Chapter 8
Human Paleoecology in the Ancient Metal-Smelting and Farming Complex in the Wadi Faynan, SW Jordan, at the Desert Margin in the Middle East

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8.1 Introduction

This chapter reviews existing information, describes new geoarchaeological evidence and from this infers aspects of the human paleoecology and land use in a landscape heavily affected by millennia of metal-winning and metal-processing in the Wadi Faynan and its tributaries in southwest Jordan. The Wadi Faynan lies in an ecotonal position on the margins between the warm desertic Wadi ʻAraba and the Jordanian uplands, which are characterized by steppe and at high altitude, Mediterranean dry forest. It was a key Middle Eastern industrial center from the early 3rd millennium BC to the Byzantine period (Barker et al. 2007a; Hauptmann 2007). The metal industry in the Faynan has considerable time depth, since in the Neolithic, before smelting started; the brightly-colored copper ores were extracted for ornamental purposes and cosmetics. The environment in the Wadi Faynan was harsh by any standards, and resources were difficult to access and extract. Metal-winning and metal-processing causes multiple, more or less severe impacts on the environment, which vary depending on the location and nature of the site. The highly-polluted environment is known to have caused severe health impacts (Grattan et al. 2002). Yet in spite of these difficulties, during several millennia people lived and extracted copper in the Wadi Faynan. This chapter describes and examines evidence of how these ancient miners, metal workers and farmers lived at the desert margin and amidst the industrial pollution.

8.2 Materials and Methods

The Wadi Faynan (Fig. 8.1) lies on the margins of the Dead Sea—ʻArabah rift in southwest Jordan and drains a landscape deeply incised into Precambrian, lower Paleozoic, and upper Cretaceous to Paleogene successions in the mountains of Edom, some 30 km north of Petra. Among the Paleozoic succession, intense sedimentary copper mineralization occurs in the Lower Cambrian Dolomite-Limestone Shale Unit, with secondary mineralization occurring in fracture-fills in the Lower Brown Sandstones, which lie later in the Cambrian (Hauptmann 2007).

Hunter-gatherer activity in the area can be traced back to the Lower Paleolithic (McLaren et al. 2007). In the Holocene, Pre-Pottery Neolithic A (PPNA) settlements appear about 9600 BC. The subsistence pattern of the PPNA appears to have been primarily hunting and gathering in a partly-wooded steppe landscape (Barker et al. 2007c). Intensive cereal use and complex settlements with substantial architecture are evident in the Pre-Pottery Neolithic B about 8500 BC (Simmons and Najjar 1996) . During the Pottery Neolithic (about 6000 BC), the landscape began to aridify, so the tree cover was markedly reduced and farming became sufficiently widespread that soil erosion caused major valley alluviation (Hunt et al. 2007a). Pottery Neolithic waterside settlements are known in the Faynan and its tributary wadis. Generalized metal pollution was minimal and episodes appear to have been short-lived and probably related mostly to the production of brightly-colored copper ore powders and beads (Grattan et al. 2007). There are raised levels of heavy metals in late

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See Plate 7 in the Color Plate Section; also available at: extras.springer.com

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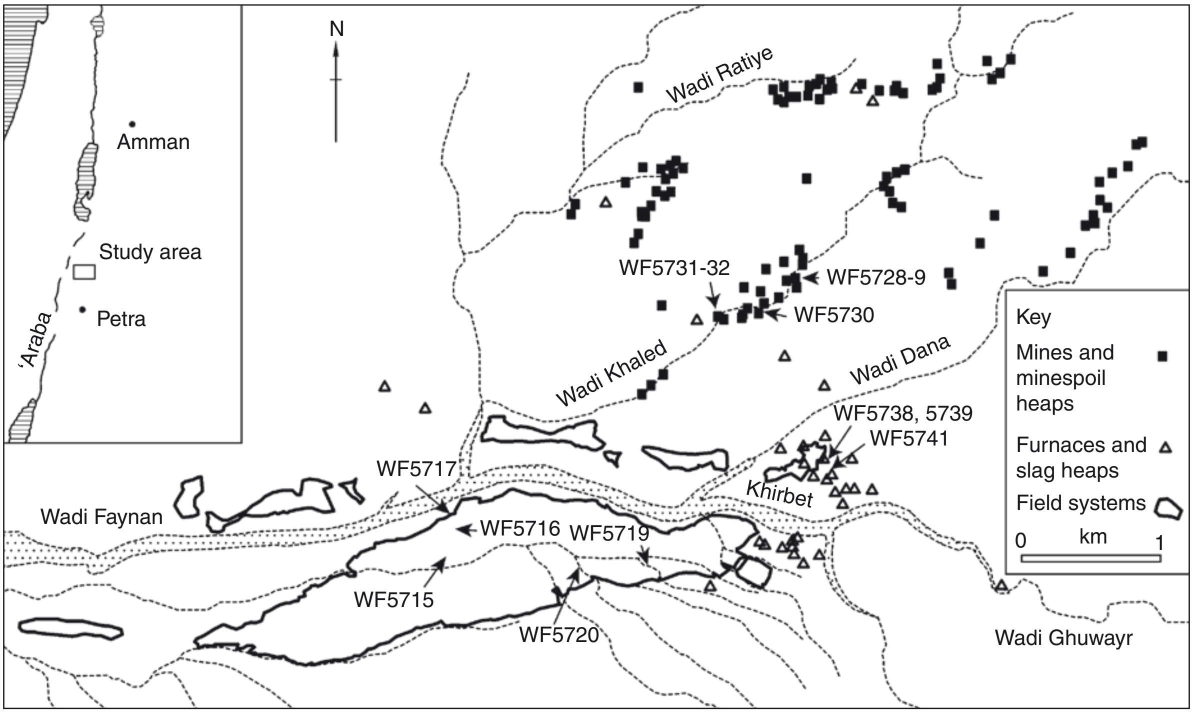


Fig. 8.1 The Wadi Faynan farming and metal-production complex showing sites mentioned in the text

Neolithic deposits consistent with the heating of copper ores, from about 5500 BC (Grattan et al. 2007).

