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RESEARCH ARTICLE

EARLY TECHNOLOGY OF COPPER MINING IN ANTIQUITY: WADI ARABA, JORDAN, SOUTHERN LEVANT (ELAF QURAYSH ROUTE)

Mohammad Waheeb, Nermin Khasawneh

Department of Sustainable Tourism, Queen Rania Faculty of Tourism and Heritage, The Hashemite University, Jordan
(✉ mwaheeb@hu.edu.jo)

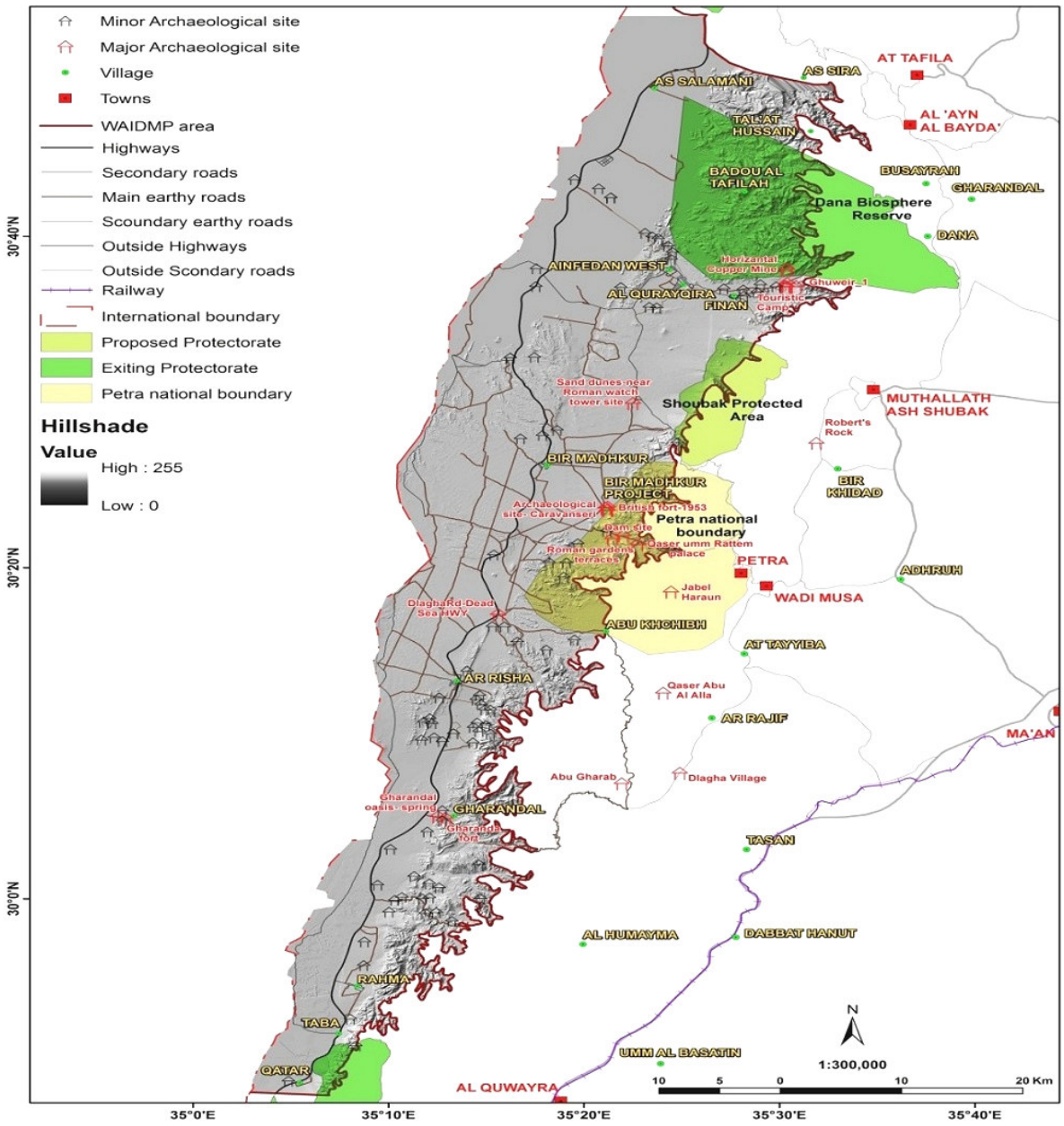

Figure 1. A map of Wadi Araba showing the distribution of significant archaeological sites (Bashar, 2020).

