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King Solomon's MinersNStarvation and Bioaccumulation? An Environmental Archaeological Investigation in Southern Jordan

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Copper mining and smelting were important activities in various predesert wadis during the Iron Age, Nabatean, Roman, and Byzantine periods in southern Jordan and major spoil tips to gether with slag heaps remain as a legacy of such enterprises. Barley has grown in the area for a prolonged period and currently
wild barley plants are a4ected by toxic cations, which reduce their yields. It is considered that such plants provide an adequate model to assess how similar plants would have performed, in terms of productivity, in the past. The population of miners/slaves, guards, etc., would have been subject to bioac cumulation of heavy metals, which conceivably would have led to detrimental effects on their health. Inhalation and ingestion of particulate pollutants cannot be discounted. It is argued that the population may have been further weakened as a consequence of food shortage, due to reduced plant productivity, as cereals are important foods for both humans and the animals upon which they are dependent. A sizeable mining community could only have been maintained by large-scale importation of food or a massive intensification of agricultural activity.

INTRODUCTION

East of the major road connecting Amman, the capital city of Jordan, with Aqaba on the Red Sea, lies an isolated boulder-strewn desert in which the Dana Reserve (managed under the auspices of the Jordanian Royal Society for the Conservation of Nature) is located. It is the focus of the Wadi Faynan survey by the British Institute at Amman for Archaeology and History. This article relates to a visit in 1998of an international, interdisciplinary team composed of archaeologists, geomorphologists, geographers, palynol ogists, and environmental quality specialists (Barker et al., 1997,1998)as part of an ongoing research program. In the isolated Faynan area are located a number of major wadis which intermittently drain limestone, sandstone, and basaltic areas to the north and east; they include Wadi Dana, Wadi Ghuwayr, and Wadi Shegar. The area has been occupied by humans for a prolonged period and the "nd, by the team, of a 250,000-year-old hand axe in a gravel terrace is of signi"cance in this context. From the Bronze Age and thence through the Iron Age, Nabatean, Roman, and Byzantine periods, extensive mining, particularly for copper (and lead), occurred and the legacy of such extensive ancient metallurgical enterprises remains today in the form of major spoil tips where cations including copper, lead, and manganese are present in high concentrations in both the spoil tips and the associated sediments. Thus, unpublished data from Grattan et al. (using ICP-MS) and Pyatt et al. (using energy dispersive X-ray microanalysis) have revealed the presence of high concentrations of copper in the area (Fig. 1).

Hauptmann et al. (1992), in their comprehensive article, noted that the sedimentary ore deposit at Feinan has been exploited since the seventh millenium B.C. and record peaks of copper production in the Early Bronze Age, the Iron Age, and the Roman period. The resultant ancient spoil tips represent potentially highly dynamic systems and heavy metals, in particulate form or in solution/suspension, can be mobilized by processes including sheet and gulley erosion, atmospheric erosion (Pyatt and Birch, 1994), and leaching and thence will ultimately contaminate adjacent habitats.

To the west of Khirbet Faynan, the major classical site in the valley, lies an extensive ancient "eld system. It is con sidered that the "eld system, with its associated irrigation channels, was used for agricultural purposes to provide food for the mining and associated military populations inhabiting and exploiting this area in Nabatean, Roman, and Byzantine periods, although it also incorporates traces of earlier agricultural systems (Barker et al., 1997, 1998).