Early copper metallurgy can be deduced from the occurrence of extremely polluted sediments and slags associated with dates as early as 4500 BC in the Chalcolithic (as documented below) but archaeological evidence of metal-smelting technology is not yet forthcoming (Adams 1999; Hauptmann 2007). More substantial, extensive and well-attested metal-producing activity occurred in the Early Bronze Age, from about 3600 BC (Adams 1999, 2002; Levy et al. 2002). Very intense metal production activity occurred during the later Early Bronze Age (about 2950–1950 BC). There was then something of a hiatus for nearly a millennium, during which the area had only transient populations (Adams 1999). Dated slag deposits suggest (Grattan et al. 2007) that metal production seems to have started again during the later Bronze Age 1 (about 1700 BC), with small scale activity episodically into Iron Age I (about 1300 BC). Activity intensified during Iron Age II (about 1000 BC), during the rise of what became the Edomite kingdom (Levy et al. 2004). The Nabateans, who seem to have come into the region from NW Arabia, seem to have been less engaged with metal-production, though there was some activity in the Nabatean period (312–106 BC) (Mattingly et al. 2007b). From shortly after the annexation of the Nabatean state by Imperial Rome, the Faynan orefield became one of the industrial powerhouses of the classical world, with large-scale mining and smelting during the Roman and Byzantine periods (106 BC–650 AD) with a cadre of professionals overseeing labor by convicts (Hauptmann 2007; Grattan et al. 2007; Mattingly 2007a).

The legacy of these episodes is a landscape which is still highly polluted. Grattan et al. (2007) argue that the Faynan metal industry made a notable contribution to global environmental levels of heavy metals during the Prehistoric and classical phases and that the intensity of pollution in the Faynan orefield was rarely surpassed elsewhere before the nineteenth century AD.

Today, the Wadi Faynan has an annual average rainfall estimated at between 70 and 150 mm/a (Hunt et al. 2007a). The landscape in the lower parts of the wadi is largely very-degraded steppe, dominated by annual grasses, sedges, knapweeds, daisies and thistles (Asteraceae) and patches of sandwort group (Caryophyllaceae) and chenopod scrub. The wadi floors show classic braided bedform morphology, are occasionally flooded by runoff from winter rainfall, but are usually dry and dotted with sparse oleander bushes except near rare mountain-front springs, where reed-dominated vegetation with palms, tamarisks and willows is present. The Edom Mountains above the Wadi Faynan are characterized by a zone of *Artemisia* steppe associated with annual rainfall of 150–200 mm at intermediate altitudes, a zone of juniper woodland associated with annual rainfall of 200–250 mm at higher altitudes and sparse remnants of mixed Mediterranean woodland at very high altitudes, associated with annual rainfall of 250–450 mm (Engel and Frey 1996; Hunt et al. 2007a). All of the vegetation belts have become extremely degraded over the last 40 years as the result of increasingly-intensive grazing by Bedouin flocks.

Research on environmental and landscape change in the Wadi Faynan suggests a relatively wet early Holocene, with Mediterranean woodland at low altitude and settlements alongside perennial rivers until the Late Neolithic (Hunt et al. 2004, 2007a; Barker et al. 2007c). A relatively diverse but treeless steppe was still present until the Chalcolithic/Early Bronze Age, when small water catchment systems appear (Hunt and Gilbertson 1998; Barker et al. 2007b), but thereafter aridification seems to have set in and floodwater-farming was apparently needed to sustain large-scale Iron Age II to Roman agriculture, resulting in the construction of the enormous Wadi Faynan field system (Fig. 8.1; Mattingly et al. 2007a, b). In vegetational terms, the effects of the wetter Roman period climate in the region (Heim et al. 1997) appear to have been negated by human impact, most notably the intense regional wood-gathering required to produce fuel for the smelting industry in the wadi, with the vegetation remaining highly degraded (Hunt et al. 2007a; Mattingly et al. 2007b).

The sites discussed here were identified and assigned to their landscape context through a combination of air-photo interpretation and ground survey. The air-photos derived from wartime British coverage held in the archives of the University of Western Australia (El-Rishi et al. 2007). Air-photo interpretation narrowed the areas for ground survey. The research area is sparsely vegetated because of aridity and heavy grazing so structures and features such as slag heaps and field walls were easily visible to ground survey. Sites were identified in the field for sampling of natural exposures (for instance in gully walls or river cutbanks), or for test excavation, if no natural exposures existed (El-Rishi et al. 2007). Natural sections or test-pit faces were cleaned, drawn, photographed and sampled. Samples were dried in the field-camp under clean newspaper to minimize contamination, then returned to the laboratory in sealed polythene bags. The normal sample size was 1 kg. In the laboratory, analysis included visual characterization, sieving for macroscopic remains, palynological analysis, analysis of heavy metal content using X-ray fluorescence (XRF) on a Spectro X-Lab, magnetic susceptibility using a Bartington MS2b meter and organic carbon content by loss on ignition. Samples were submitted for radiocarbon analysis using accelerator mass spectrometry and calibrated using Calib 501. Radiocarbon dates are displayed in calendar years BC or AD (Hunt et al. 2007b). Pollen and metal data were displayed graphically using Tilia and TGView.

In a general way, undated sites can be placed in their chronological context using chemostratigraphy. The pollution was characteristically copper-dominated and relatively low in lead during the Early Bronze Age to Iron Age (2000–750 BC), then much higher in lead through the Classical-Byzantine periods (750 BC–620 AD) as a result of changes in the ore sources exploited (Grattan et al. 2007). Other lines of dating evidence, such as radiocarbon dates (Hunt et al. 2007b) and archaeological seriation are also sometimes available.

8.3 The Farmscape

One of the most prominent parts of the Faynan complex of sites are the field systems, which in broad terms date to a series of episodes between the early Bronze Age and the Late Byzantine period. The farmscape around the metal-processing sites was sampled in a series of sites in and on the edge of the Wadi Faynan farming system. Some of these sites, such as WF5715 (Fig. 8.2) and WF5717 (Fig. 8.3) are field-fills, which accreted vertically as sediment-laden irrigation water was distributed on the fields of the irrigation system. Most, such as at WF5717, show sedimentary and pedogenic structures consistent with vertical accretion from relatively quiet waters interspersed with welded soil development. Signs of plough cultivation are unusual in the field system—Site WF5715 is the only site at which a plough soil was recorded. It is possible, how-

