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Pests in an ancient Egyptian harbor

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ABSTRACT

Our investigations combine detailed identification and interpretation of plant remains and associated fauna and their mode of arrival in one of the rock-cut galleries, Cave 3, at the site of Mersa/Wadi Gawasis on Egypt's Red Sea coast. The site served as a staging area and harbor from which Middle Kingdom pharaohs launched seafaring expeditions to the land of Punt in the early second millennium BC. Quantities of wood, including ship timbers, fastenings, debris related to ship dismantling and reworking, and charcoal were excavated and analyzed. Evidence of marine mollusk infestation (shipworm) was abundant in Cave 3, as were the remains of insect pests of stored foods. We also report on a unique find of a plaster "spill" that preserved the floor of Cave 3 as it was when people worked in the gallery ca. 3800 years ago. The plaster spill created a sealed deposit of plant and insect remains with a diagnostic ceramic fragment, allowing us to securely associate insect remains and "hollow" spikelets of emmer wheat (*Triticum dicoccum*) recovered from the gallery. An impression of the beetle *Trachyderma hispida* and its associated exoskeleton fragments provide new evidence of this species as a potential pest not yet reported from an archaeological grain storage site in Egypt. The finding of *Tenebroides mauritanicus* from the same deposit is the earliest known association of this pest with stored grains. These unique finds shed new light on the risks associated with preserving food supplies, combating pest infestation, and dealing with marine organisms on land and at sea in the pharaonic harbor.

1. Introduction

Storing and transportation of food supplies is often associated with transportation of insects, many of which become pests. Plant remains and associated insects have been reported from several archaeological sites in Egypt (cf. Panagiotakopulu, 2001) and from shipwreck sites elsewhere (Haldane, 1991; Smith et al., 1995) but not yet from a government-run harbor complex that served as an arsenal and storage facility in an ancient Egyptian harbor. Even when insects are found directly associated with stored crops, it is often impossible to prove that the insects found in a site were contemporary with human use of the site (cf. Kislev, 1991, 1992; Panagiotakopulu, 1998, 2001; Simchoni and Kislev, 2009; Valamoti and Buckland, 1995).

In this paper, we report an investigation of plant and some invertebrate faunal remains from one of the rock-cut galleries at the site of Mersa/Wadi Gawasis, the ancient Red Sea harbor of *Saww* in Egypt, dating to the first quarter of the second millennium BC (Bard and Fattovich, 2007). Gawasis is an ancient port site, ca. 23 km south of the modern port of Safaga (Fig. 1). From this ancient harbor, state-organized seafaring expeditions set out on ca. 1800 km roundtrip voyages to the land of Punt (the southern region of the Red Sea, including the Horn of Africa) and returned with exotic products such as gold, incense, ebony, ivory, plants, and wild animals (Boivin and Fuller, 2009; Kitchen, 1993; Shaw and Nicholson, 1995).

2. History of research

During the past nine fieldwork seasons (2001–2010), led by Kathryn Bard and Rodolfo Fattovich, six human-made galleries and two rock-cut chambers (referred to as caves) were discovered in a fossil coral reef terrace ca. 700 m inland of the present-day sea shore (Fig. 2). A lagoon once connected the terrace area with the sea, but to reach the harbor in antiquity, teams of men and animals had to carry all necessary equipment and supplies ca. 150 km from the Nile Valley, through wadis across the Eastern Desert to the site. An inscription on a stone monument at the site documents 3756 men

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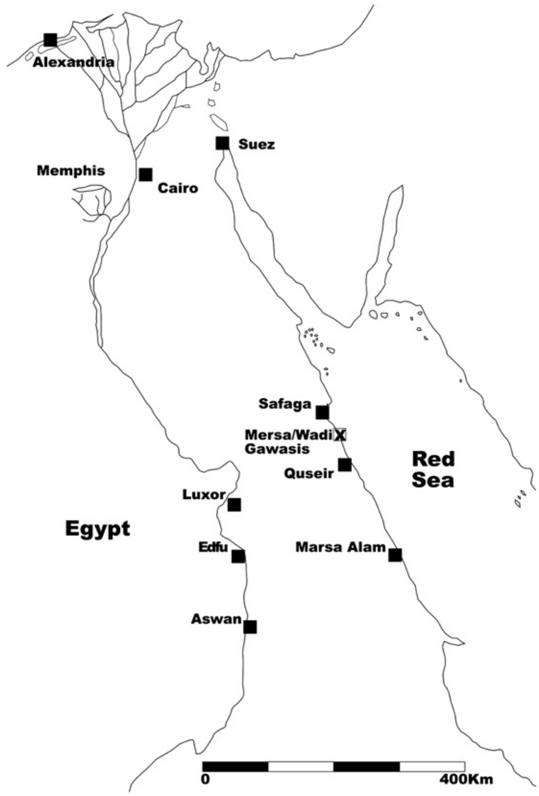

Fig. 1. Map of Egypt showing Mersa Gawasis site on the Red Sea.