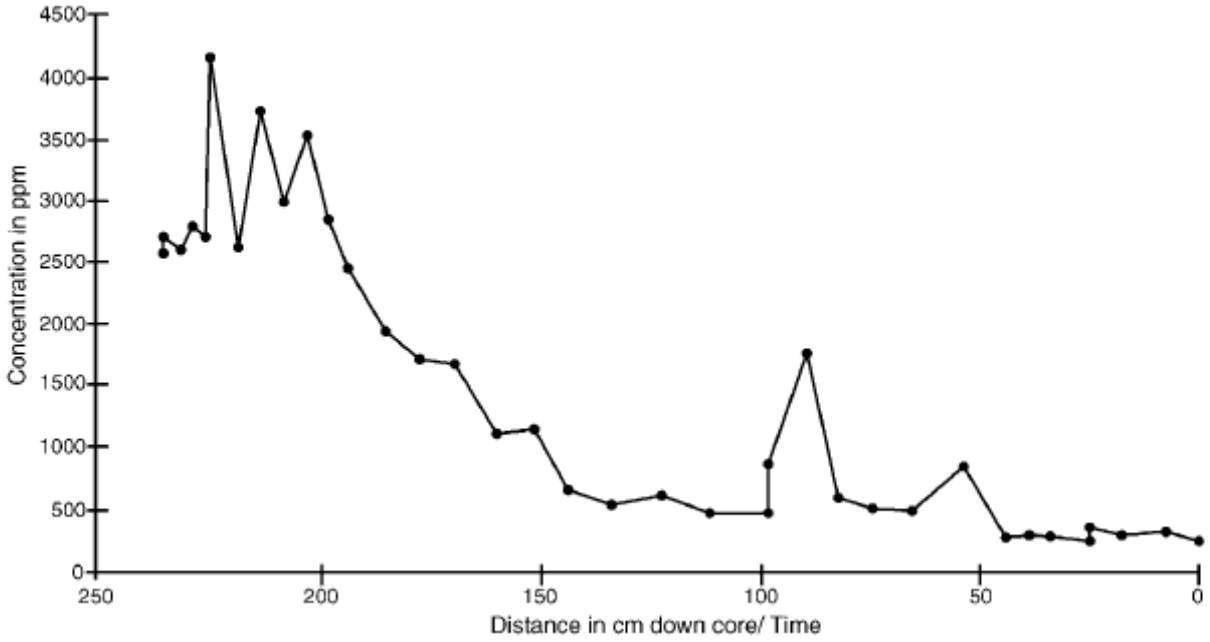

FIG. 1. Copper concentration in deposits adjacent to Khirbet Faynan.

RESULTS

The spoil and slag tip chosen for this current investigation lies on the southern side of Wadi Dana adjacent to Khirbet Faynan. It commences (#oor of the tip) at ca. 18 m above the rock-strewn wadi #oor and thence achieves additional heights varying between ca. 9 and 12 m; the overall length of the tip is currently ca. 320 m. The substrate includes spoil, slag, pottery, limestone, sandstone, and basaltic material of varying sizes. An organic increment is generally lacking but slight accumulation of material occurs, for example, where protection from erosion is a!orded by abiotic features such as boulders. The results are presented in Tables 1, 2, and 3.

TABLE 1
Major Species of the Wadi Ghuwayr Spoil Tip

Species	Family	Spoila	Spoilb	Conta	Contb
Asphodelus ,stulosa	Liliaceae	5	0.3	6	0.4
Ephedra alte	Ephederaceae	18	0.7	15	0.6
Gymnarrhena micrantha	Compositae	10	1.3	12	2.2
Haloxylon salicornicum	Chenopodiaceae	11	0.4	15	0.6
Hordeum glaucum	Gramineae	21	2.0	15	2.4
Plantago coronopus	Plantaginaceae	8	0.8	6	0.2
;rginea maritima	Liliaceae	30	1.2	18	0.7
Total percentage cover:			6.7		7.1

Note. Values are presented as percentage cover (derived from 25]1.0 m2 quadrats).

It has not currently been established whether any of these species are presented in the form of heavy metal ecotypes.

a Maximum percentage cover.

b Cover value derived from mean of 25]1 m2 quadrats.

Table 1 lists the major plant species of both the spoil tip and a control site (cont) some 0.5 km to the south}southeast.

A transect was established from the spoil tip to a site ca. 1.0km to the south}southeast where metallurgical activity, at any time, was not evident. The heights of wild barley plants in the spoil tip area varied between 11 and 15 cm