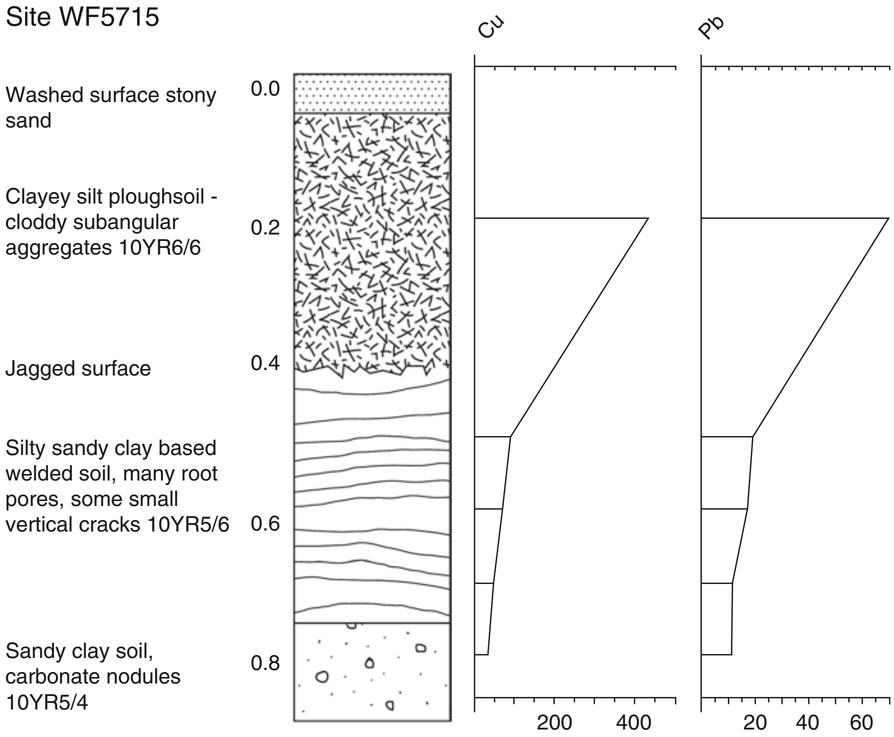


Fig. 8.2 Summary of stratigraphy and geochemistry of a field-fill at WF5715. Depths in meters, Cu and Pb concentrations in ppm. The very low lead figures in the welded soil suggest that this accumulated before the Iron-Age/Classical metal production episodes when lead pollution was relatively high, and thus that it relates to the Early Bronze Age episode

ever, since parts of the field system are highly deflated, that plough soils were more prevalent in the past, but have been removed subsequently by erosion. The presence of *Melanopsis* at site WF5717 suggests irrigation from a perennial water source, while *Theba*, which is common in field system soils and watercourse deposits, is associated with steppe vegetation in the study region, but not with arable fields.

Other sites, such as WF5716, contain waterlain sediments, often sandy and gravelly, laid down in the channels of the irrigation system (Fig. 8.4). Others, such as 5719 (Table 8.1) and 5720 (Figs. 8.5, 8.6, 8.7) are buried water-control features within or marginal to these channels. Site 5719 contained two generations of water-control structures and stratified between them several Late Iron Age shards. A pollen assemblage was recovered from a silty horizon stratified beneath the stonework of the upper water-control structure (Table 8.1). The assemblage is dominated by steppe taxa—Caryophyllaceae, *Artemisia*, *Asphodelus*, *Bidens* type, Lactucae. Pollen derived from woodlands on the Edom Mountains (*Pinus*, *Ostrya*, *Juniperus*) is fairly prominent. Pollen of cereals is frequent enough in the assemblage to suggest nearby cultivation. The palynofacies assemblage contains abundant burnt woody matter and some spherules, consistent with metal-processing nearby.

Site 5720 is broadly Nabatean-Late Roman in age (Figs. 8.5, 8.6, 8.7). The pollen assemblages (Fig. 8.6) are again dominated by steppe taxa—Caryophyllaceae, *Artemisia*, *Asphodelus*, *Trifolium*, *Plantago*; although the youngest sample, which may be Late Roman in age, shows a decline in steppe species and higher percentages of taxa typical of degraded (*Centaurea*, *Helichrysum*, Lactucae, *Malva*) and desertic (*Ephedra*) landscapes. Pollen of cultivated taxa (cereals and date palm) is very sparse. Algae (mostly Zygnemataceae) suggest standing water in the system for several months, as a minimum. This contrasts with the assemblage from WF5719, where algae are not present, suggesting ephemeral water-supply in the Iron Age. This observation chimes with the work of Heim et al. (1997), who suggest higher regional rainfall in the Roman period. The palynofacies analysis shows high percentages of thermally mature woody matter and some spherules, most probably derived from nearby metal production areas (Fig. 8.7).

While cereal cultivation seems to have taken place locally until the Late Iron Age, the surviving soils, mollusc and pollen evidence for the Classical period together suggests that much of the field system was used primarily for grazing, rather than for arable agriculture as suggested by Mattingly et al. (2007a).