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ABSTRACT. *Our research was prompted by the need to study the history of metallurgy in Wadi Araba during the Bronze Age, as the beginning of this period witnessed the development and prosperity of copper metallurgy in the Near East. This study deals with copper and its metallurgy concerning industrialization sites and facilities during the Bronze Age. This achievement led the craftsman to produce hard-bronze metals. Apart from the very early stages when copper ores could be collected from the surface, all copper ores had to be mined, and different mining methods were used, such as open pits, tunnels (horizontal and shaft), and fire settings. The research concludes that limited archaeological investigations have been carried out in the prospective region, probably because of the difficult accessibility of the area. Therefore, the importance of the copper deposit in prehistoric and early historic times in Wadi Araba deserves more attention in terms of more scientific investigations and public awareness in order to preserve valuable cultural heritage resources and to be adopted as a tourist site.*

KEYWORDS. *Metallurgy, Mining Tools, Archaeology, Copper, Bronze, Cultural Heritage, Excavations, Wadi Araba, Jordan.*

INTRODUCTION

The terms mine and mining are related to the Celtic word *mein* meaning raw metal and the Cymric word *mwyn*, but the classical term for a mine was *metallon* or *metallum* (Forbes 1950). Another view is that the word is related to Greek *metallao*, which means looking for other things (Forbes 1963).

Mining began very early in the Pre-Pottery Neolithic, but smelting activities started much later in Wadi Araba, which is one of the most important regions for ancient copper ores in the southern Levant, exploited since the 7th millennium BC, where the first metal was smelted during the Chalcolithic period (Hauptmann *et al.* 1992). From the very early stages, when copper ores could be collected from the surface, all the copper ores had to be mined. Simple tools used for quarrying were adequate for this purpose. As the mines moved deeper into the mountains, ventilation developed. Tools were introduced and used by workers in direct relation to the material being worked on (Esterer 1969). Here, we present data on the tools, mining methods, transport of metal ores and our view that the ancient mining sites of Wadi Araba (Figure 1) should be preserved as a distinctive environment for early technology.

MINING TOOLS

Mining tools have been used since prehistoric times in many parts of the Old World. Most of these tools are made of stone. It is worth noting that the arrival of the Bronze Age did not stop the stone mining for tool making for many centuries. Stone tools have a long history of use, as well as the techniques for making them well-developed (Forbes 1963).

These tools are made from different types of stones, such as flint, basalt, and limestone. Many Bronze Age workshops have been found to produce a variety of materials and tools for different purposes (Waheeb 1988). Amiran has mentioned that Arad, a place in southern Palestine, was used as a workshop for manufacturing the flint tools during the Bronze Age (Amiran *et al.* 1978). Another stone tool workshop was discovered at the Yarmuk site (Rosen 1983). The manufacture of flint tools continued during the Middle and Late Bronze Ages (Ben-Tor 1975).

Bronze Age workshops were located near raw materials, such as Khirbet Nahas in Wadi Araba (Figure 2) and the Jordan Valley (Kenyon 1966), in Galiel (Dever 1973). The manufacturer depended on stones that were scattered on the surface of the ground and on stones beside the rivers (Amiran & Porat 1984). As the demand for some types of stones increased, workers began to search for new sources and quarry stones. This quarrying occurred approximately 3000 BC (Lucas & Harris 1962).

Figure 2. Remains of the Khirbet Nahas complex at Wadi Araba (Waheeb, 2015).

Figure 3. Remains of a horizontal mine at Wadi Khaled (Waheeb, 2015).

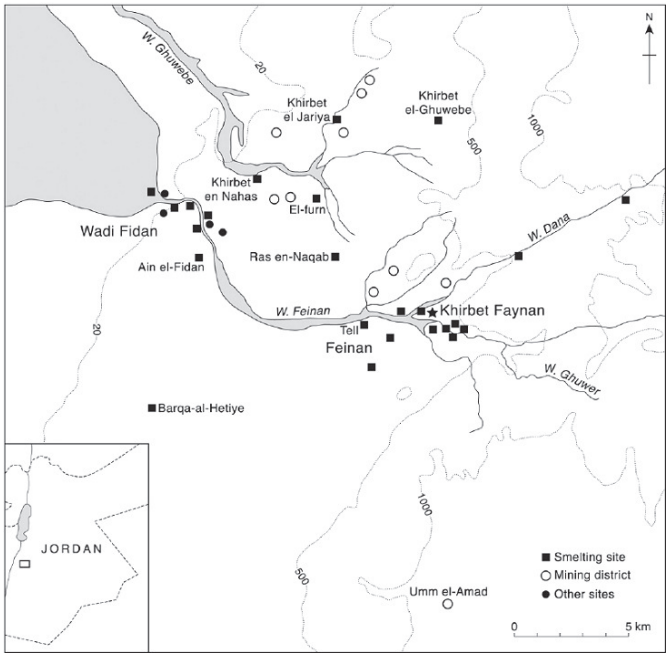

Figure 4. Mining areas in Feinan, Wadi Fidan and surrounding areas (Grattan *et al.* 2007)