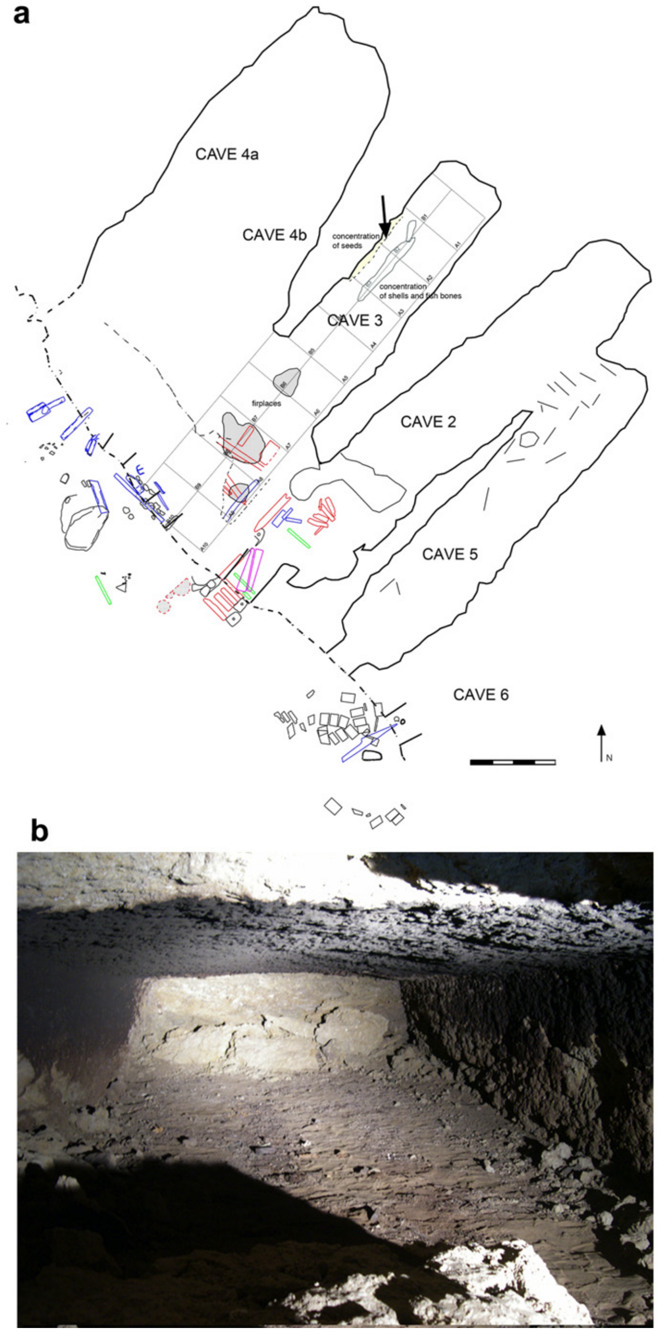

Fig. 2. View of Cave 3. (a) Plan view of the galleries, showing units and features in Cave 3; (b) Interior of Cave 3.

who conducted the work of an expedition that built ships on the Nile, transported them to *Saww*, and reassembled them for a journey to Punt (Sayed, 1978, 1999).

At Gawasis, excavators uncovered ship timbers and associated wood debitage, wooden cargo boxes, inscribed limestone stelae (slabs), ceramics and clay sealings (several with inscriptions), ration bowls, and limestone anchors in front of gallery entrances (Bard and Fattovich, 2007; Ward and Zazzaro, 2010). Two cargo boxes left there from an expedition of Amenemhet IV (ca. 1786–1777 BC) had hieroglyphic inscriptions describing their contents, “the wonderful things of Punt.” More limestone stelae were located in niches carved above the cave entrances. The stelae have hieroglyphic inscriptions bearing royal names of the Middle Kingdom kings Senusret II, Senusret III, Amenemhet III (ca.1877–1786 BC). The most recent archeological finds are ceramics of the early New Kingdom, ca. 1500 BC, found in the entrance of Cave 2 (Perlingieri, 2007). Finds in the galleries identify them as areas for living, working, and storage. Entrances to the galleries were originally sealed and subsequently covered with windblown sand accumulated after the abandonment of the site. Bard and Fattovich (2007) discovered the first gallery in 2004, and excavations continue for a few weeks each year. Below the galleries in the coral terrace was a production area with hearths, ceramic vessels, conical bread molds, platters, and numerous sherds along with charred grains of emmer and barley (Bard and Fattovich, 2007; Bard et al., 2007).

The eight Cave excavated to date served as storage facilities and work areas and extraordinarily well preserved, desiccated organic material was recovered from them, including cedar ship timbers, coils of rope, linen and cordage fragments, emmer spikelets, plant brushes, and insect remains (Fig. 2). Food processing may be indicated by finds such as the saddle querns found in Cave 1 and 2 that may have been used for milling grain into flour. Excavations in Cave 3 while the first author (K.B.) was present on site provided the opportunity for extensive sampling of sediments for botanical remains. The results of those studies are presented here.

3. Materials and methods

Visible plant remains were gathered during the excavation of Cave 3 (Fig. 2) and from the areas outside the galleries during the 2006–2007 season for investigations of macro botanical remains, wood, and charcoal. The excavations in Cave 3 were carried out by C.Z. and Claire Calcagno, and plant material was retrieved by the fourth author (C.Z.). A trench 22 m × 4 m (WG 39), divided into 2 m × 2 m squares was placed in Cave 3 (Fig. 2). Although the floor was not investigated completely, the average height in the innermost

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Table 1
Plant macro remains, insect, and coprolite finds from archaeobotanical samples from Cave 3 (all material desiccated, unless otherwise indicated).

Cave 3 (squares/units)	A1 SU 1	A2 SU1	B2	B2 SU 8	B3	SU 1	A3	Total
Context	Cave floor		Surface	Cave floor	Surface	Cave floor		
Hand picked (hp)/Soil volume (ml)	hp	hp	hp	300 ml	Plaster floor impression	hp	hp	
Emmer (*Triticum dicoccum*) spikelets				45	several	8		53
Cereal grain fragments (charred)				2				2
Salt tree (*Nitraria retusa*) seeds	1					8		9
Doum palm (*Hyphaene thebaica)* fruit	1							1
Papyrus (*Cyperus papyrus*) rope fragments	2		2					4
Plant (monocotyledon) “brushes”				3				3
Twig			1					1
Cedar (*Cedrus libani*) wood chips					several	1		1
Insect remains (various)		3	7	several	1		3	14
Sheep/goat (ovicaprine) coprolites		17	25				3	45
Total finds	4	20	35	50	1	17	6	133

part of the cave was estimated at ca. 1.80–1.60 m. In the squares closest to the entrance, three hearths were excavated. A concentration of fish bones and shells, along with substantial numbers of wood fastenings and other wood debitage fragments from ship components marked the center of the trench. Along the western wall in squares B2 and B3, a shallow concentration of wheat spikelets, seeds and insects was found. A deposit (spill) of white plaster ca. 15 cm in diameter was also recovered from the same area (Fig. 2a, Table 1).

3.1. Plant macro remains

From Cave 3, seven samples were hand picked by the excavators and one sediment sample (300 ml) was collected that included the plaster deposit (Table 1). Sediment samples were dry sieved using four geological sieves (mesh aperture 0.25–2.00 mm). The identification of plant macro remains was based on identification of their morphological characteristics using a binocular microscope at the site and later from the photographs taken during the analysis. Plant macro remains were preserved as desiccated or charred (carbonized) and were analyzed on site by the first author (K.B.), separately from the wood and charcoal remains analyzed by the third author (R.G.). Ship components, wood debitage, and the likely sea fauna were investigated by the fifth author (C.W.).

3.2. Insect remains

Insect remains were retrieved from sediment samples (initially collected for the analysis of plant macro remains) by dry sieving (Tables 1 and 2). Representative specimens were photographed and later identified by the second author (W.E.S.) based on comparisons with recent identified museum specimens and taxonomic literature.

3.3. Wood and charcoal

Wood and charcoal samples were collected separately from the plant macro remains. They were hand picked and retrieved by dry sieving of the sediment by the excavators in Cave 3 (Table 3). The timber and wood were very well to well preserved, dry, hard and strong. Parts of some ship timbers and complete deck planks were incorporated into the gallery to stabilize the gallery floor and reinforce entrances and walkways. The wood anatomical examination was carried out by the third author (R.G.) using a binocular and a high power reflected light microscope at the site. The charcoal was fractured manually or, more often, already existing breaks were used. The wood structure was observed in the three anatomical planes: transverse, tangential, and radial. Charcoal pieces of each taxon were counted and their volume and weight were recorded. Ship timbers were documented by dimensions, fastenings and wood condition. Debitage from activities related to cleaning ship timbers was documented by dimensions, weight and presence/absence of marine borer infestation.

