating flood events: coarser yellow particles brought by a higher-energy flow were surmounted by finer gray particles from a low-energy flow in three clear repetitions. The layer of finer particles which fell out of deposition, presumably at the end of each flood season, had cracked from desiccation, as they were left exposed to the sun. The alternating yellow and gray laminae may be indicative of oxidizing and reducing environments associated with higher and lower velocity flows. Sediment samples were taken for OSL dating, but a large and stratified ceramic sample was also recovered from the trench.

Beneath the flood deposits was another thin layer of windblown sand [Unit 010] resting upon the salt-stained and cracked surface clay surface of the FD 017 Phase 1 channel previously identified in FD 017. All of the channels were preserved to a much greater penetration of the channel on the south side and a series of erosive features visible where the convex berm transitions to a concave channel are indicative of flow (Figure 143). Tentatively, they should be interpreted as the mean flow height for the channel.

A late cut [Unit 009] had been made running E-W in the trench at north and had disturbed the geological layers. It is possible that this cut was the source of geological material used for the construction of the most recent relict berm [Unit 002]. It may also have removed a more northerly berm which must have been associated with the yellow and gray flood deposits [Unit 005]. It seems possible that the entire concave depression (Figures 129, 131) on the south side of the kom is a massive robber pit which removed the northern berm of Phase 3 in FD 017 and FD 020.

Interpretation:

The phasing of FD 020 is the same as that given for FD 017 (above) and may be seen clearly in the baulks (Figures 142-3, 145). Only the eastern portion of each unit was removed allowing for a stepped view of the superimposed berm deposits (Figures 141, 143, 146). Given the slightly undulating face of the berms, no attempt was made to estimate channel depth on the basis of the slope visible in the trench.

Fayum Desert 021

UTM Coordinates: 36R N29 32.928 E30 51.170
Elevation: 5.0 m ASL
Canal Name: Canal K
References: None
Figures: 34-5, 116-18

Location and Description:

A pair of low parallel berms ca. 0.15 m high and ca. 1.0 m apart was identified running generally southeast to northwest to the north of Canal G (Figures 116-18). Designated Canal K, this alignment had been badly disrupted by surface clearance using a bulldozer, but could be traced for ca. 1.5 km. As it did not appear to be modern, a small trench was excavated to ascertain its dimensions.

Excavation:

A trench 0.5 m E-W x 1.0 m N-S was excavated at a point near the westernmost visible segment of the alignment. It revealed a shallow concave channel [Unit 002] ca. 0.50 m wide x 0.15 m deep beneath the topsoil [Unit 001] (Figure 118). No artifacts were recovered.

Interpretation:

The course of Canal K is broadly parallel to that of Canal G and mimics some of the turns made by the latter to follow the hillside. It seems unlikely that any modern channel or property division would do so. It is possible that Canal K may have served as a drain from the fields watered on the slope above by Canal G, If so, it led the excess water to the west and almost certainly attempted to enter the X-Basin at an elevation slightly below that of Canal G. However, it is possible that it could have been a separately-excavated channel intended to irrigate its own fields or proceed directly to the X-Basin.

Fayum Desert 022

UTM Coordinates: 36R N29.30996 E30.54391
Elevation: -18.0 m BSL
Canal Name: Canal J
References: None
Figures: 34, 120-1, 147-57

Location and Description:

Trench FD 022 was a further attempt to define the relict channels associated with a probable main canal alignment on the south side of the kom at Karanis which had been exposed in FD 017 and FD 020. The trench was situated ca. 650 m to the northeast of the latter trenches on the north side of the modern Bahr Wahbī just to the west of a small modern bridge across the canal (Figure 147). Preliminary inspection of the surface had discovered that the berm on the northern side of the modern canal bifurcated in the vicinity; part of the berm continued along the line of the modern channel, while an apparently separate berm continued to the northeast at an angle of circa 20°. This relict berm was preserved as a linear feature ca. 50 m long and ca. 1.0 – 2.0 m high and was covered with many very large bushes attesting to the rich sediments beneath (Figures 147-8).

Excavation:

Trench FD 022 was laid out 17.0 m N-S x 4.0 m E-W between the berm of the modern canal and the relict berm visible on the surface and perpendicular to the latter (Figure 149). The surface sediments [Unit 001] were thickest to the North where the bushes lining the relict berm had retained windblown sand forming a small dune. Removal of [Unit 001] revealed two berms at the northern end of the trench and a shallow E-W running channel in the southern end (Figure 150). The northernmost berm [Unit 002] was composed almost entirely of sand which had been built up on top of the northern side of the southern berm [Unit 006]. The saddle between the two peaks had been lined with a very thin layer of clay forming a late channel [Unit 003] ca. 1.0 m wide which ran E-W across the square (Figure 151). A dense deposit of sherds [Unit 007] rested upon the northern face of the berm and upon the mottled red-yellow-grey sandstone [Unit 004] typical of the area.