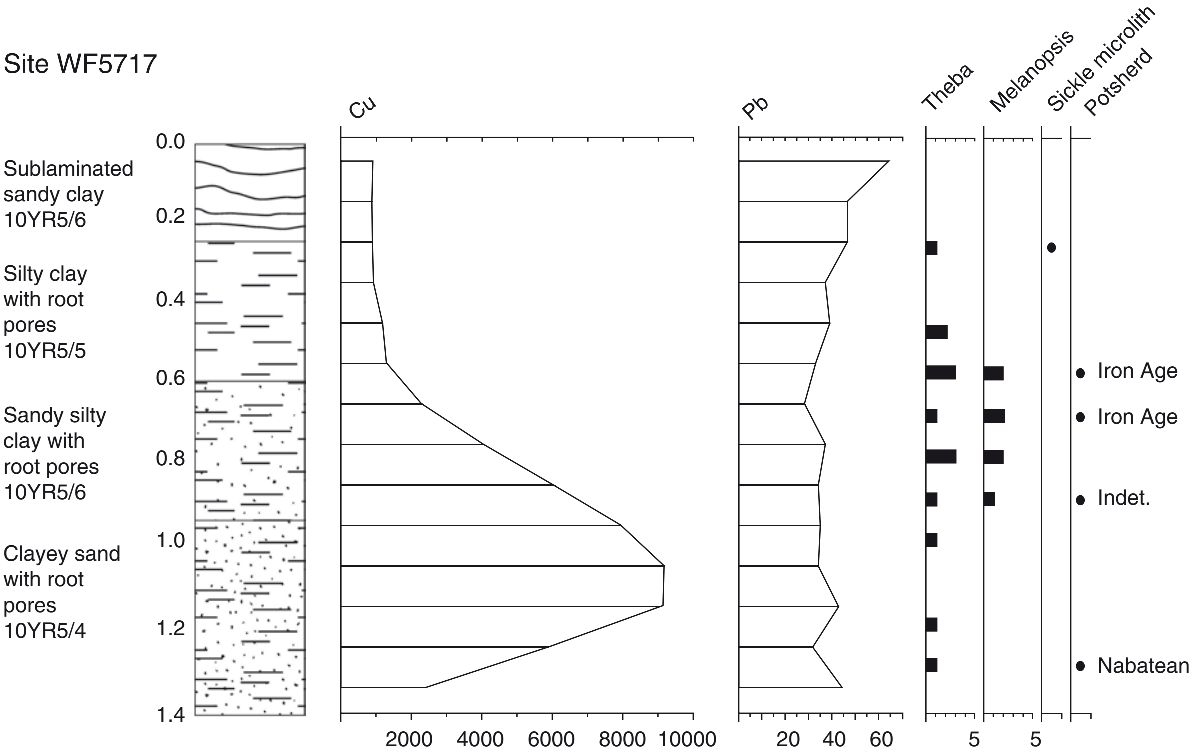


Fig. 8.3 Summary of stratigraphy, geochemistry, molluscs and artefacts from a field fill at WF5717. Depths in meters, Cu and Pb concentrations are in ppm. It would appear that this sequence was initiated in Nabatean (early Classical) times, on the pottery evidence, and the high lead levels in the upper part of the deposits can be used to suggest that sedimentation continued during Roman-Byzantine times. The Iron Age potsherds are thus recycled

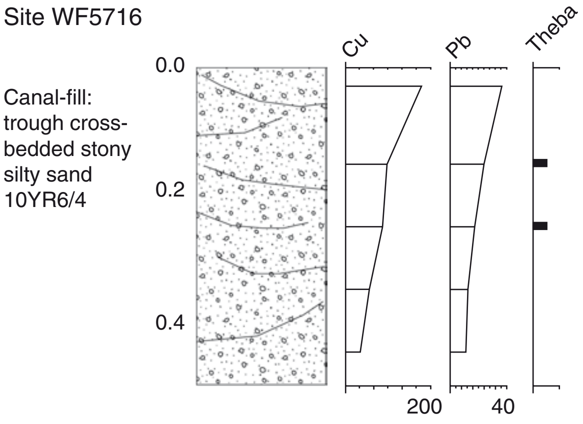


Fig. 8.4 Summary of stratigraphy, geochemistry and molluscs from an irrigation canal fill at WF5716. Depths in meters, Cu and Pb concentrations are in ppm. The low, but rising figures for heavy metals, especially the low lead level, may suggest that this is a relatively early feature, perhaps broadly contemporaneous with the nearby field fill WF5715

It is clear from the chemical analyses that the field fills are highly polluted, with pollution levels during Nabatean and later periods certainly high enough to impact severely on plant productivity (cf. Pyatt et al. 1999, for modern comparative studies, which show that grain yields in highly polluted areas in the region diminish to half those in relatively unpolluted locations). Thus it could be argued that the field system was very large because yields were low. It could further be argued that the Roman and Byzantine managers of the field system were aware that yields were low, since field-walking has disclosed evidence of intensive Roman/Byzantine manuring of the fields using the contents of domestic middens (Mattingly et al. 2007a). These, of course, were likely also polluted with heavy metals and thus will have increased the pollution load in the field-soils. Animals grazed on the field system and people eating their meat or eating grain grown there will have bio-accumulated heavy metals, particularly lead.

Table 8.1 Pollen and palynofacies assemblages from Sample WF5719A

Species	Number	Percentage
Plateau		
Cedrus	1	0.3
Pinus	35	10.7
Ostrya	7	2.1
Juniperus	1	0.3
Daphne	1	0.3
Waterside		
Palmae	5	1.5
Pteropsida	1	0.3
Montia	1	0.3
Cultivated		
Cereal	7	2.1
Steppe		
Caryophyllaceae	110	33.5
Artemisia	71	21.6
Bidens type	20	6.1
Asphodelus	17	5.2
Lactuceae	15	4.6
Poaceae	11	3.4
Cyperaceae	3	0.9
Helichrysum type	2	0.6
Bellis type	2	0.6
Acacia	2	0.6
Hippophae	1	0.3
Anenome type	1	0.3
Trifolium type	1	0.3
Desertic		
Chenopodiaceae	9	2.7
Haloxylon type	2	0.6
Indeterminate	2	0.6
Total	**328**	**100.0**
Palynofacies		
Thermally mature	72	43.1
Spherules	2	1.2
Plant cell walls etc.	32	19.2
Pollen	56	33.5
Insect	1	0.6
Fungal spores	1	0.6
Fungal hyphae	3	1.8
Total	**167**	**100.0**

8.4 Metal-Extraction Sites

The landscape around Wadi Faynan is littered with the remains of metal-winning sites (Hauptmann and Weisgerber 1987, 1992; Hauptmann 1989, 2000). These include surface trenches, shaft and adit mines and spoil heaps, but few provide depositional sites in which environmental evidence has been preserved relating to the period of the metal-winning, often because of their position, high on steep hillsides. Minespoil heaps and related fluvial sediments were sampled in the main mining area, the Wadi Khaled (Table 8.2). Both copper and lead levels are extremely high, especially in the minespoil, which is often silty in texture and extremely friable. Runoff from the minespoil heaps introduced significant pollution into watercourses, as can be seen from the pollution levels in the related riverine deposits. The dust produced during mining and spoil dumping would also have carried considerable pollution loads. The high sediment input seems to have led to substantial aggradation of the wadi floor—the wadi has subsequently incised between 2 and 3 m into these deposits of highly polluted alluvium, leaving a substantial river terrace at the studied sites, which can be traced downstream to the confluence of the wadi with the Faynan. These deposits do not contain pollen or molluscs, but it can be inferred from the aggradation and its contained fluvial/colluvial bedforms that the landscape during the mining episodes was largely devegetated as a result of the extreme toxicity of the minespoil, which would have been highly mobile in the environment.