MINING METHODS

Open-Cast Mining

Initially, prehistoric miners may have used this method when they first attempted to explore copper deposits. The open-cast mining could have eventually been abandoned because it was too time-consuming, and a new method was subsequently adopted.

This method was used in the western and eastern parts of Wadi Araba, but a different stage of mining technology was utilized in Timna. Many of the pit walls showed clear evidence of open-pit mining, a quarrying technique (Forbes 1972).

Tunneling

To extract copper ores with a hammer or pickaxe, miners made holes in rocks (De-Jesus 1978). Therefore, the tunnel presumably follows the ore deposit. This type of mining was associated with vein-type deposits. The science of mining had to be applied in the form of digging through rocks, both soft and hard (Duncan 1931). It is not known where these techniques were developed first, but it has been noted that some aspects of mining bear a close resemblance to quarrying, particularly in the form of rock cutting (Rothenberg 1962) (Figure 3).

Horizontal Tunneling

The shafts in which they worked perforated horizontally (Figure 3) the mountain in the form of corridors. Since the Chalcolithic period, the shafts were driven into the rock with a groove cut around the entrance, presumably at the beginning of an attempted enlargement of the opening (Rothenberg *et al.* 1978).

The very beginning of the Early Bronze Age (EBI) has thus far been represented in Timna by the earliest underground mining system, area T, found to date. It is a real shaft and gallery system, hammered out with stone tools and square and round mining hammers, with a biconical shaft hole in the center. It has been dated by pottery found in underground workings together with numerous typical mining tools, including a typical Early Bronze Age I lamp. No copper mine in the Early Bronze Age has yet been identified in Timna, but this period is represented by several sites in the southern Araba, such as sites numbered 67, 68, 144, 67, and 201 (Paul & Dever 1973).

In some mines, rock pillars were left standing at the entrance to the mine, while other pillars supported the roof inside to prevent any caving-in. Glueck referred to the copper mines in western Arabia, at Timna. These mines were investigated in the Middle Bronze Age, approximately 2000 BC (Glueck 1940).

In the eastern part of Wadi Araba, without exaggeration, most of the nearly 60 mines at Qalb-Ratiye began in the Chalcolithic or Early Bronze Age. They represent the oldest known large copper mining area in the Near East (Hauptman 1986). In Wadi Abaid, more Chalcolithic-Bronze Age mines have been exploited. In addition, there was one Roman prospecting tunnel. These are extraordinarily wide dimensions, which makes

it clear that nearly all other mines date back to older activities and are rarely enlarged in the entrance area (Forbes 1963). Miners dug small, narrow horizontal tunnels on the wadis slopes to reach the copper stratum. They then followed the slope into the mountain, enlarging the galleries into chambers and leaving pillars standing to carry the roof. Sometimes, these chambers are interconnected with tunnels (Hauptmann & Weisgerber 1987).

Bronze Age mining was concentrated in the area of Feinan (Figure 4), particularly at Wadi Khalid. Several mines were observed between Wadi Khalid and Wadi Ratiye. Preliminary observations suggest dating to the Early Bronze Age on the evidence of pottery that occurred in tailings inside mines. In order to exploit the mineralized straight, the pits were built in a chamber-pillar construction. The height is 1–1.5 m and extends horizontally at least 30 × 50 m. These chambers are sometimes supported by artificial pillars. They followed a slightly inclined or horizontal direction to a depth of 15–20 m. Near the mouths of the mines, only small dumps are visible, which gives no indication of the true dimension of the early mines (Bender 1974). It is possible for the extent of the tunnels to reach 40–50 in the rock, as was noticed in Wadi Araba (Kind 1965).

The most impressive mining monument is Umm El-Amad, located 5 km south of Feinan. In contrast to the mines in the Wadi Ratiye, this pit was still well-preserved. The mouth, which is typical of Roman mining, may date back to a far earlier period, perhaps to the Bronze Age. The mine was driven almost horizontally into a horizon with secondary copper minerals in the white sandstone. Slit samples cut from the copper-bearing layer near the mouth had a copper content of only 1.12% (Glueck 1940), in contrast to earlier reports that were written by Frank and Glueck (Hauptmann & Weisgerber 1987).