The southern berm [Unit 006] was ca. 2.0 m wide and 0.50 m high. To the south of the berm, hard-packed clay fill layers [Unit 005 and Unit 009] were found immediately below the surface. They filled the concave channel [Unit 008] which had been cut into the underlying layers of geological clay [Unit 010 and Unit 011] (Figures 152-3). A slight extension of the square to the south revealed a rising bottom of the cut indicating the opposite side of the channel (Figure 154-7). The channel was circa 4.0 m wide but only ca. 0.40 m deep. Cleaning of the southern baulk revealed another channel profile of similar dimensions [Unit 012] and identical fills, indicating an intersection between two channels at that point (Figure 154).

Interpretation:

Trench FD 022 identified a very narrow and shallow but complete relict channel and its well-preserved northern berm which had been excavated into geological layers (Phase 1). As the channel bottom could be seen to rise to the south, the southern berm of the relict channel must lie immediately beneath the northern berm of the modern canal. A remarkable stroke of luck preserved the profile of a second channel in the southern baulk indicating an intersection with another relict channel at that point. Given the constraints imposed by the modern canal it was not possible to determine with certainty which of the relict channels was a lateral alignment. However, it seems logical that the channel on the uphill (i.e. northern) side served as a lateral designed to divert water from the main canal and maintain its elevation. Both channels appear to have silted up and gone out of use (Phase 2). At some point after the construction of the first berm a second berm was added on its northern side (Phase 3) permitting the construction of a small lateral between them (Phase 4). Given that the lateral was on the north side of the channel, it may have served as a source of drinking water or for industrial applications, rather than as an irrigation channel.

A large amount of ceramic evidence, as well as some slag, was recovered from the square, particularly from the channel fills. The samples have not yet been analyzed and it is not possible to provide a date for the establishment of the channel. The very shallow depth of the channel and its position immediately below the surface imply a relatively late date. However, the rapid drop in elevation which is noticeable in the area today means that even if the same channels were identified in FD 017/FD 020 and FD 022, their relative elevations could differ dramatically.

The modern Bahr Wahbī follows a relatively gentle slope for most of its course along the northeast Fayum (Figure 4). Its surface elevation is ca. 25 m ASL at Hawara and drops to ca. 17 m ASL at Kom al-Kharabah al-Kebir (ancient Philadelphia), a distance of ca. 26 km.[12] It then descends to ca. 14 m ASL at Kom al-Atl (Bacchias), over a distance of ca. 12 km. It maintains this gentle gradient for another ca. 7 km until it begins a much steeper descent, passing Kom Aushim (Karanis) at ca. -18 m to reach the modern lake at ca. -47 m BSL. The sharp drop in the landscape begins ca. 3 km to the east of Karanis and a number of drop-structures have been installed along its course in order to facilitate its rapid descent without generating sufficient energy for the canal to breach its berms (Figures 158-60).[13]

A similar arrangement was probably necessary in antiquity. However, the steep drop in elevation which the modern and ancient canals undergo in the area creates a dynamic and unstable environment (Figure 160). Differing approaches to the problem of elevation combined with changes in the landscape since antiquity have caused the modern channel to diverge significantly from the line of the relict channel. This fact

[12] All elevations were obtained from canal height measurements indicated on the 1:50,000 topographic map series. Ancient elevations will have been similar, but not identical as the ancient canal was both wider and deeper. Distances are approximate.
[13] For the term "drop-structure", see Foster, Woodson, and Huckleberry 2002: 112 with additional references.

strongly indicates that the area east of Karanis would be the most profitable focus of further prospection and excavation in any attempt to locate and excavate a fully-preserved relict channel.

Fayum Desert 023

UTM Coordinates: 36R N29.30973 E30.54335
Elevation: -15.0 m BSL
Canal Name: Canal J
References: None
Figures: 34, 120-1, 161-6

Location and Description:

Another attempt to examine the series of relict channels on the south side of the kom at Karanis was undertaken in Trench FD 023. The trench was located ca. 100 m to the southwest of FD 022 in an area where a high elevation was maintained for nearly 10 m on the northern bank of the modern canal (Figure 161). In FD 020, a higher elevation was indicative of excellent berm preservation below and a similar pre-excavation surface in FD 023 implied another good exposure.