Table 2
Indentified insect specimens retrieved from archaeobotanical samples from Cave 3.

Taxa	
Trachyderma hispida (Forskål)	paired elytra, head capsules of darkling beetle
Tenebroides mauritanicus (L.)	broken corps of cosmopolitan grain pest
cf. *Mesostena* sp.	fused elytra of a tenebrionid beetle
Muscidae, Calliphoridae, or Sarcophagidae	fly puparium
Sphecidae	cocoon mud wasp

Table 3
Wood and charcoal remains and debitage with shipworm infestation from Cave 3.

Wood taxa	Presence [in number of samples]	Count [pieces]	Volume [ml]	Weight [g]	
Acacia nilotica	28	426	5179.7	3238.3	
Acacia sp.	1	1	6	4	
Avicennia marina	4	5	35.1	31.6	
Cedrus libani	13	99	572.7	241.7	
Ficus sycomorus	9	22	125.4	45.2	
Quercus sp., deciduous	12	58	485.2	299.3	
Rhizophora/Bruguiera	1	1	3.6	1.8	
Suaeda sp.	1	1	0.5	0.2	
Total charcoal	33	613	6408.2	3862.1	
					Shipworm infestation [pieces]
Acacia nilotica	5	255		521.7	46
Cedrus libani	7	919		1542.3	318
Ficus sycomorus	3	14		63.4	0
Total wood debris	7	1188		2127.4	364
Acacia nilotica		3			
Cedrus libani		8			
Ficus sycomorus		1			
Quercus sp., deciduous		1			
Total timbers (planks, beams, poles, block)		13			
Acacia nilotica		17			
Total fastenings (dovetail and tongue tenons)		17			
Total wood pieces		1831			

Fig. 3. Group of plant remains from archaeobotanical samples from Cave 3. Plant brushes (left); emmer spikeletes (center); chips of cedar wood (right).

4. Results

4.1. Plant macro remains

Due to the dry conditions, most of the plant material from Cave 3 was extraordinarily well preserved, i.e., desiccated (Fig. 3). Several taxa of plant and insect material were retrieved from seven collected samples from the surface and floor of the gallery. Plants recovered are presented in Table 1 and illustrated in Fig. 3 and 4. They include: emmer spikelets without grains (*Triticum dicoccum* Schübl.); seeds of the salt tree (*Nitraria retusa* (Forssk.) Aschers.); an endocarp of doum palm fruit (*Hyphaene thebaica* (L.) Mart.), measuring ca. 6 × 4.3 cm; "brushes" of a monocotyledon plant ca. 10 cm long; four pieces of plant fiber rope; and two charred cereal grain fragments. All the emmer spikelets were well preserved and do not show signs of pounding. Emmer chaff (Fig. 4a) was almost intact, but there were no grains; all of the spikelets were "hollow." Several spikelets (chaff) had visible round holes. Similarly, only the outer part of the *N. retusa* seeds (Fig. 4b) remained and the inner part (endosperm) was missing. The doum palm fruit was gnawed by rodent(s). The teeth marks are small, each 0.5 mm wide and ca. 5 mm long (Fig. 4c). A piece of rope ca. 11 cm long with a diameter of 7 mm was made from papyrus stalks (*Cyperus papyrus* (L.)) and had several insect holes (Fig. 4d). All the plant finds indicate that cereals and other plant material were infested by pests.

Outside of the galleries, especially in the production area below the galleries, numerous burnt grains of hulled barley (*Hordeum vulgare L.*), fewer emmer grains (*T. dicoccum*), and a large quantity of mineralized barley chaff were recovered, including several small pieces of burnt hulled grains of barley "kasha" (ca. 1 × 5 cm large). Numerous pieces of wood charcoal and a few fragments of charred leaves of a mangrove tree (*Avicennia marina* (Forssk.) Vierh.) were collected from the same area.

4.2. Insects

Many exoskeleton fragments of insects were found together with the plant macro remains in Cave 3 (Table 1, Fig. 5). The insect remains were so well preserved that initially it was not realized

Fig. 4. Selected plant remains from Cave 3. (a) Hollow desiccated spikelets of emmer (*Triticum dicoccum*); (b) Salt tree (*Nitraria retusa*) seeds without endosperm; (c) Endocarp of doum palm fruit (*Hyphaene thebaica*) gnawed by a rodent(s); (d) Piece of rope made from papyrus stalks (*Cyperus papyrus*) with insect holes.

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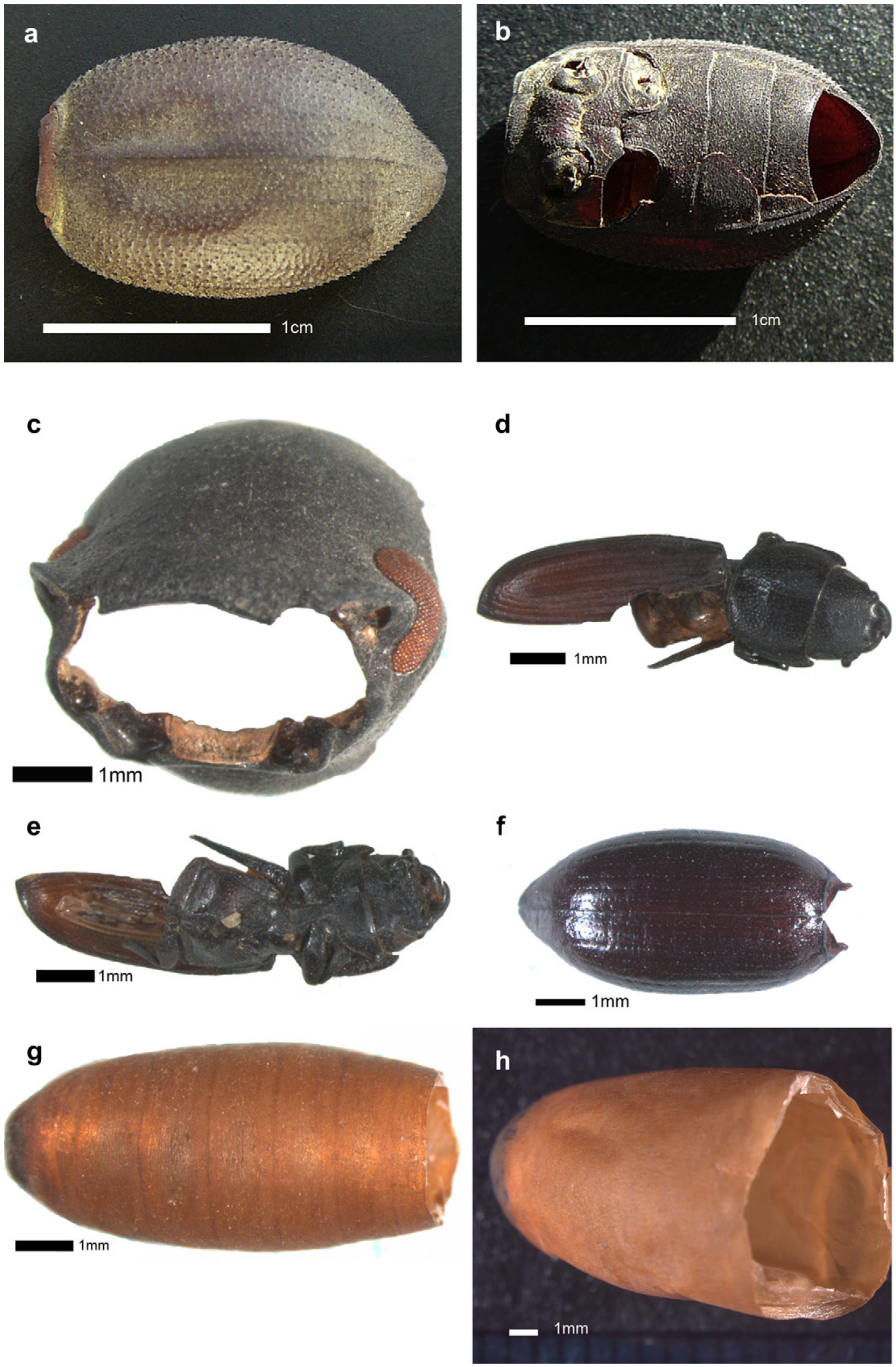