8.5 Metal-Working Sites

Three sites near Khirbet Faynan were sampled (Figs. 8.8, 8.9, 8.10). These are localities where metal-rich smelting spoil was discarded on the edge of the braidplain of the Wadi Dana, close to its confluence with the Wadi Faynan. The sediments date from the Chalcolithic (base of WF5741), Iron Age I and II (WF5738, WF5739), Roman (WF5738, WF5739) and Mameluke (WF5741) periods and all are extremely polluted. The intensity of human activity in these locations caused the disturbance of the stratigraphy, and thus to dating reversals, especially in Iron Age II. Nevertheless, the ashes, silty ashes and gravels preserve abundant food debris and other environmental evidence, including charred barley, grape pips and date stones, bones of sheep/goats and fish, shells of land and marine molluscs. The sheep/goat bones are mostly rib and long-bone fragments, suggesting butchery elsewhere of sheep and/or goats and consumption of high-quality meat on site, while the fishbones must represent dried or salt fish imported from coastal areas or the Jordan

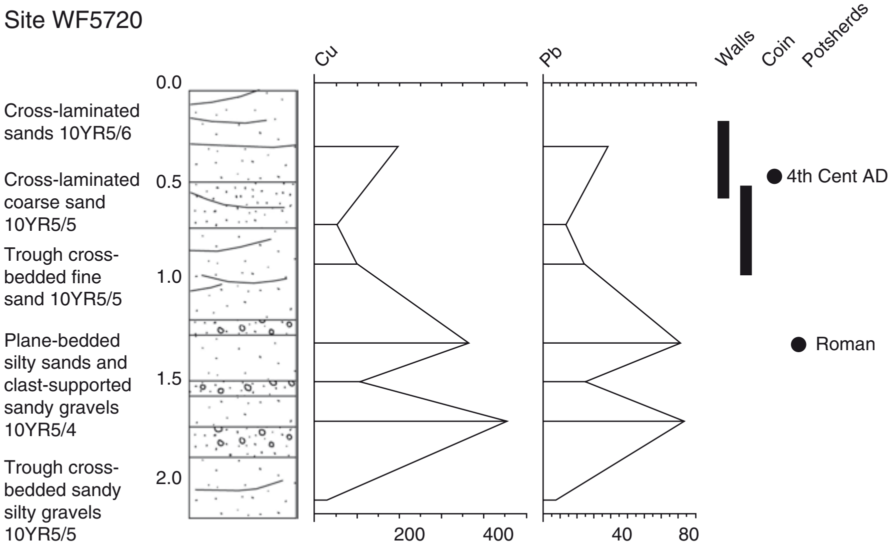


Fig. 8.5 Summary of stratigraphy, geochemistry and archaeology associated with a water-control structure at WF5720. Depths in meters, Cu and Pb concentrations are in ppm. The metal concentrations and artefacts are consistent with this site being broadly of Roman age

Valley, as there are no local sources. Given the highly polluted and active environments represented by these sites, it is possible that the land snail fragments also represent food items, rather than animals which were living on site—there are occasional records of land molluscs being a regular part of the prehistoric diet elsewhere in the arid zone, although these are not usually seen as high-status food. The marine molluscs are derived from the Mediterranean or Red Sea coasts and are extremely unlikely to have been food items, partly because of the difficulty of rapid transportation from the coast to ensure freshness, partly because the specimens are all very small, and partly because the taxa concerned—cowries and *Conus* sp.—were rarely eaten but were prized for ornamental purposes and sometimes currency. It is thus more probable that these had some non-dietary significance for their owners. Artefacts are also abundant, mostly coarseware potsherds, but also substantial numbers of lithic artefacts. These latter are mostly irregular, but sharp, chert flakes and it is probable that these reflect the regular use of stone tools as late as the Iron Age.

8.6 Discussion

The Faynan was challenging climatically—cold in winter, unbearably hot in summer and with a seasonal, scanty and irregular rainfall regime. By the Bronze Age, the Faynan landscape was already too dry for rainfed farming, so irrigated agriculture was necessary from then on (Hunt et al. 2007a), and was certainly still in operation as late as the Roman period. Similarly, it is likely that the demand for wood for fuel for smelting could only be supplied from regional sources (Hunt et al. 2007a).

Cereal pollen and traces of agricultural soil erosion are known in Neolithic (Hunt et al. 2007a), Chalcolithic/Early Bronze Age (Barker et al. 2007b) and Iron Age contexts. The evidence presented here is, however, inconsistent with the field system being the breadbasket of the Faynan metal industry during the Classical period. The soils, mollusc and pollen evidence would instead be consistent with the field system being used mostly for grazing rather than for arable agriculture at this time. Certainly, the levels of cereal pollen during Classical times are significantly less than those present in the Chalcolithic/Early Bronze Age (Hunt et al. 2007a; Barker et al. 2007b) or Iron Age farmscapes when grain was almost certainly produced in the Faynan. Thus, it is extremely likely that a large proportion of grain was imported into the Faynan during Roman and most probably Byzantine times. There is no trace of grape or olive and only very occasional grains of date pollen from the Faynan for any period, so it is highly likely that the seeds found in the present study reflect imported produce, from the Chalcolithic onward.

Pastoral agriculture occurred in the Faynan from the Pottery Neolithic, and possibly earlier. Hunt et al. (2007) suggest that vegetational change and soil ero-