Excavation:

Trench FD 023 was laid out 23.0 m N-S x 2.5 m E-W on the north side of the modern Bahr Wahbī. Removal of the topsoil [Unit 001] revealed that the entire trench had undergone robbing on a massive scale. Even the geology below, a hard gray geological clay with many large white inclusions [Unit 003], had been cut to great depth throughout the square and numerous irregular, deep pits litter its bottom (Figures 162-3, 166). Modern plastic and garbage was recovered from more than 1.0 m beneath the surface. Nevertheless, excavation was conducted to bedrock in order to ascertain the date and nature of the robbing.

The entire trench was contaminated and no canal alignment could be positively identified, although remains of the Phase 1 berm of FD 017 and FD 020 may have been located in the south [Unit 014] (Figures 162, 164-5). This very recent robbing activity seems to have been designed to remove the geological clay which local informants report is desirable as an admixture in the nearby fields, but it is also possible that the primary objective was the robbing of the relict berms on the north side of the ancient canals for *sebbakh*, which could have implications for interpreting the topography and recent history of the site.

Interpretation:

No phasing was possible. However, if the clay deposit in the southern end of the trench was the remains of the Phase 1 berm known from FD 017 and FD 020, the other phases were no longer extant. Either they were robbed out, or the channels follow a more southerly course in the area.

Fayum Desert 024

UTM Coordinates: 36R N29.33325 E30.52800
Elevation: 10.0 m ASL
Canal Name: Canal E
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix, xci.
Figures: 5, 7, 9, 32-4, 36, 50-3

Location and Description:

On their map and section drawings (Figures 5-6), Caton-Thompson and Gardner indicated Canal E as the widest and largest of the channels at the western end of their irrigation system. At first glance, the large size of the channel indicates greater discharge. However, experience in the excavation of the Canal G alignment indicated that the size and depth of cuts could be related to maintaining slope. A trench was excavated across the Canal E alignment at the southern end of a large vacant lot in the village of Qarya Ula. The objective was to ascertain whether Canal E was a substantial distribution canal or merely a deep cut to maintain slope for a smaller channel.

Excavation:

Trench FD 024 was laid out 13.0 m NE-SW x 3.0 m NW-SE and perpendicular to the parallel bands of vegetation visible on the surface. Removal of the topsoil [Unit 001], which was composed of hard and compacted debris from recent bulldozing in the area, revealed geological shale to the west [Unit 004] and to the east [Unit 005]. The relict channel [Unit 003], varying in width between ca. 7.0-7.5 m, was clearly visible as a line of windblown sand fill [Unit 002] running from southeast to northwest. The unexpected depth of the trench (ca. 3.0 m) resulted in serious danger of baulk collapse and made excavation of the windblown fills treacherous. They were removed rapidly in arbitrary spits ([Unit 002]/[Unit 006]/[Unit 007]/[Unit 008]) and later phased based upon an examination of the baulks (Figure 53).

Interpretation:

The natural geological surface of the area, a white limestone (now missing) surmounting gypsum-rich marine shale, was cut to form a channel ca. 7.0 – 7.5 m wide (Phase 1). The channel initially had very steep sides and reached a depth of ca. 3.0 m, although the upper portions had been removed by later activity. At a later date the channel appears to have been deepened to a depth of ca. 4.0 m and a concave bottom excavated to the east of center (Phase 2). A period of abandonment may be indicated by a pocket of windblown sand identified under shale boulders which had eroded and collapsed into the channel from the eastern baulk (Phase 3).

Next, the entire channel appears to have filled with windblown sand, which is laminated in dozens of layers and bedded from the northwest (Phase 4). The windblown fill of the channel was cut by any an irregular, stepped trench ca. 3.4 m wide (phase 5) which ran from southeast to northwest and reused the eastern side of the Phase 1 channel. The lowest portion of this cut filled with windblown sand (phase 6) and a then hard but very thin layer of clay sediments covered it (Phase 7). This seems to imply use of this later feature as a small channel, which re-utilized the eastern side of the original channel. Another period of abandonment is indicated by the many laminated windblown deposits which again filled the channel (phase 8).

Another cut was made into these windblown deposits (Phase 9). This small concave cutting was also lined with fine clay sediments which appeared to be waterborne. Apparently the east side of the original channel was used once again to form a late, high-elevation channel. This final channel once again filled with windblown sand during a period of abandonment (Phase 10). In recent times the bedrock of the area was stripped off using mechanical excavators and the area was levelled for future construction (Phase 10), establishing a thick, hard cap of debris over the trench.