TABLE 2
Potential Seed Production by Wild Barley Plants

Distance from spoil tip (m)	No. of potential seeds	Mean
Spoil		
0	14,16,15,16,18	15.8
1	16,14,16,14,14	14.8
2	16,14,14,16,16	15.2
3	16,18,12,14,16	15.2
4	14,14,16,14,16	14.8
5	16,16,14,14,16	15.2
6 (ecotone)	20,14,16,16,14	16.0
Nonspoil		
7	20,16,18,16,16	17.2
8	14,12,18,16,18	15.6
9	16,14,14,16,18	15.6
10	18,16,14,12,16	15.2
15	16,16,18,20,22	18.4
20	20,16,14,18,20	17.6
25	20,18,16,14,20	17.6
50	20,22,18,20,20	20.0
100	20,18,20,22,20	20.0
200	20,20,18,22,18	19.6
300	18,20,18,24,18	19.6
400	18,22,20,22,20	20.4
500	28,26,28,28,28	27.6
1000	28,26,26,28,28	27.2

TABLE 3
Copper Values[a]

Sheep urine	5
Sheep feces	10
Goat milk	3
Surface of spoil tip	200
Control site	0

a ppm.

(mean 13.2 cm), while in the control area the values varied between 13 and 15 cm (mean 13.6 cm); no signi"cant di!erence in height, as a measure of biomass, was hence apparent.

Table 2 indicates potential seed production by barley plants on the same transect and it is apparent that with a decrease in metalliferous pollution with increasing dis tance from the pollution source, the number of potential seeds produced was enhanced.

Copper content was determined in the "eld by means of Merck Merckoquant strips and the obtained values are found in Table 3.

Hence it is apparent that the herbivore trophic level had bioaccumulated copper from the grazing of vegetation in this polluted landscape a!ected by ancient metallurgical enterprises; this cation would be subsequently available in the human food chain, e.g., in the forms of milk, cheese, and yogurt, to the Bedouins in the area of Wadi Dana and further a"eld.

A more severely polluted site is located to the north of Wadi Faynan at Khirbet en Nahas where surface material has a copper content in excess of 300 ppm and sheep feces have an enhanced value of ca. 25 ppm. Engel (1993) examined a strati"ed slag tip in this area and obtained radiocar bon dates for the charcoal which ranged from the 12th to the 9th century B.C. A dramatic change in wild barley plants was evident at this location: the heights of the plants were markedly reduced from those described earlier, to 6}10 cm, while the seed production potential was massively reduced, to 9 seeds per 20 plants (cf. Table 2).

DISCUSSION

Wild barley plants exhibit a decrease in biomass as the metalliferous spoil tip is approached. More importantly, however, potential seed production is detrimentally a!ected by the spoil tip environment. It is suggested that this model would have also been applicable to such plants grown for food by the populations (miners/slaves, guards, etc.) living in the area during the Nabatean, Roman, and Byzantine periods when such environmental pollution would have been even more severe because of factors including air pollution episodes resultant from the active smelting furnaces. Eras of food shortage as a result of poor plant performance are conceivable. The "nding of barley pollen in sediments of Nabatean and Roman date (Hunt, personal communication) is of importance in this context. Braidwood (1967) has also noted that, in Jarmo (Iraq), deposits dated at 6750 B.C. contained seeds of both barley and wheat.

Interestingly, there is evidence of intensive manuring throughout the large "eld system, suggesting that measures were taken in the Roman period to try to counterbalance declining yields and crop fertility which were likely to have been a consequence of the enhanced environmental pollu tion at that time. Slaves weakened by such exposures to heavy metals and starvation were unlikely to survive long and their e!ectiveness to their masters would have been limited. It is likely that fresh supplies of slaves, to mine the copper, would need to have been imported on a fairly regular basis. This would have been a time of food shortage, bioaccumulation, and severe occupational health problems.

CONCLUSIONS

Barley has grown in this area since ancient times and plants of wild barley still persist. With the marked decrease in both biomass per unit area and especially the seed pro duction of barley plants caused by metalliferous pollution, as illustrated in this model, there would have been a need, in earlier times, to either import additional food or extend the "eld system away from the more obvious sources of envir onmental pollution, to provide adequate food for the popu lation.

It is considered that individuals living in earlier periods (e.g., Roman and Byzantine) would have been weakened physiologically as a consequence of bioaccumulation of metals such as copper and lead through trophic levels, together with the direct inhalation and ingestion of atmo spherically transported pollutants. Evidence is presented concerning the current bioaccumulation of copper through trophic levels which conceivably may have deleterious ef fects on the local Bedouin as a consequence of eating con taminated dairy produce.

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