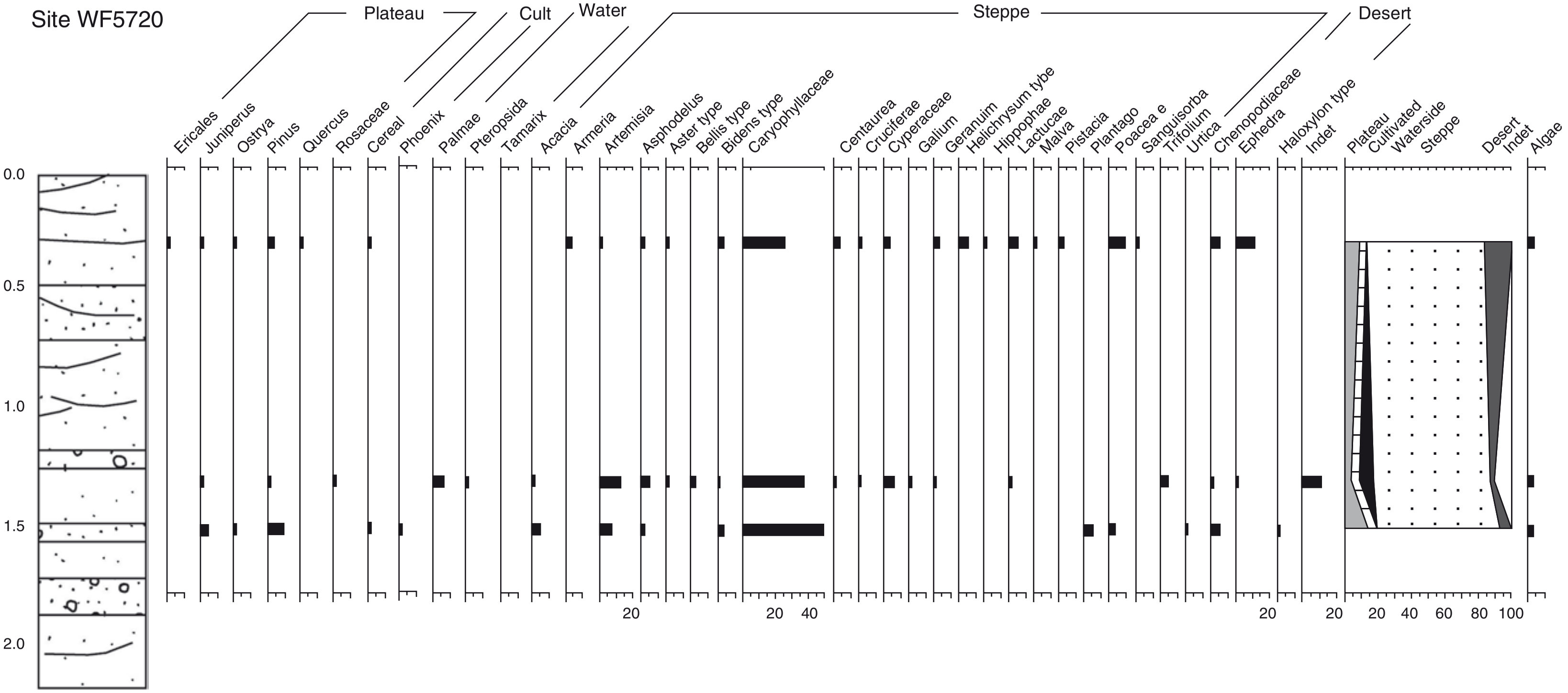
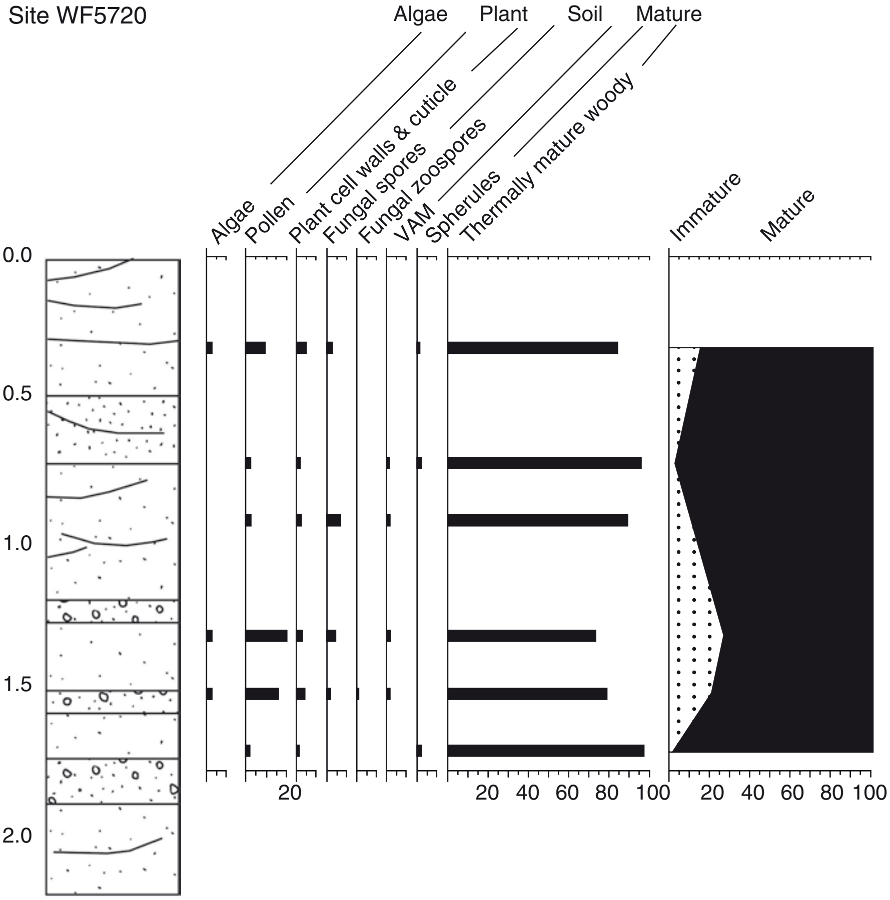


Fig. 8.6 Pollen percentage diagram from site WF5720. Depths in meters. Presences of pollen taxa in samples at 0.7, 0.9 and 1.7 m, which were too sparse to count, are shown as dots

Fig. 8.7 Palynofacies analysis from site WF5720. Depths in meters



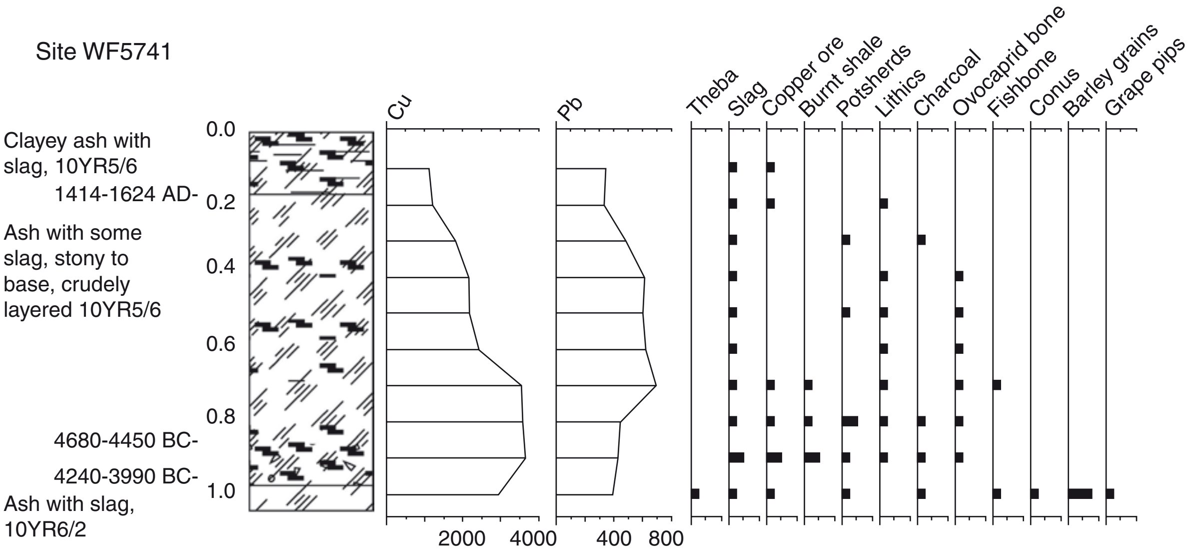


Fig. 8.8 Summary of dating, stratigraphy, heavy metals, molluscs, artefacts and environmental evidence from site WF5741. (Cu and Pb values are in ppm)