It appears that the canal E alignment went in and out of use intermittently. Initial deepening of the channel is indicative of a miscalculation involving slope, an adaptation to lower hydraulic head upstream, or an attempt to increase total discharge. The later channels (smaller, and at ever-higher elevations) attest to diminished volume and an attempt to maintain hydraulic head. While it is not yet possible to determine the length of each period of abandonment (but OSL samples were taken from the relevant sediments), it appears that windblown sand deposition was a greater problem than sediment deposition in the Canal E alignment. Canal E occupied an exposed position at the top of the limestone ridge and ran directly into the prevailing winds from the northwest and north. This may have increased the total maintenance required to maintain a channel of this size.

Fayum Desert 025

UTM Coordinates: 36R N29.33855 E30.52577
Elevation: 4.0 m ASL
Canal Name: Canal F
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix-xc.
Figures: 5, 6-8, 10, 36, 54-8

Location and Description:

While excavation was under way at FD 024 a local informant approached the team with information about a cave ca. 1.0 km to the north. The site lies ca. 450 m north of the modern village of Qarya Ula beside the main road on the eastern bank of the *Tira'at al-Jamhurriyah* (Figure 36). The tunnel is not visible from the modern road owing to the great number of broken bedrock slabs which have been piled up in the vicinity and would not have been located without assistance (Figure 54). A visit to the site, ca. 70 m east of the road, confirmed that this was the probable location of a tunnel located by Caton-Thompson and Gardner at the western end of the Canal F alignment.

Almost the entire Canal F alignment has been destroyed by farmers. Mechanical excavators have shattered the surface bedrock and piled it beside the road and along field boundaries in the vicinity as well as in lines above the roof of the tunnel (Figure 54). The tunnel itself is choked with sand and debris to within ca. 0.50 m of its roof (Figures 55-6). An access hole, ca. 0.75 m in diameter has been cut in the roof of the tunnel at its western end and this appears to have served in the past as an entry point for water. Most likely, water was moved by hand from the modern canal and dumped through the roof of the tunnel which was reused as a reservoir of some kind. A small portion of the tunnel mouth was exposed above the surface. It had obviously been used as a latrine and, according to local people, as a well-known locus of magical activity. The latter may explain the presence of many bottles and cans, bones, and other detritus inside the tunnel mouth.

Caton-Thompson and Gardner reported that the Canal F alignment in the area was 6 feet deep and 10 1/2 feet wide. Stone cut steps were preserved on the north side of the channel interior to the East of the tunnel. The tunnel had an interior width between 6'3" and 6'9" and the height between 5'8" and 6 feet leaving the limestone roof 17 inches thick. It ran underground for a total distance of 112 feet before re-emerging as an open channel for another 23 feet before terminated in a vertical face which had been drilled in preparation for further excavation. The open western section of Canal F was probably destroyed by the modern canal alignment.

Excavation:

Excavation of FD 025 was conducted by Mr. Jurgen Van Oostenrijk. The objective was to expose the entire channel profile for re-drawing in comparison with the report of Caton-Thompson and Gardner. However, as Caton-Thompson and Gardner had emptied the entire length of the tunnel, its current fill was unquestionably modern and the work was treated as a cleaning operation rather than a thorough excavation.

Excavation of a trench 3.0 m N-S x 2.0 m E-W and perpendicular to the tunnel mouth exposed the channel ca. 3.05 m wide with vertical sides cut into the shelly limestone bedrock and the shale beneath. At a depth of only ca. 1.25 m the trench filled with ground water (Figures 57-8). It seems that the proximity of the modern canal to the west and constant irrigation of crops to the east has raised the water table in the area significantly.[14] As excavation of a waterlogged environment would have required

[14] A Common problem throughout Egypt, see Attia 1989.

substantially more time and resources with little prospect of a significant result, the excavation was abandoned.

Interpretation:

There is no question that trench FD 025 exposed the mouth of the tunnel recorded along the Canal F alignment by Caton-Thompson and Gardner. As a result of their investigation, they believed that the Canal F tunnel had not been completed but that its objective had been to link the K-Basin with the L-Basin. This seems a strange interpretation. As the Canal E alignment ran SE-NW only a few hundred meters to the west, it seems more likely that the objective was to irrigate all or part of the western slopes of the K-Basin from Canal E. However, this interpretation assumes that Canal E and Canal F were contemporary. If the alignment was not finished, it seems probable that the western slopes of the K-Basin were not irrigated, except perhaps by other laterals from the Canal E alignment.[15]

Fayum Desert 026

UTM Coordinates: 36R N29.33839 E30.52702
Elevation: 12.0 m ASL
Canal Name: Canal F
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii, lxxxix-xc.
Figures: 5, 6-8, 10, 34, 36, 59-60

[15] Such as the small tunnel designated on Caton-Thompson and Gardner’s map as E-I (Figure 5).