Fig. 5. Insect remains from Cave 3. (a) Paired elytra of the darkling beetle *Trachyderma hispida*; (b) Ventral view of hind body of *T. hispida*; (c) Head capsule remains of *T. hispida*; (d-e) Broken corpse of the trogossitid beetle *Tenebroides mauritanicus*, dorsal and ventral views, respectively; (f) Hind body of a tenebrionid beetle, cf. *Mesostena* sp.; (g) fly puparium with anterior segments missing, indicating emergence; (h) wasp cocoon, empty.

that they were of the same age as the plant remains. The identified insect remains include several specimens of the darkling beetle *Trachyderma hispida* (Forskål) (Tenebrionidae) (Fig. 5a–c) and a smaller beetle, the cosmopolitan grain pest *Tenebroides mauritanicus* (L.) (Trogossitidae) (Fig. 5d–e). Fused elytra of another tenebrionid beetle, probably *Mesostena* sp. (Fig. 5f); a fly puparium (Fig. 5g) of either the family Muscidae, Calliphoridae, or Sarcophagidae; and a cocoon (Fig. 5h), possibly of a mud wasp (Sphecidae), were also found. There is a possibility that the wasp cocoon and fly puparium may be recent; if the gallery was opened for a few weeks, these insects could have moved in. With the exception of the wasp, these insects are scavengers as larvae on carrion or food. Small entry or emergence holes seen in some of the spikelets (Fig. 4a) may have been made by young larvae of *T. mauritanicus*, the grain weevil *Sitophilus granarius* (L.), or the bostrichid *Rhyzopertha dominica* (F.). Fragments of the latter two species were not found at this site but are known from archaeological sites in Egypt (Panagiotakopulu, 2001; Van Neer et al., 2007).

4.3. Plaster deposit

An exceptional find from Cave 3 (Square B3) is a small plaster deposit (spill) that preserved the contents of the gallery floor, capturing a moment in time (Fig. 6a–c). The ancient Egyptians probably mined chalky limestone locally, mixed the resulting powder with water to make plaster and then spilled it on the gallery's floor. Plaster could have been used for various purposes. Many of the wooden cargo boxes were plastered, as were some exterior surfaces on ship components found throughout the site.

The plaster deposit found inside of Cave 3 resulted from a spill that remained intact on the floor for ca. 3800 years. The plaster deposit was oval in shape, ca. 20 cm long, and white (Fig. 6). The upper face was smooth (Fig. 6a–b) with no inclusions, but the underside (Fig. 6c) incorporated at least three whole desiccated emmer wheat spikelets (*T. dicoccum*), chips of cedar (*Cedrus libani* A. Rich.), pebbles, a pottery fragment, and an impression of the paired elytra of *T. hispida* (see Fig. 5). Other fragments of the same species were found in loose debris nearby. The three emmer spikelets were well preserved and do not show signs of processing, but they were "hollow," i.e., without grains (Fig. 6c), like the emmer spikelets found nearby (see Fig. 4a). The plaster find proved that the beetles were contemporaneous with the emmer spikelets, and they, along with *T. mauritanicus* and other smaller beetles such as grain weevils, may have been eating the grains.

4.4. Coprolites

From the samples that contained plant macro remains and insects, 45 small desiccated coprolites were also retrieved (Fig. 7, Table 1). They are oval in shape, ca. 10–12 mm long and 7 mm wide, and contain plant fiber remains, visible in the cross sections, indicating that they belong to an herbivore(s). Based on the size and shape, they were identified as excrement of sheep or goat, i.e., domestic ovicaprines (Linseele et al., 2010).

4.5. Wood and charcoal remains

A total of 1831 wood pieces of eight different wood taxa were identified from the charcoal, wood debitage, ship timbers, and fastenings from Cave 3 (Table 3). The main taxa are Nile acacia (*Acacia nilotica* (L.) Willd. ex Del.), cedar of Lebanon (*C. libani*) and deciduous oak (*Quercus* sp.). The three principal taxa recorded for the entire site at Gawasis are *A. nilotica*, *C. libani* and *A. marina*. The fragments of oak charcoal derived from a burnt wooden block.