This mine, which extends 55–120 m and reaches a height of up to 2.5 m, is six times larger than previously known. The pillars were perfectly cut and situated at regular intervals. Just as on the roof, they also show precise and still fresh chisel marks, which are surprisingly not oriented slanting downward but rather horizontally (De-Jesus 1978).

Shaft Tunneling

This type of mine can be described as a vertical hole going down into the deposit. The nature of the deposit can affect the structure of the mine shape; for example, a shaft may be sunk to exploit a mineral outcrop on or near the surface (William 1976). Shafts may also be a starting point in vein-type deposits. This method of digging or following copper veins resembles the methods of quarrying stones. Therefore, the shape appears to be good. This method was first reported in Timna by Rothenberg (1972) and was used in the eastern part of Wadi Araba. Shafts were sunk either from the surface of the mountains or even in the mines themselves, such as mine 12 in Qalb Ratiye, which dates to the Early Bronze Age (Hauptmann 1986).

Fire Setting

A magnificent description of all the methods of Bronze Age mining is provided in the Bible. This story is based on copper mines in Wadi Araba, in the eastern and western parts. These mines worked from the Early to Middle Bronze Ages and again between the eighteenth and thirteenth centuries BC (Singer *et al.* 1957). The fire setting method consisted of creating a fire to rapidly heat the rock to be mined to a high temperature. Subsequently, it was allowed to cool naturally or quench with water. Thus, loosened to some extent in its natural structure, the rock would develop cracks and flaws, and unless lumps of rock tumbled down by their weight, they would have to be loosened and knocked off with suitable tools (De-Jesus 1978). This method could be used in Wadi Araba for mining copper ore because fire setting was a normal mining technique some 3000 years ago (Singer *et al.* 1957).

MINING SEASON

Weather is very important for those working in mines in Wadi Araba. This should generally be considered a clement. In cold weather, mining operations are complicated by excessive seepage of water into the mine or mining area, which causes difficulty in transporting ores from the mine. In addition, the daily lives of workers and their living conditions may not have been comfortable. As we have mentioned, the ores in Wadi Araba exist in (are situated in) mountainous regions and valleys where they have been exposed to erosion and geothermal activity.

The people who worked in mines depended on a seasonal basis, so they may have seen no need to construct permanent dwellings. It seems likely that due to these factors, the early miners worked during the driest peri-

ods of the year. The summer was the best season for those who worked in the Wadi Araba mines (Forbes 1972). Glueck (1940) indicated that work in the Wadi Araba mining areas could be carried out in the spring and part of winter. The Egyptians followed this system in their mines in the Sina area, and this may refer to the relationship between the Wadi Araba mines and the Sina mines in Egypt during the Bronze Age. The commercial road that was noticed goes to Edom to the west, to Feinan and then to Sina.

Summer is very hot, and the winter is very cold in the area of Wadi Araba. Therefore, spring was expected to be the best season for exploiting these ores from the mines. However, it is possible to work in winter, since the copper ore is important for manufacturing tools and weapons for daily life and military purposes. So investing in Wadi Araba copper ores extended to all the seasons of the year, despite of the lot of hazards in that area.

TRANSPORTATION

The methods of how copper ores were transported in prehistoric times and over what distance are still not clear. Ore was most definitely transported from some mines to centers where smelting could take place during longer periods of the year.

Hauptmann (1986) noticed in mine no. 51 a shaft with stairs along the wall where the ore could be easily carried out, but normally ores and minerals were moved by winches or tripods with wheels. Also, he found indications that perhaps animals were used underground to carry loads. Beside the mouth of mine no. 51, three tanks, two with "tapping holes," were hewn out in the sandstone rock. A typical device to fix animals nearby may indicate that they were used to feeding and watering animals. Animals transported the ore to the central smelter at Feinan town.

As we know, animals had been domesticated and used for loads and for riding, although there is evidence that the domestication of animals in Palestine, at the site of Jericho, had taken place as early as 5000 BC. In addition to that, the geographical situation of the area of Wadi Araba enabled the workers just to use the animals, such as donkeys and horses, to transport the ores to other areas for different purposes (Dajani 1964).

In comparison to the mines of Sinai, we know that food, water and fuel supplies were transported over long distances regularly to its turquoise copper mining camps.

Figure 5. A Byzantine church at Khirbet Feinan used by the community of miners in Wadi Araba during the Byzantine period (Waheeb, 2019).