Table 8.2 Heavy metal concentrations in minespoil heaps and related sediment in the Wadi Khaled

Sample	Description	Cu (ppm)	Pb (ppm)
5728/1	Fluvial gravels predating main mining episode	224	36
5728/2		201	30
5728/3		232	31
5728/4	Minespoil interbedded with fluvial gravels	7485	734
5728/5	Fluvial gravels interdigitating with spoil heap	4331	415
5729/1	Fluvial gravels downstream from spoil heap	812	91
5730/1	Fluvial sands predating mining	261	41
5730/2	Minespoil	3388	362
5730/3	Fluvial sands interdigitating with spoil heap	2821	251
5730/4	Minespoil	9526	3127
5731/1	Fluvial gravels interdigitating with spoil heap	938	85
5731/2	Minespoil	5550	438
5732/1	Fluvial sands downstream from spoil heap	505	62

sion during the later Neolithic may relate to overgrazing. It is likely that pastoral agriculture persisted in the Faynan after the Neolithic, but the increasing aridification is likely to have forced the herders to have adopted increasingly-extensive foraging strategies and possibly to have adopted a transhumant lifestyle, taking stock up to the Edom Plateau during the summers, when the rainfed spring vegetation would have died back. Today, the current stocking density operated by the local Bedouin is sufficient to maintain the vegetation in a rather degraded state and it could be argued that the rangeland is near its carrying capacity. In those times when there was a large industrial population to be fed, however, it is very probable that local rangeland resources would have been insufficient for the necessary herds. Thus, it is likely that the majority of the animal protein eaten by the Faynan workforce in Roman and Byzantine times was derived from more or less distant sources. Part of the logic for this statement is that most of the Faynan field system

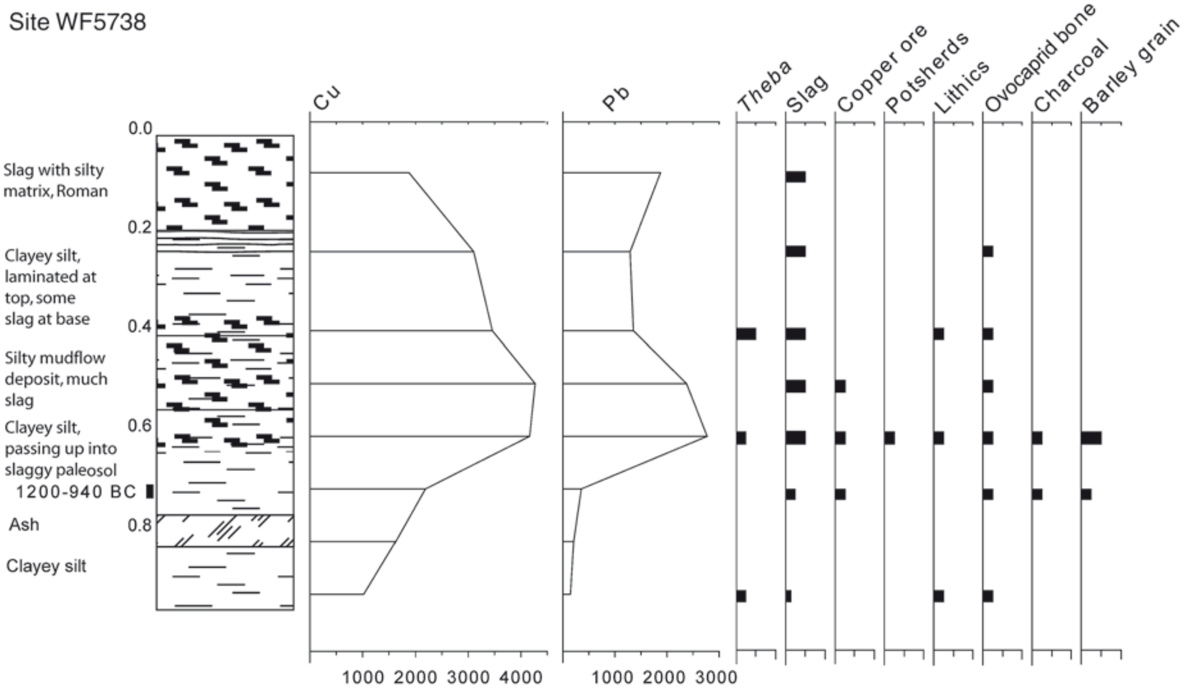


Fig. 8.9 Summary of dating, stratigraphy, heavy metals, molluscs, artefacts and environmental evidence from site WF5738. (Cu and Pb values are in ppm)

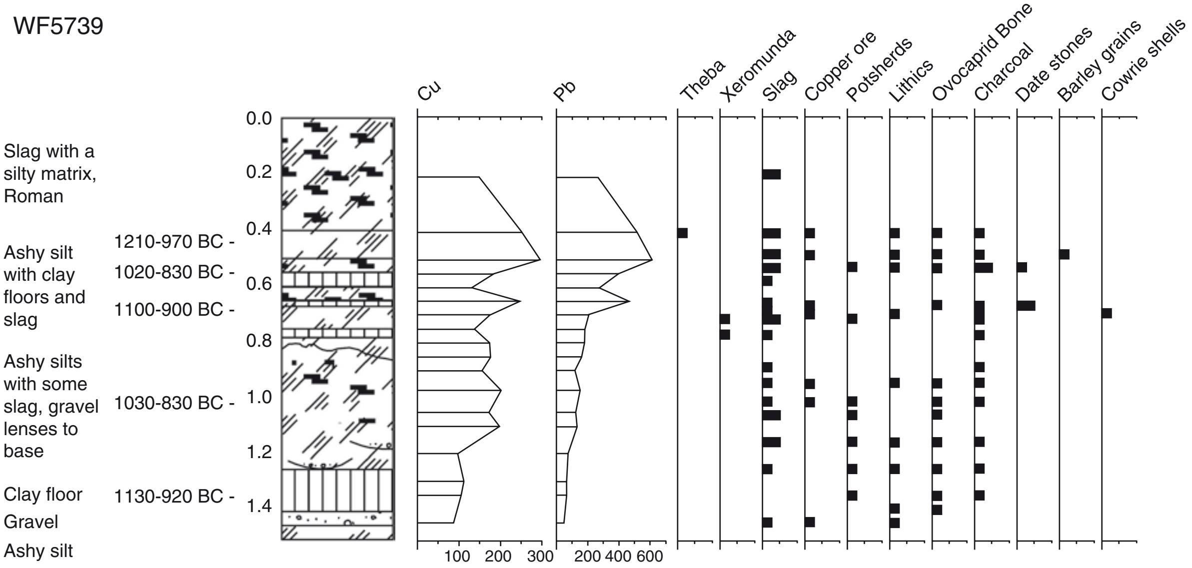


Fig. 8.10 Summary of dating, stratigraphy, heavy metals, molluscs, artefacts and environmental evidence from site WF5739. (Cu and Pb values are in ppm)