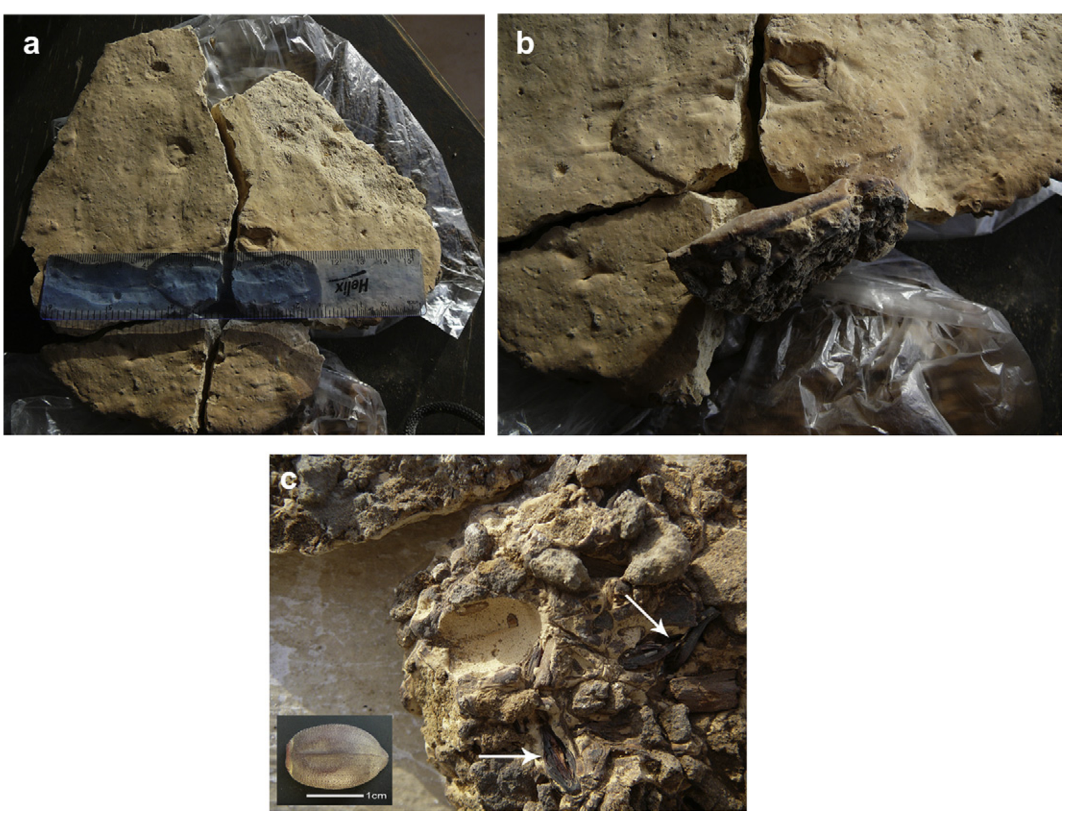

Fig. 6. Spill of plaster from a floor of Cave 3. (a) Upper side of a spill of plaster on a cave floor with a cm ruler; (b) detail of a spill of plaster; (c) Underside with emmer spikelets (indicated with arrows), an impression of a beetle, and a chip of cedar wood. Inset (left) shows the hind body of the beetle (*Trachyderma hispida*) found nearby.

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The surface in the central part of Cave 3 was covered with large concentrations of wood debitage, marine shell fragments, and charcoal. In the southwest area, several shallow hearths were excavated (Fig. 2a). The uppermost level of a large hearth was characterized by a concentration of burnt wood, fragmentary timbers, fastenings and wood debris and contained *A. nilotica* (93 pieces, 1180 ml); the middle level consisted of ash and large charcoal fragments from *A. nilotica* (75 pieces, 973 ml), *Ficus sycomorus* L. (1 piece, 1 ml), and *Quercus* sp., deciduous (4 pieces, 38 ml).

The wood debitage comes from cleaning and reworking used ship timbers, including planks, tenons, and other ship components fashioned from cedar, Nile acacia, and sycomore fig wood. About one-third of the wood material showed evidence of shipworm infestation, indicating that the ships were exposed to salt water for an extensive period. From a total of 1188 pieces of wood debris, 364 pieces had visible shipworm infestation (Table 3). The fifth author (C. W.) suggests ships from Gawasis required approximately four weeks to reach Punt, six to eight weeks there to acquire goods, and another eight weeks to return. Upon return, ships were disassembled and individual timbers were roughly trimmed to remove areas damaged by marine borers or other shelled fauna such as barnacles.

A number of ship timbers were recycled within the gallery. For example, ramps leading to the entrances of Caves 2, 3, 4, and 6 were made of ship components that included deck planks, hull planks from ships and also from small craft and ship's equipment (rudder blades). The entrances themselves are reinforced by thresholds and sills that originally were ship planks and by sawn-up planks and beams laid out to stabilize entry areas. The large ship planks are cedar wood (from the richly forested mountains of Lebanon), while smaller boat planks and tenons are of Nile acacia wood (from the alluvial plain of the Nile Valley). Deck planks are cedar or sycomore.

Damage by shipworm infestation remains visible on some planks and tenons. Damaged surfaces indicative of the activities of wood-consuming organisms supported the classification of any particular piece as a hull plank, as planks positioned below the water line would be particularly prone to the incursion of these invertebrates common to warm salt water environments (Ward and Zazzaro, 2010). Marine wood-boring bivalves of the family Teredinidae and members of the xylophagous isopod genus of crustaceans known as gribble worms (*Limnoria* spp.), which feed gregariously on wood are likely responsible for most of the recorded infestations. Teredinid larvae easily attach to wood surfaces and begin to burrow below the surface and devour the wood from within, building long tunnels with calcareous linings as they grow. The size of the tunnels reflects crowding as well as species (Cragg et al., 2009). Cedar planks at Gawasis incorporate burrows that run along the grain of the wood and frequently retain the calcareous lining; tunnel diameter ranges from 3 mm to 21 mm (Fig. 8). More sponge-like patterns of tunnels 2 mm or less in diameter also occur; this typical gribble damage usually results from *Limnoria* sp. infestation. In almost all cases, infestation is confined to the outer 5 cm of plank thickness, and the wooden fasteners between planks were placed beyond that boundary, preserving them from attack in most cases. Removal of shipworm damage from the outer surface was a primary goal of timber cleaning activities; some reworked planks show fragmentary tunnel edges and entrances.

5. Discussion

The results of the analysis of plant macro remains have shown that the principal cereals found at Mersa/Wadi Gawasis were emmer and hulled barley, cereals that were staples of ancient Egypt and recorded at many sites (cf. Murray, 2000; Samuel, 2000). Cereals and Nile acacia wood were likely brought to the site from the Nile Valley, which is ca. 150 km away via wadi routes. Barley, which is a hardy cereal, could have been grown in the wadi after spring floods on a small scale only, but not if the site was only temporarily occupied. Emmer could not be grown around the site if there was no sufficient water supply in the past. Emmer, like hulled barley, is a glumed cereal and has chaff that tightly encloses the grains. Cereals were likely transported in spikelets already coarsely threshed in some sort of bags on donkeys. Emmer probably was stored in the galleries in spikelets to be processed later and may have been intended to be ground into flour for bread or used for brewing beer (cf. Samuel, 2001). The two charred cereal grain fragments found in Cave 3 and numerous charred barley and emmer grains found outside the galleries attest to cereal food preparation at the site. Emmer spikelets in the galleries were infested by insects, which were responsible for eating the grains. The spill of plaster sealed plant and animal remains, a pottery fragment, and cedar wood chips. As a composite artifact, it provides exceptional direct evidence that the discovered beetles were associated with the emmer grains and other plant material. The stored grains were intended to be used by soldiers and mariners at the harbor, as indicated by charred grains and pottery that were found outside the galleries, especially from the production area.