Location and Description:

An angular cut in an outcropping of exposed bedrock was located amid the modern fields ca. 200 m to the east of FD 025 (Figure 59). The outcrop is used today as a threshing floor and has been disturbed by various associated activities. As the sharply cut interior corner of abandoned was visible on the surface, it seemed probable that the feature was the remains of the eastern end of the Canal F alignment identified by Caton-Thompson and Gardner.

Excavation:

As the soil in the cut was very shallow and badly disturbed, no formal trench was laid out. Instead, a brief cleaning operation was undertaken by Mr. Jurgen Van Oostenrijk. Between 0.01 and 0.10 m of sand, manure and threshing remains were removed from the channel which had been cut into the sandy white limestone typical of the area. The channel was revealed to be ca. 3.20 m wide. It ran to the northwest for a distance of ca. 2.4 m before turning due west for ca. 3.1 m towards FD 025. The sides of the channel were preserved to a height of ca. 0.38-0.48 m, but any associated berms had been destroyed (Figure 60).

Interpretation:

There is little doubt that the channel examined the by FD 026 belong to the eastern portion of the Canal F alignment identified by Caton-Thompson and Gardner. However, their general plan shows a bend to the southeast at the eastern end of Canal F whereas the band visible in FD 026 turns to the northwest. Either a slight error was made in the composition of their plan or the rediscovered portion is a localized variation in the alignment which could not be illustrated at a scale of 1:50,000. It seems less probable that a new segment of the alignment has been located. The portions of the channel intervening between FD 025 and FD 026 have been completely destroyed by the local farmers who shattered and removed the bedrock in order to access the fertile sediments below. However, a narrow, modern irrigation channel follows most of the original line to the west.

Fayum Desert 027

UTM Coordinates: 36R N29.31665 E30.53899
Elevation: 11.0 ± 3.0 m ASL
Canal Name: Canal C
References: Caton-Thompson and Gardner 1934: 142-5, Figures lxxxvii-lxxxviii.
Figures: 34, 40-6

Location and Description:

Modern activity, including quarrying and an extension of the village of Qarya Thalatha, have severely disturbed the landscape (Figure 40) and locating the Canal C alignment proved difficult. A bend in a nearby road (Figure 41) appeared to mimic a similar bend on Caton-Thompson and Gardner’s map (Figure 5), but no relationship could be established. Trench FD 027 was laid out to examine a possible section of the Canal C alignment to the north of the Karanis cemetery where berms ca. 0.50-0.75 m high could be seen to either side of a concave depression (Figure 42).

Excavation:

Trench FD 027 was laid out N-S x 3.0 m E-W perpendicular to the line of the berms. A few sherds were recovered from the surface. Removal of the surface sand [Unit 001] recovered several ceramics and revealed a second layer of sand and desert pavement below [Unit 002]. The latter rested on the mottled sandstone bedrock [Unit 003]. The concave channel [Unit 004] was ca. 2.55 m wide and sloped sharply to the west (0.08 m over 3.0 m). The berms were natural high points in the bedrock between which the channel had been cut (Figures 43-5).

Interpretation:

The channel preserved in FD 027 is almost certain to be the Canal C alignment identified by Caton-Thompson and Gardner. They indicated a greater concentration of sherds along Canal C and its presumed line of continuation towards Canal A. The greater volume of sherds is undoubtedly related to the proximity of Karanis to the south. The banks of canals are often loci of human activity, for domestic chores, fetching water, and cool shade bordering fields. It seems that a great deal of activity took place along the Canal A alignment.

Appendix 2: Small Rural Sites Relocated Near Karanis, Egypt, 2007-8

As part of the process of re-locating the irrigation system identified by Caton-Thompson and Gardner in 1927-8, a concerted effort was made to re-identify several small rural sites indicated on their map of the irrigation system (Figure 5).[1] In most cases, no additional information about the sites was given beyond their identification on the map and only their general position could be determined. However, the sites held enormous potential both for dating the occupation of the hinterland north of Karanis and for reconciling their map of the irrigation system with the modern landscape. The search for the sites seemed an acceptable commitment of time and resources and, as a result, five of the sites were certainly or tentatively re-located during the course of the 2007 and 2008 field seasons: the “Ptolemaic Houses” at the western end of the irrigation system; the “Roman Gebel”, which seems to be exclusively a necropolis; the “Ptolemaic Settlement” at the northern end of the L-Basin; the “Reservoir”/“Well” in the K-Basin; and a group of “Roman Houses” at the eastern end of the irrigation system (Figure 167).

[1] The precise reasoning is explained in Chapter 5, *Survey Methodology*.