can only have functioned seasonally and inefficiently (Crook 2009). The field system was fed by run-off, either from adjacent slopes, or from diversions from the main wadi channel. Although there is occasional evidence for perennial water in parts of the irrigation system, it is likely that there was, at most, a seasonal flush of forage in the largest part of the system: it would have been necessary to take stock elsewhere to graze at other times, possibly onto the upland plateau of the Edom Mountains, as some local Bedouin groups do during summer today. Indeed Mattingly et al. (2007a) document Classical-period pastoral sites at this time in the hills overlooking the Faynan. Thus, for much of the year, the stock would have been feeding in areas where the level of metal pollution was relatively low.

Imported food (and other items) was thus present in the Faynan from the Chalcolithic, when the import of dried fish and raisins can be substantiated (Fig. 8.8). There is also good evidence for the import of food items in the Iron Age. Mattingley et al. (2007a) document imported fish for the Roman period and it can be argued that by Classical times, it is very likely that the overwhelming proportion of food consumed by the Faynan workforce originated elsewhere. This observation has profound significance for the health of the industrial population, since it means that the dietary ingestion of heavy metal pollution would have been minimized. The metal workers evidently had the resources to be able to import exotic food items and other non-essentials, such as seashell, even in the earliest phases. It is notable also that the sheep/goat bones associated with the smelting sites are derived from the high-quality parts of the carcass. These were not low-status individuals, but seem, rather, to have been well-rewarded professionals in each of the key metal-winning phases: the Chalcolithic/Early Bronze Age, the Iron Age and the Roman/Byzantine periods.

In addition to the climatic problems, the metal extraction and smelting which characterized the Faynan orefield led to considerable risks for the workforce. Metals would have been ingested through the breathing in of vapours and from polluted dust, through polluted water, through contamination of food on dusty surfaces during preparation, and from the metal load contained in locally-grown food, as both cereals and grazing animals are known to bioaccumulate (Grattan et al. 2002, 2007; Pyatt and Grattan 2001; Pyatt et al. 2005). The only mitigating factor is the strong probability, discussed above, that much of the food was imported and would thus have been relatively low in metal pollution. Nevertheless, life expectancy among the professional groups who operated the system would have been low and it is thus likely that the metal industry in the

Faynan was a net importer of personnel: professionals as well as the well-documented slave laborers of the Roman Period. This could only have been possible in regional systems with well-developed linkages—the very systems which could generate sufficient demand for copper to justify industrial activity in such a remote and arduous locality as the Wadi Faynan.

As it expanded and became more polluting, the Faynan complex became progressively more dependent upon the outside world, for fuel, food, labor and for a market for its copper. By the Roman period, it could no longer have been self-sufficient, but was instead completely dependent on the network of exchange within the Empire. Export to, and supply from, distant localities, together with local transport of ore from mines to smelting sites, would have required numerous draught animals. The maintenance of these animals would have generated considerable demand for forage in the Faynan. Forage and holding areas would have also been necessary for animals imported for meat, while they awaited slaughter. We therefore reinterpret the great WF4 field system as primarily operated for animal forage and stock-penning, rather than for arable agriculture. This interpretation would conform to the hydrology of the system (Crook 2009) and to the geoarchaeological evidence described above.

8.7 Conclusions

This chapter has explored the human Paleoecology of the Faynan orefield over the Holocene and has reinterpreted the function of the WF4 field system. During the Pre-Pottery Neolithic, early inhabitants adopted stock-rearing and cereal cultivation in a relatively benevolent wooded steppe landscape. In the later Neolithic, aridification set in, the steppe became devoid of trees and soil erosion became marked. The exploitation of copper ores started, at first for powders and ornamental stone, although there are indications that ores were being heated by the end of the Neolithic, whether purposely or by mistake is unclear.

Aridification became more marked during the Chalcolithic and Early Bronze Age. Cereal farming was still occurring locally, but now irrigated using small-scale floodwater farming. Sizeable settlements are known at this time. The earliest dated slags point to the inception of copper extraction during the Chalcolithic. Already, at that stage, imported items including seashells, fish and raisins were present in the diet of the metal-processors, and they were eating the best cuts of the sheep/goat carcass, suggesting external linkages by this time and also that they were of relatively high status.

The area was largely abandoned apart from transient pastoralists during the Middle Bronze Age and metal-winning seems to have restarted during the Late Bronze Age. Some activity continued during Iron Age I, with intensification during Iron Age II during the rise of the Edomite kingdom. Again, imported items were present in the metal processors' diet and they ate the 'best cuts'.

The Edomite kingdom was replaced by the Nabateans, and the metal industry of the Faynan waned in importance at this time. Under Imperial Rome, however, the Faynan reached its apogee. At this stage, convicts were at times imported as laborers. The skilled work was done by professionals, however, and again, they seem to have been well-fed and well-rewarded, with most food coming from distant sources. The fact that their food was largely imported and thus low in bioaccumulated heavy metals would have been critical in prolonging the lives of the metal workers. Miners and metalworkers on the Faynan orefield confronted a harsh environment, which their activities seem to have made even more hostile. They ran considerable risks, but it seems that they were relatively well-rewarded, by the standards of the ancient world.

The orefield was exploited only to satisfy the needs of the outside world for copper during phases where there were well-integrated economic systems, and there seems to have been tangible rewards for so doing. In many ways, the exploitation of copper ores in this remote and hostile landscape seems only to have happened and been possible because of its linkages with the outside world. The geoarchaeological evidence points to the overwhelming importance of the instrument of these linkages—pack animals—as the object of the great field system of the Faynan. As a metal-winning center Faynan was nothing without its linkages—it could only exist as a node in the local and regional networks.

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