The seeds of the salt tree (*N. retusa*) were once part of the fleshy red fruits, ca. 1 cm large and containing a single seed. Humans and

Fig. 7. Coprolites of sheep or goat (domestic ovicaprine), plant fiber visible in cross section.

Fig. 8. Shipworm infestation in a piece of cedar wood (*Cedrus libani*) from Cave 3.

animals eat fruits and young plants (Sudhersan et al., 2001), and a sweet concentrate made from the red drupes that produces a pleasant drink when diluted with cool water is consumed in Egypt (Osborn, 1968). Both seeds and fruits are consumed by Bedouins and animals in Sinai and the Negev (Bailey and Danin, 1981). The dried leaves were used in tea in traditional medicine in Egypt (Osborn, 1968) and in Israel (cf. Ronel and Lev-Yadun, 2009). The wood of *N. retusa* (thorny branches) was identified from the Mount Sedom caves in Israel in sediments dated to 6000 years ago (Liphschitz, 2005). No *Nitraria* wood remains have been identified yet from Mersa/Wadi Gawasis (Gerisch et al., 2007), perhaps indicating that only salt tree berries were gathered from the shrubs growing locally and were likely intended for human use but were instead consumed by pests in Cave 3.

A single large fragment of the woody endocarp of a doum palm (*H. thebaica*) is the only preserved part from Cave 3. It bears gnaw marks all around the edges (Fig. 4c). When whole, doum palm fruit has a leathery shiny skin (exocarp), below which is an edible fibrous pulp (mesocarp) that contains sugar and smells like gingerbread. Mesocarp surrounds the woody endocarp, recovered from Cave 3. Inside the fruit is a white seed that is very hard when ripe and often compared to ivory. The nutritious pulp is the primary food source of this fruit and can be chewed, soaked in water, or ground into flour and mixed with water (Osborn, 1968). Baboons readily eat the doum palm fruit pulp (Manniche, 1989; Murray, 2000).

The doum palm is native to Egypt and Sudan (Zahran and Willis, 2009). The extensive archaeobotanical and pictorial record provides evidence of various uses of doum palms in Egypt from the Late Paleolithic period until today (see Cappers, 2006; Manniche, 1989; Moulins and de Phillips, 2009; Murray, 2000; Smith, 2003; Springuel, 2006). Archaeobotanical finds of the fruits include whole intact fruits from tombs and cut fruits with only the endocarp preserved (Cappers, 2006; Murray, 2000). Most of the ancient finds of doum palm are from Upper Egypt, probably reflecting its geographical distribution in antiquity (Murray, 2000).

Since doum palm tolerates a wide range of soil conditions and high temperatures, it can grow in wadis (Springuel, 2006). It is possible that in the past doum palms grew locally and that the fruits were collected, but no wood of this palm has been identified so far. The part of the fruit found in Cave 3 does not show evidence that it was cut to extract the white ivory seed. The doum fruit was likely collected for its sweet pulp and the leftovers were consumed by rodent(s). Similar to the specimen from Cave 3, 10 doum palm fruit endocarps bearing holes were discovered from Abi'or Cave near Jericho and were probably eaten by rodents (Kislev, 1992).

The presence of a relatively small number (45) of ovicaprine desiccated coprolites in Cave 3 could represent a single event of a sheep or goat excrement (Landsberg et al., 1994). Caves used as animal shelters at other locations have more substantial dung layers. The thickness of these deposits may vary between several centimeters and more than a half meter, such as in Sodmein Cave in the Egyptian Eastern Desert, which was used for penning animals in the seventh millennium B.P. (Linseele et al., in press). It remains unclear whether a goat or sheep was kept briefly in Cave 3 or if the dung was incidentally brought with some other cargo or for use as fuel.

Analysis of wood and charcoal remains from Mersa/Wadi Gawasis shows that some of the wood originated from distant regions. The charcoal assemblages from Cave 3 consisted mainly of Nile acacia from the Nile Valley and cedar and oak from Lebanon used in the ship construction and equipment. Some of the timbers and fastenings found in the cave were partly or completely burnt. Local woody vegetation of the Red Sea coastal land, including gray mangrove and sea blite (*Suaeda* sp.), comprised only a small portion of the charcoal finds. One piece of the mangrove taxon Rhizophora/Bruguiera was recovered from Cave 3, although it is frequently found in other excavation areas of Mersa Wadi/Gawasis. *Rhizophora mucronata* Lam. occurs presently at the Egyptian Red Sea coast only close to the Sudanese border and *Bruguiera gymnorrhiza* (L.) Lam. does not grow further north than Sudan (El-Khouly and Khedr, 2007; PERSGA, 2004). One can assume that these trees were cut in the south and taken with the ships to the harbor of Mersa/Wadi Gawasis.

The extensive deposit of wood debitage, shipworm-infested wood fragments, and marine shells mixed with wood fragments degraded by marine borers testify to the trimming and reworking of hull planks in the galleries of the ancient harbor. Timber remains at Mersa/Wadi Gawasis demonstrate that when ships returned to the harbor from spending several months at sea, they were disassembled. Some parts had to be reworked, and reused, but those wood pieces badly damaged by the burrowing of shipworms were discarded and some were used as fuel (Ward and Zazzaro, 2010). Damage characteristic of both gribble and marine-borer bivalves is present.

A plaster spill from Cave 3 may have been a part of a mixture intended for coating ships planks or cargo boxes as a protective measure against water incursion or marine borers. A knot in the wood on a large hull plank (T34) found at the site was covered by plaster or gypsum, most likely to protect it from shipworms as the wood grain of large knots permits easy access to plank interiors. Similar techniques are used in traditional boat building in the Red Sea and Western Indian Ocean regions, where the use of plaster or gypsum is common. In Yemen, a mixture of animal lard and gypsum (*shaham*) is spread over a portion of the keel infested by marine borers.

While ancient Egyptian ships were infested by marine borers during sea voyages, the beetles identified in Cave 3 at Mersa Wadi/Gawasis were local and most likely not transported from distant places. Apparently, beetles had taken advantage of the presence of humans and their food in the galleries during the Middle Kingdom. *Trachyderma hispida* is a common desert beetle in the region and known to have synanthropic affinities (Attia and Kamel, 1965; Panagiotakopulu, 2001; Matthews et al., 2010); they may feed on grains stored in open containers that they can access (Buckland, 1981, 1990). They forage for wild grains and plant parts in the open but also frequent caves (including human-occupied caves) where animal nests, food and debris accumulate. The galleries' lower temperatures and the darkness were more conducive for the development of storage pests than the lethally hot temperatures outside.