Catalogue of Sites

The sites are presented below in geographical order from west to east. The following format is used in the catalogue:

Site Name: Each previously-identified site is referred to by the terminology used to describe it on the 1:50,000 topographic map produced by Caton-Thompson and Gardner in their pioneering study of the hydraulic system (1934: 140-53 and Fig. lxxxvii; reproduced as Figure 5).

UTM Coordinates: Universal Transverse Mercator (UTM) coordinates were obtained using a Garmin 76sx handheld Geographical Positioning System (GPS). Current accuracy of the device is estimated at ± 4m, but clear desert visibility and the removal of Selective Availability restrictions by the United States Government have made greater accuracy possible. Readings are given in standard UTM order of Geographical Zone identifier, followed by a seven digit northing and a seven digit easting (e.g. 36R 1234567, 8901234). All locations presented below are visible on the Egyptian Series 1:50,000 *Kawm Ūshīm* (NH36-E5b) map sheet published in 1995 by the Irrigation Management Systems Project, Surveying and Mapping Component, in conjunction with the Egyptian General Survey Authority. Unfortunately, the 1:50,000 map series provides 1 m contour lines in cultivated areas, but only 10 m contour intervals in the desert, limiting its usefulness in certain locations.

Elevation: Absolute elevation is recorded in meters (m) Above Sea Level (ASL) or Below Sea Level (BSL). While elevation is the least accurate of the three spatial measurements recorded by handheld GPS units, the unobstructed satellite visibility provided by desert conditions and the use of "averaging" (the automated calculation and averaging of dozens of readings over several minutes) brought elevations to within a few metres accuracy for selected locations. Each elevation is presented with the accuracy reported by the unit (e.g. 45 ± 3 m ASL).

References: All references are to Caton-Thompson and Gardner *The Desert Fayum* (1934).

Figures: References are made to the relevant Figures accompanying this report.

Location and Description: Each entry includes a discussion of the size, location, orientation, and preservation of the site. No attempt has been made to convert the imperial measurements made by Caton-Thompson and Gardner to the Metric System.

"Ptolemaic Houses"

UTM Coordinates: 36R N29.0897, E032.7146636R
Elevation: 3.0 m ASL
References: Caton-Thompson and Gardner 1934: 141, 145-9, Plate lxxxvii.
Figures: 5, 11-18, 167-72

Location and Description:

Caton-Thompson and Gardner discovered a series of low mounds built on a limestone outcrop on the south side of the Canal G alignment (Figure 5): "The group of houses consisted of six separate mounds, five of which lay close to each other, the most southerly being about 100 yards from Canal G. towards its westerly end, while the sixth bordered closely on it."[2] The houses were excavated by Captain Gardner and are accorded their own section in the publication.

The houses were constructed of mudbrick, stone, or a mixture of both and varied considerably in size (Figures 11-12). Numerous ceramics were recovered as were stone and wooden artifacts, baskets, and organic remains, including beans (Figures 13-18). Eleven coins of Ptolemy II were recovered from various contexts, providing a *terminus post quem* for occupation of the houses which Caton-Thompson and Gardner believed to be very brief. It is odd, however, that "Old-Kingdom flints" were reported from House 2. Three houses and a "store-room" are reported in the text, although six mounds were mentioned, an apparent discrepancy of two mounds.

While attempting to locate missing sections of the Canal G alignment, the author located several large ceramic scatters on the south side of the channel beside a recent quarry cut (Figures 168-9). In fact, dozens of ceramics, including intact and virtually intact vessels, were bulldozed into giant heaps beside the cut as part of the preliminary preparation for commercial exploitation of the geological strata below (Figures 170-2). It seems that the limestone ridge upon which the houses were located was targeted specifically, as there is a large bay in the quarry which has removed a substantial but specific area and part of Canal G (Figure 168). No limestone outcrop is visible today and the houses appear to have been completely destroyed. The presence of so many well-

[2] Caton-Thompson and Gardner 1934: 145.

preserved ceramics and stone artifacts is a mystery considering the “thorough” nature of most early 20th century archaeologists. It is possible that they derive from structures unnoticed by Caton-Thompson and Gardner, or from the two mounds which seem to have been omitted from the text.

The date of the structures is problematic. While many of the published vessels appear plausibly Ptolemaic, almost all of the ceramics are red and some of the carinated red-wares recovered from the surface by the author are more indicative of a later date. A cooking pot from the nearby trench FD 014 appears to date to the late first century BCE or early first century CE (Figure 95).[3] Careful re-examination of the published ceramics, many of which are scattered in small British museums, and the newly acquired surface sample may extend the occupation of the houses over a longer period.

