



# The geoarchaeology of “waste heaps” from the ancient mining and beneficiation of copper-rich ores in the Wadi Khalid in southern Jordan



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## ABSTRACT

Two main types of ancient mining-waste/spoil deposits were identified on the floor of the Wadi Khalid in the foothills of the Mountains of Edom near the ancient metallurgical centre of the Khirbat Faynan. The Khalid OP Beds are primarily the product of the purposeful breaking and selection of copper-rich clasts of particular sizes as part of the beneficiation of the mined ores, whereas the Khalid W Beds appear to be the result of the widespread discard of the more abundant final “waste products”. Geochemical studies of their surface copper contents by p-XRF of both deposits at eroding exposures conform to these interpretations.

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## 1. Introduction

This reconnaissance within the hyper-arid Wadi Khalid in southern Jordan examined if it is possible to relate “mining waste-spoil heaps” associated with the ancient mining of copper ores to:

- (i) ore-beneficiation after its quarrying; and/or
- (ii) the discard of unwanted “final” waste materials after all such activities had ceased.

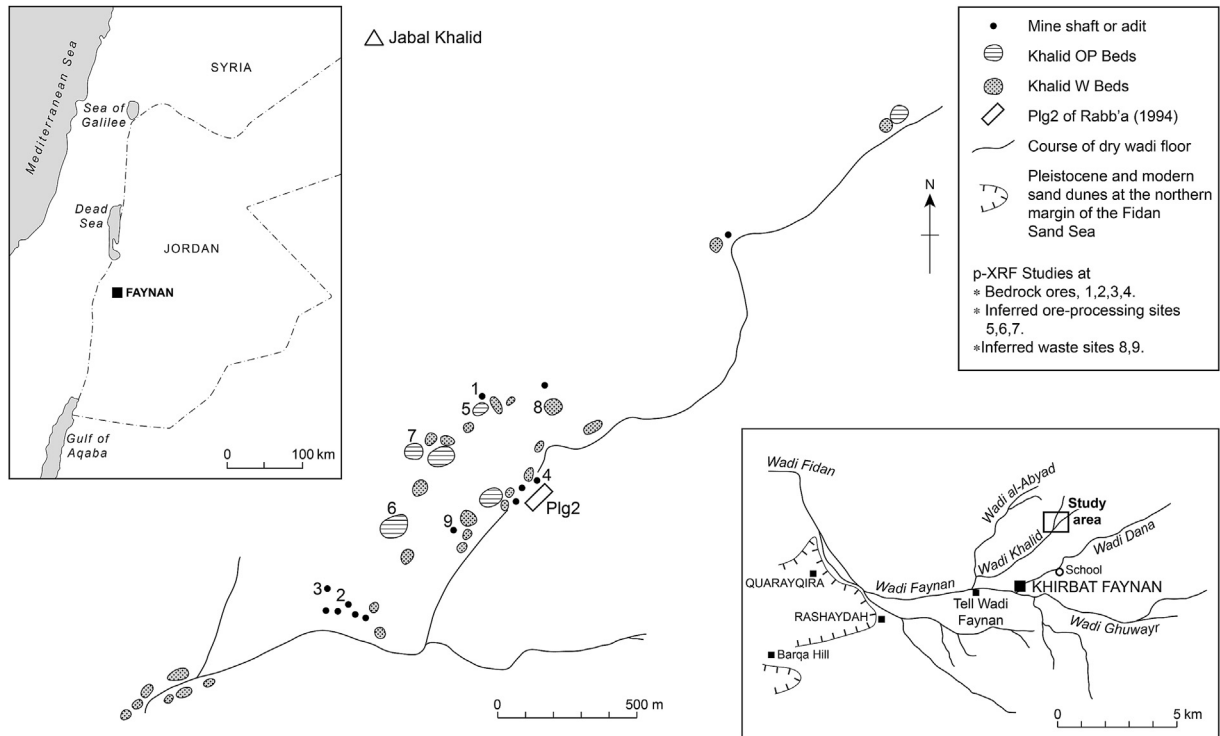
The consequences of recognising different stages in the metallurgical preparation of ores at this location before their smelting is of self-evident importance for the understanding and management of polluted sediments or soils from industrial-scale metallurgy, here and elsewhere, that have taken place in “recent historic” times. In specifically archaeometallurgical terms, they are clearly also relevant to the identification of any ancient “metallurgical chain” – “*chaîne opératoire*” – likely to have existed in this centre of

ancient metallurgy. This chain is a central concept in Hauptmann's (2000; 2007) remarkable monograph on this area and the ancient copper metallurgy that took place within it. He simplified the idea as a series of “metallurgical steps” in the types of human activities that might have taken place and of associated transformations of materials. The chain begins with the prospection for and the mining-quarrying of ore sources. It continues through the pre-treatments and concentration of the more copper-rich materials (beneficiation) to improve effectiveness at the next metallurgical stage with its recognisable hot metallurgical activities that include ore smelting (and perhaps ore roasting). These were followed by further processing, alloying, casting, shaping etc., eventually leading to the export/trade/use of the metal products (Hauptmann, 2007; page 7, his Figure 2.1).