Though known from ancient Egyptian tombs (Panagiotakopulu, 2001; Levinson and Levinson, 2001), this is the first report of *T. hispida* from an archeological food storage site in Egypt. *Tenebroides mauritanicus* has not been reported previously from any site of this age, and its discovery at Mersa/Wadi Gawasis offers good evidence that this cosmopolitan grain pest, also known to be a predator of other insects in stored grain (Barron, 1971), is of Old World origin.

Insects can invade storage facilities and tombs after humans abandoned the places in the antiquity. Due to bioturbation, seeds and insects remains can be displaced, and contamination with more recent material can easily occur in caves (Goldberg and Macphail, 2006). In Cave 3, we identified hollow emmer spikelets, a type of glumed wheat that has not been grown in Egypt since Roman times; thus, it must be ancient. Furthermore, because the plaster spill incorporated hollow emmer spikelets and the impression of the beetle *T. hispida* nearby, we know that at least *T. hispida* was present in the gallery while the ancient Egyptians occupied it. Rodents also have contributed to the consumption of doum palm fruit and perhaps grains. The extensive damage to the wood recovered from Cave 3 excavation areas dates to the period of its use, not to its presence in the gallery. Approximately one-third of the wood remains exhibit signs of being infested by marine borers, demonstrating that the ships were exposed to salt water before the wooden parts were brought to the gallery, an additional testimony to the antiquity of the pest infestation.

Another question is whether the ancient Egyptian mariners transported some of the insects found in the galleries to the places where they landed, e.g., the land of Punt, and thus contributed to the spread of some Egyptian insects. Much more entomological research will be required from the sites in the Red Sea area before we can answer this question.

6. Conclusion

Hollow emmer spikelets, salt tree seeds, gnawed doum palm fruit, ship debris showing shipworm damage and other plant and insect remains were recovered from Cave 3 from a Middle Kingdom harbor on the Red Sea. Cave 3 is one of several galleries that were used as arsenals where equipment and food for sea voyages were stored and where boats returning from sea expeditions were cleaned and repaired. The parts of the ship planks infested by sea borers were trimmed off, discarded and, together with the wood from the local vegetation from mangroves and wadis, used as fuel.

Food preserves well in dry places and recovered food remains could have been consumed at the site or taken on the voyages, unless infested by pests. We suggest the possible modes of the arrival of the identified plants and insects into Cave 3 and the likely uses of the plants found. Emmer was most likely brought in spikelets to the harbor from the Nile Valley together with other food supplies. Salt tree berries and doum palm fruits could have been gathered from the local vegetation of the Red Sea and nearby wadis. They could have provided additional nonstarchy nutrients and/or they could have been used medicinally. They were brought to the cave to be stored, and there they became infested by insects and rodents. At sea, different pests, gribbles and shipworms, infested the ships. The Egyptians chose to dismantle the ships and remove the damaged areas rather than to abandon them in the harbor. Cleaned timbers were recycled on the spot as architectural features or possibly returned to the Nile for reuse.

We cannot ascertain when the salt tree seeds and doum palm fruits were eaten by pests in Cave 3; however, the spill of plaster provides exceptional direct evidence that the discovered tenebrionid beetles were associated with emmer grains and other plant material. The spill preserves a part of the Cave 3 floor as it was when the ancient Egyptians walked on it ca. 3800 years ago. The impression of the beetle *T. hispida* and its associated exoskeleton fragments provide new evidence of this species as a potential pest not yet reported from an archaeological grain storage site in Egypt. In addition, finding *T. mauritanicus* in the same deposit makes this the earliest known association of this pest with stored grains. These unique finds throw new light on the risks in preserving food supplies and struggling with pest infestation on land at the ancient harbor and at sea and on the complexities of provisioning for maritime expeditions to the land of Punt.

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References

Attia, R., Kamel, A.H., 1965. The fauna of stored products in U.A.R. Bulletin Société Entomologique d’Égypte 49, 221–232.

Bailey, C., Danin, A., 1981. Bedouin plant utilization in Sinai and the Negev. Economic Botany 35, 145–162.

Barron, J.R., 1971. A revision of the Trogositidae of America north of Mexico (Coleoptera: Cleroidea). Memoirs of the Entomological Society of Canada 75, 1–143.

Bard, K., Fattovich, R. (Eds.), 2007. Harbor of the Pharaohs to the Land of Punt: Archaeological Investigations at Mersa/Wadi Gawasis, Egypt, 2001–2005. Univeristà delgi Studi di Napoli L’Orientale, Naples.

Bard, K.A., Fattovich, R., Ward, C., 2007. Sea port to Punt: new evidence from Marsā Gawāsīs, Red Sea (Egypt). In: StarkeyJ., StarkeyP., WilkinsonT.J. (Eds.), Natural Resources and Cultural Connections of the Red Sea. BAR International Series 1661, Oxford, pp. 143–148.

Boivin, N., Fuller, D.Q., 2009. Shell middens, ships and seeds: Exploring coastal subsistence, maritime trade and the dispersal of domesticates in and around the ancient Arabian Peninsula. Journal of World Prehistory 22, 113–180.

Buckland, P.C., 1981. The early dispersal of insect pests of stored products as indicated by archaeological records. Journal of Stored Products Research 17, 1–12.

Buckland, P.C., 1990. Granaries, stores and insects: the archaeology of insect synanthropy. In: Fournier, D., Sigaut, F. (Eds.), La préparation alimentaire des céréales, avril 1988. PACT, Rixensart.

Cappers, R.T.J., 2006. Roman Foodprints at Berenike: Archaeobotanical Evidence of Subsistence and Trade in the Eastern Desert of Egypt. Cotsen Institute of Archaeology, University of California, Los Angeles.

Cragg, M., Jumel, M.C., Al-Horani, F.A., Hendy, I.W., 2009. The life history characteristics of the wood-boring bivalve *Teredo bartschi* are suited to the elevated salinity, oligotrophic circulation in the Gulf of Aqaba, Red Sea. Journal of Experimental Marine Biology and Ecology 375, 99–105.

El-Khouly, A.A., Khedr, A.A.-H., 2007. Zonation Pattern of *Avicennia marina* and *Rhizophora mucronata* along the Red Sea Coast, Egypt. World Applied Sciences Journal 2, 283–288.

Gerisch, R., Manzo, A., Zazzaro, C., 2007. Finds: Other wood and wood identification. In: Bard, K., Fattovich, R. (Eds.), Harbor of the Pharaohs to the Land of Punt: Archaeological Investigations at Mersa/Wadi Gawasis, Egypt, 2001–2005. Univeristà delgi Studi di Napoli L’Orientale, Naples, pp. 165–188.

Goldberg, P., Macphail, R.I., 2006. Practical and Theoretical Geoarchaeology. Blackwell Publishing, Malden.

Haldane, C., 1991. Recovery and analysis of plant remains from some Mediterranean shipwreck sites. In: Renfrew, J.M. (Ed.), New Light on Early Farming. Recent Developments in Palaeoethnobotany. Edinburgh University Press, Edinburgh, pp. 214–223.