“Roman Gebel”

UTM Coordinates: 36R N29.2274 E32.74436
Elevation: 23.0 m ASL
References: Caton-Thompson and Gardner 1934: 158, Plates lxxxvii; xcviii, 8-15; cvi,2.
Figures: 5, 167, 179-81

Location and Description:

Caton-Thompson and Gardner indicated a “Roman Gebel” on their map of the irrigation system, but only brief mention of it is made in the published text (Figure 5). The name is particularly interesting as no other site in the central or western portions of the survey

[3] See also Chapter 5 and Appendix 1.

area is identified as Roman; in addition, the site is the most northerly on their map and one of the most northerly in the entire Fayum.

Caton-Thompson and Gardner excavated a single rock-cut tomb at the site. The tomb had a sloping dromos ca. 5’ 6” long x 2’ 9” wide that led into an oblong central chamber. A series of eight apsidal loculi had been carved into the sides of the main chamber and separated from it by mud-brick walls. Each of the loculi had been robbed, but several whole vessels and plaster fragments remained in the debris.

The Roman Gebel was easily located on the only rocky prominence to the north of the L-Basin. The three exposed sandstone peaks are only a few meters high, but are visible for many kilometres (Figure 179). As a result of its remote location, the site has been robbed repeatedly. In some cases it was literally possible to discern robber pits inside robber pits. The sides of the gebels are riddled with tombs cut into the sandstone, and perhaps as many as thirty are visible immediately (Figures 180-1). In addition, robber pits in the desert surface below the peaks seem to have disturbed numerous human burials; the entire area may be riddled with them. The site seems to be exclusively a cemetery; no evidence of habitation is evident.

The site is something of an enigma. It is clearly the cemetery of a substantial settlement, but the only known site in the area is the “Ptolemaic Settlement” to the south (see below). It is not clear what led Caton-Thompson and Gardner to identify one site as Roman and the other as Ptolemaic, but either the settlement has a longer occupation history than they thought, or there is an as yet unknown site further to the southeast (near the X-Basin) or southwest (bordering the northern end of the K-Basin).

The site is under immediate threat and action should be taken. The massive agricultural expansion project in the area has superimposed a canal system and accompanying road network over the surrounding landscape. There is a major canal and pumping station just to the north of the site. An access road has been bulldozed between the westernmost peaks, damaging some (already disturbed?) burials and bringing the site to the attention of a wider audience. Without intervention, the site will likely succumb to the development project.

"Ptolemaic Settlement"

UTM Coordinates: 36R N29.2772 E32.73348
Elevation: 16.0 m ASL
References: Caton-Thompson and Gardner 1934: Plate lxxxvii.
Figures: 5, 167, 173-8

Location and Description:

The so-called "Ptolemaic Settlement" must be the most mysterious site in the survey zone (Figure 5, 167). Caton-Thompson and Gardner do not discuss it in their text, choosing instead to focus their attention on a nearby "Dyanasty IV Kom", but it must have been substantial;[4] the six mounds near the Canal G alignment did not merit the term "settlement". As noted above, the "Roman Gebel" is a cemetery and the only known site it could have served is the "Ptolemaic Settlement". If so, the many burials there substantiate the size of the community. It is surprising that such an important rural habitation site has escaped further scholarly attention.

[4] "Kom IV" is discussed in some detail by Caton-Thompson and Gardner (1934: 97-101 and liv-lv) as the site's *in situ*, stratified artifacts permitted them to associate conclusively certain stone tools noted elsewhere in the survey area with their contemporary ceramic forms and establish a dynastic date.

Equally curious is the fact that this site of apparently significant size is the only one in the survey zone which is not in immediate proximity to a canal or other source of water. The Canal E alignment seems to aim directly at the settlement for most of its length as depicted on the plan of the irrigation system, but the alignment turns sharply to the west ca. 1 km away from the site (Figure 5). It would be impossible for a habitation site to remain viable without a closer source of fresh water, so an additional branch of the irrigation system must have existed in antiquity. The author walked several north-south transects along the side of the ridge at the site and farther to the east in hopes of finding a canal alignment to feed the site from a higher elevation with a source at or near the Canal B channel, but none could be located.

The site was rediscovered in a quarry at the northern end of the L-Basin (Figure 173), where it is preserved as a series of strata resting on limestone bedrock (Figure 174). The layers above are filled with sand, modern garbage, and construction debris, perhaps deriving from the abandoned military installation to the northwest (Figure 175). They appear to have been built-up in order to form a level surface for agricultural development. The ancient strata dip sharply to the west and it is possible that they are only slump or debris which has eroded from further to the east. Decomposed mudbrick and ceramics are abundant, but also organic matter such as fish bone and chaff (Figure 176-7). The preservation is undoubtedly the result of desiccation until very recent times, raising the possibility that the site may yet preserve papyri, although irrigation has begun in the vicinity. A large black and gray stain on the desert pavement ca. 50 m to the west may indicate an extension of the site in that direction (Figure 178).