The Wadi Khalid is a short and broad wadi in the order of 3–4 km long, ~1.3 km wide in the northern portion of the archeologically-intensively surveyed areas of the Wadis Dana and Faynan in the Faynan Orefield and on the lower slopes of the mountain front of the Mountains of Edom and ~1.5 km north of the major ancient centre of copper-smelting at the Khirbat Faynan (classical Phaeno: Figs. 1 and 2; and see Adams, 1999; Adams et al., 2010; Barker et al., 2007; Gilbertson et al., 2007; Grattan et al.,

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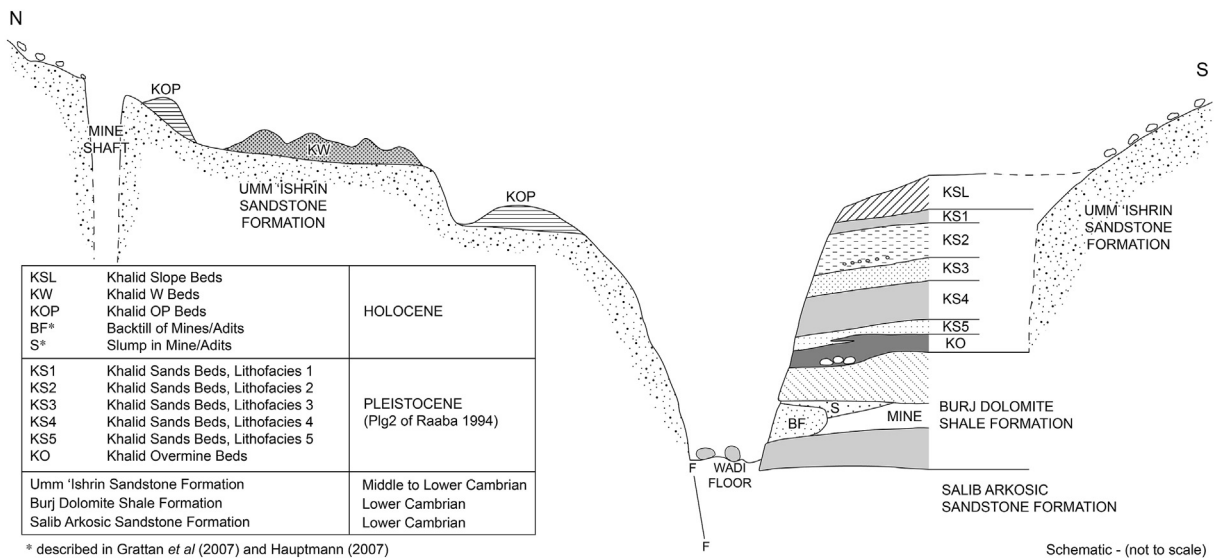
E-mail addresses: [dave.gilbertson@plymouth.ac.uk](mailto:dave.gilbertson@plymouth.ac.uk), [jpg@aber.ac.uk](mailto:jpg@aber.ac.uk) (J.P. Grattan).



**Fig. 1.** The distribution of the major archaeometallurgical sites at and around the Khirbat Faynan in the Faynan Orefield of southern Jordan; the hyper-arid Wadi Khalid; the high point of the Jabal Khalid, the large through-wadis of the Dana and Ghuwair that cross the mountain front of the Mountains of Edom; the distributions of ancient copper mines and adits studied in the Wadi Khalid; the outcrop of Pleistocene deposits designated Plg2 by Raab'a; the distributions and sites codes of the two surficial Beds designated and mapped in this paper – the *Khalid OP Beds* and the *Khalid W Beds*; and the closest proximity of the modern and Pleistocene aeolian sand dunes and sand sheets that comprise the Fidan Sand Sea and their distance from the Late Pleistocene dune sands and colluvium recognised here as the *Khalid Sand Beds* within the Wadi Khalid (many sources, this survey and McLaren et al., 2004, 2007; Raab'a 1994; Waller, 2010).

2007; Hauptmann, 2000, 2007; Hunt et al., 2004; Hunt and el-Rishi, 2011; Mattingly et al., 2007a,b; Weisburger, 2006). The climate is very hot in summer and hyper-arid. The patchy and limited vegetation is a grazed-steppe. The surficial deposits and the soils on the hillslopes are poorly known with little natural exposure. They frequently appear thin, or non-existent, with extensive

outcrops of hard sandstones whose often bare surfaces are sometimes littered with angular breccia and thin blown sands (El-Rishi et al., 2007; Raab'a 1994). The rugged deserts terrain of the floor and sides of the Wadi Khalid is mainly eroded into Palaeozoic and Late Proterozoic bedrocks whose high points, such as Jabal Khalid, are over 700–800 m to the north of the Wadi (Fig. 1). To the east,



**Fig. 2.** Schematic profiles, **not to scale**, indicating the relationships between the wadi floor, mines, adits and vertical shafts driven to the copper-rich ores of the Burj Dolomite Shale Formation (Cambrian); the sequence of Late Quaternary dune-sediments and colluvium (KO to KSL, Grattan unpublished) previously grouped as the mapping unit Plg2 of Raab'a (1994); and the surficial anthropogenic deposits of the Khalid OP Beds and the Khalid W Beds within the Wadi Khalid recognised in this study and described in detail in Table 1.

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