Kitchen, K.A., 1993. The Land of Punt. In: Shaw, T., Sinclair, P., Bassey, A., Okpoko, A. (Eds.), The Archaeology of Africa, Food, Metals and Towns. Routledge, London, pp. 587–608.

Kislev, M.E., 1991. Archaeobotany and storage entomology. In: Renfrew, J.M. (Ed.), New Light on Early Farming. Recent Developments in Palaeoethnobotany. Edinburgh University Press, Edinburgh, pp. 121–136.

Kislev, M.E., 1992. Vegetal food of Bar Kokhba rebels at Abi’or Cave near Jericho. Review of Palaeobotany and Palynology 73, 153–160.

Landsberg, J., Stol, J., Muller, W., 1994. Telling the sheep (dung) from the goats’. Rangeland Journal 16, 122–134.

Levinson, H., Levinson, A., 2001. Venerated beetles and their cultural-historical background in ancient Egypt. In: Insekten als Symbole gottlicher Verehrung und Schadlinge des Menschen: Ausgewahlte Kapitel der kulturgeschichtlichen und angewandten Entomologie. Spixiana, Zeitschrift fur Zoologie, pp. 33–75.

Linseele, V., Marinova, E., Van Neer, W., Vermeersch, P.M., 2010. Sites with Holocene dung deposits in the Eastern Desert of Egypt: visited by herders? Journal of Arid Environments 74, 818–828.

Liphschitz, N., 2005. The vegetation of the Chalcolithic period in the Southern Levant. Israel Antiquities Authority Reports 27. In: Brink van den, E.C.M., Gophna, R. (Eds.), Shoham (North), Late Chalcolithic Burial Caves in the Lod Valley, Israel. Israel Antiquities Authority, Jerusalem, pp. 191–197.

Matthews, E.G., Lawrence, J.F., Bouchard, P., Steiner, W.E., Jr., Slipinski, S.A., 2010. Tenebrionidae Latreille, 1802. In: Leschen, R.A.B., Beutel, R.G., and Lawrence, J.F. (Eds.), Handbook of Zoology. Volume IV—Arthropoda: Insecta. Part 39. Coleoptera, Beetles, Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim), vol. 2. Walter de Gruyter, Berlin, pp. 574–659.

Manniche, L., 1989. An Ancient Egyptian Herbal. British Museum Publications Ltd., London, pp. 108–109.
Moulins, D., de Phillips, C., 2009. The doum palm (Haphaene thebaica) in South Arabia: past and present. In: Fairbairn, A.S., Weiss, E. (Eds.), From Foragers to Farmers: Papers in Honor of Gordon C. Hillman. Oxbow Books, Oxford, pp. 117–126.
Murray, M.A., 2000. Cereal production and processing; Fruits, vegetables, pulses and condiments. In: Nicholson, P., Shaw, I. (Eds.), Ancient Egyptian Materials and Technology. Cambridge University Press, Cambridge, pp. 505–536; 609–655.
Osborn, D.J., 1968. Notes on medicinal and other uses of plants in Egypt. Economic Botany 22, 165–177.
Panagiotakopulu, E., 1998. An insect study from Egyptian stored products in the Liverpool Museum. The Journal of Egyptian Archaeology 84, 231–234.
Panagiotakopulu, E., 2001. New records for ancient pests: archaeoentomology in Egypt. Journal of Archaeological Science 28, 1235–1246.
Perlingieri, C., 2007. Finds: Egyptian ceramics. In: Bard, K., Fattovich, R. (Eds.), Harbor of the Pharaohs to the Land of Punt: Archaeological Investigations at Mersa/Wadi Gawasis, Egypt, 2001–2005. Univeristà delgi Studi di Napoli L'Orientale, Naples, pp. 101–126.
PERSGA, May 2004. Status of Mangroves in the Red Sea and Gulf of Aden. Draft 09-05-2004. PERSGA Technical Series No. 11, Jeddah. http://www.persga.org/Files/Publications/Technical/TS/TS11_Status_of_Mangroves_in_RSGA.pdf.
Ronel, M., Lev-Yadun, S., 2009. Spiny plants in the archaeological record of Israel. Journal of Arid Environments 73, 754–761.
Samuel, D., 2000. Brewing and baking. In: Nicholson, P., Shaw, I. (Eds.), Ancient Egyptian Materials and Technology. Cambridge University Press, Cambridge, pp. 537–576.
Samuel, D., 2001. Beer; bread. In: Redford, D.R. (Ed.), The Oxford Encyclopedia of Ancient Egypt. Oxford University Press, Oxford, pp. 171–172; 196–198.
Sayed, A.M., 1978. The Discovery of the Twelfth Dynasty Port in the Region of the Wadi Gawasis on the Red Sea Coast (in Arabic). University of Alexandria, Alexandria.
Sayed, A.M., 1999. Wadi Gasus. In: Bard, K.A. (Ed.), Encyclopedia of the Archaeology of Ancient Egypt. Routledge, London, pp. 866–868.
Shaw, I., Nicholson, I., 1995. The Dictionary of Ancient Egypt. British Museum Press, London, p. 231.
Simchoni, O., Kislev, M.E., 2009. Relict plant remains in the "Caves of the Spear." Israel Exploration Journal 59, 47–62.
Smith, W., 2003. Archaeobotanical Investigations of Agriculture at Late Antique Kom el-Nana (Tell el-Amarna). Egypt Exploration Society, London.
Smith, R., Spirek, J., Bratten, J., Scott-Ireton, J., 1995. The Emanuel Point Ship, Archaeological Investigations, 1992–1995. Florida Department of State, Division of Historical Resources, Bureau of Archaeological Research, Invertebrate Remains, pp. 85–88.
Springuel, I., 2006. The Desert Garden: A Practical Guide. American University in Cairo Press, Cairo.
Sudhersan, C., Abo El-Nil, M., Hussain, J., 2001. Tissue culture technology for the conservation and propagation of certain native plants. Journal of Arid Environments 54, 133–147.
Valamoti, S.M., Buckland, P.C., 1995. An early find of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) from final Neolithic Mandalo, Macedonia, Greece. Journal of Stored Products Research 3, 307–309.
Van Neer, W., Hamilton-Dyer, S., Cappers, R., Desender, K., Ervynck, A., 2007. The Roman trade in salted Nilotic fish products: some examples from Egypt. Documenta Archaeobiologiae 4, 173–188.
Ward, C., Zazzaro, C., 2010. Evidence for pharaonic seagoing ships at Mersa/Wadi Gawasis, Egypt. International Journal of Nautical Archaeology 39, 27–43.
Zahran, M.A., Willis, A.J., 2009. The Vegetation of Egypt, second ed. Springer, Berlin.

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