“Ptolemaic Houses” or “Reservoir”

UTM Coordinates: 36R N29.4826 E32.71835
Elevation: 0 m ASL
References: Caton-Thompson and Gardner 1934: 141, 143, 149-50, Plate lxxxvii.
Figures: 5, 167, 182-3

Location and Description:

Caton-Thompson and Gardner make no reference to the “Ptolemaic House(s?)” indicated just to the east of the Canal E alignment. The reservoir to the northeast of the houses (labelled as a “well” on the map) was excavated by Miss Gardner’s brother, Captain Gardner. The reservoir was a massive feature constructed of carefully-fitted blocks of local sandstone and bonded with a mud and chaff mortar. The nearly-circular plan was ca. 24 feet wide at the top, ca. 20 feet wide at the bottom, and ca. 33 feet deep. The walls were found to be ca. 2 feet thick, with 161/2 feet of packing behind at the surface. Caton-Thompson and Gardner estimated the maximum capacity of the reservoir at 86,000 gallons.

The interior of the reservoir was filled with windblown sand to a great depth. Some lower layers of sand included vine trimmings, indicating grape cultivation in the vicinity at some time after the abandonment of the feature. A thick layer of silt covered the geological sandstone floor. In the silt were numerous vessels including the remains of ca. 15 *qawadys*, the oddly shaped vessels used to lift water when attached to the ropes of a *saqqiya* or bucket-chain. The vessels are virtually useless for any other function and convincingly demonstrate the presence of a water-lifting device at the site. The reservoir was dated by a single coin of Ptolemy II Philadelphos recovered near a series of hearths in a quarry (the presumed source of the sandstone for the reservoir) 150 yards to the east.

The reservoir and houses in the L-Basin were the least easily re-located sites. There is now intensive farming in the area and there has been considerable terracing activity. Visits to the K-Basin were infrequent owing to the proximity of the Kom Aushim airbase. However, a careful inspection of the area was conducted once the positions of the Canal E and Canal F alignments had been established securely. A farmer reported a mudbrick feature which had been cut by a drainage ditch ca. 400 m northeast of trench FD 024 in Qarya Ula (Figure 182). The decomposed remains of probable mudbricks and some large stones were visible (Figure 183), but the hostility of some local landowners prevented further investigation. As no mudbrick was reported in or near the reservoir, it may be more likely that this location preserves part of the "Ptolemaic Houses".[5]

"Roman Houses"

UTM Coordinates: 36R N29.9532, E032.69622
Elevation: 8.0 m ASL
References: Caton-Thompson and Gardner 1934: Plate lxxxvii.
Figures: 5, 37-8, 167, 184-7

Location and Description:

Two groups of "Roman Houses" are illustrated on Caton-Thompson's and Gardner's map, one to the east and one to the west of the southern end of the Canal A alignment (Figure 5). Neither is mentioned in the text. While conducting an examination of the

[5] But all of the locations are somewhat difficult to establish. The reservoir is reported in the text as 50 yards south of canal F, but is shown on the plan closer to 500 yards distant.

area for traces of Canal A alignment, local informants reported a site with many sherds south of Izbet Ashūr (Figure 37, 167).

A visit to the area identified a massive sand dune more than 100 m long and 50 m wide amidst the fields on the west side of the modern Masraf Azzam (Figures 38, 184-5). The entire surface of the dune, which is higher to the north and seems to have been truncated, is littered with mudbrick fragments and ceramics (Figure 187). No clear plan could be discerned, but the sand on the upper surface is higher in several linear paths, suggesting the preservation of walls below. An area at the southern end of the dune has been used as a threshing floor and chaff and manure have built up in several areas obscuring visibility, but numerous cuts in the site could be seen in the exposed section there (Figure 186).

On the west side, mudbrick walls protrude from the dune where an SCA excavation was conducted at some time in the past. A local landowner suggested that they had found a well lined with fired brick. A regional SCA inspector claimed that the deed to the site had once belonged to the SCA but had been given up recently and that it dated to the Islamic period. The claim of recent abandonment appears credible, as the SCA has been under considerable pressure to release land for development. It is unlikely that the site would have remained untouched for so long without some sort of legal protection, particularly during major programs of agricultural expansion in the 1960s-1980s.

The site at Izbet Ashūr is probably the remaining portion of the “Roman Houses” identified by Caton-Thompson and Gardner on the west side of the Canal A alignment. If so, the eastern set of houses should lie at or near a ridge some 500 m to the east, but the area has been heavily terraced and no trace of them could be found.

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