The ancient mines were worked by annual expeditions sent out from Egypt during the spring. In connection with one of these Egyptian mining expeditions to Sinai, Egyptian records indicate that trains composed of hundreds of donkeys were conducted by peasants, each of whom was responsible for five donkeys. Donkeys were used to maintain a steady flow of supplies of all kinds, including food and water, to the various mining camps. Here, Glueck (1970) believed that a similar organization must have existed to take care of some of the needs of the mining camps in the Wadi Araba. The food, fuel and even water supplies in part must have been brought to such places as Khirbet Nahas and Khirbet Jariyeh by trains of horses and donkeys, which returned laden with the smelted ores (Figure 5).

A little had been written about the workers. There is no doubt that the miner's craft was not regarded as a healthy and pleasant one. Because so many criminals and slaves worked in the mines, most of the labor employed there was unskilled. Sometimes, apart from criminals or slaves, a number of experts must have been presented to direct the work. We still know little about the evolution of the economic and legal aspects of mining, such as claims, ownership of mining rights, etc. (Forber 1963).

In Near Eastern countries, presumably, the same conditions were enjoyed by metalsmiths in the past as today are found among the Gypsies. Itinerant metalworkers from villages and deserts, who are granted certain amenities by villagers and Bedouins, were able to travel from place to place and could trespass on tribal lands because of their useful activities. If in the invasion periods metalworkers were the only people able to travel easily, this may explain the distribution of some types

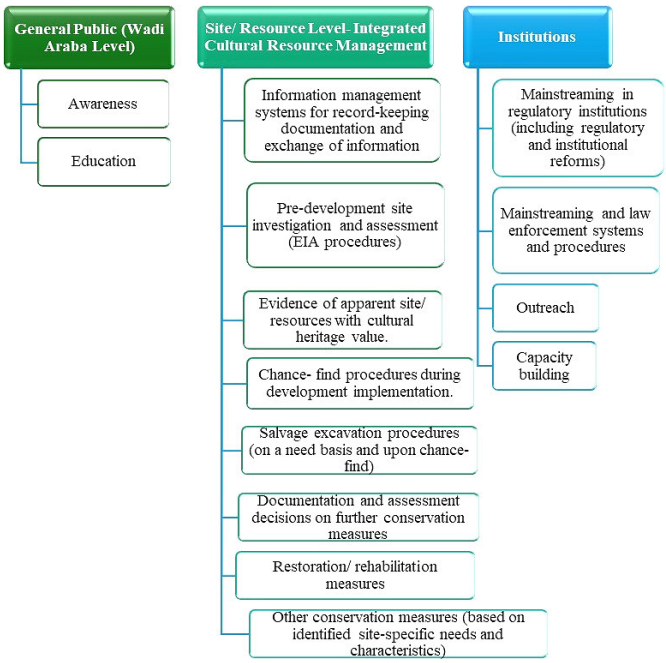

Figure 6. Conceptual model for Wadi Araba.

of metals in Jordan, Palestine, Syria, Mesopotamia, Anatolia, Egypt, and Iran (Dajani 1962).

The question about the situation of those workers in the Bronze Ages is not very clear. The archaeological excavations in Wadi Araba and south Palestine prove that there were specialized workers in many fields of crafts, such as stone makers, textile makers, metalworkers, etc. It is possible to say that the first specialized makers were revealed at the site of Tell Abu Matar, south Palestine, which was dated to 4000–3000 BC (Perrot 1955).

Mendelsohn (1940) mentioned in his book *Guilds in Ancient Palestine* that the workers in early ages organized themselves in guilds to facilitate the exchange. Without suspicion, such guilds existed in the Bronze Ages; therefore, they had relations with those workers in Wadi Araba as members of these guilds.

PRESERVING WADI ARABA MINING SITES

The involvement of the local community in preserving the distinctive environment of the early technology at Wadi Araba is one of our preferences. A conceptual model presenting the proposed impacts and responses is illustrated in Figure 6.

The following are recommended actions to address the positive impacts in light of their relationship to the mining technology debate and, in general, to improve the conservation of archaeological and cultural heritage resources in Wadi Araba. The actions are envisaged to be integrated into the Jordan Valley strategy and/or form the basis for the formulation of an *integrated cultural heritage conservation strategy* for Wadi Araba. Desired outcomes of each action are also described to aid outcome-oriented future planning and implementation of related strategies and action plans. The logical framework of the overall scope and sequence of the proposed response actions is summarized in Figure 7.

Given the serious shortage of information, the need for timely implementation, and the different levels of response measures needed, it is therefore suggested to

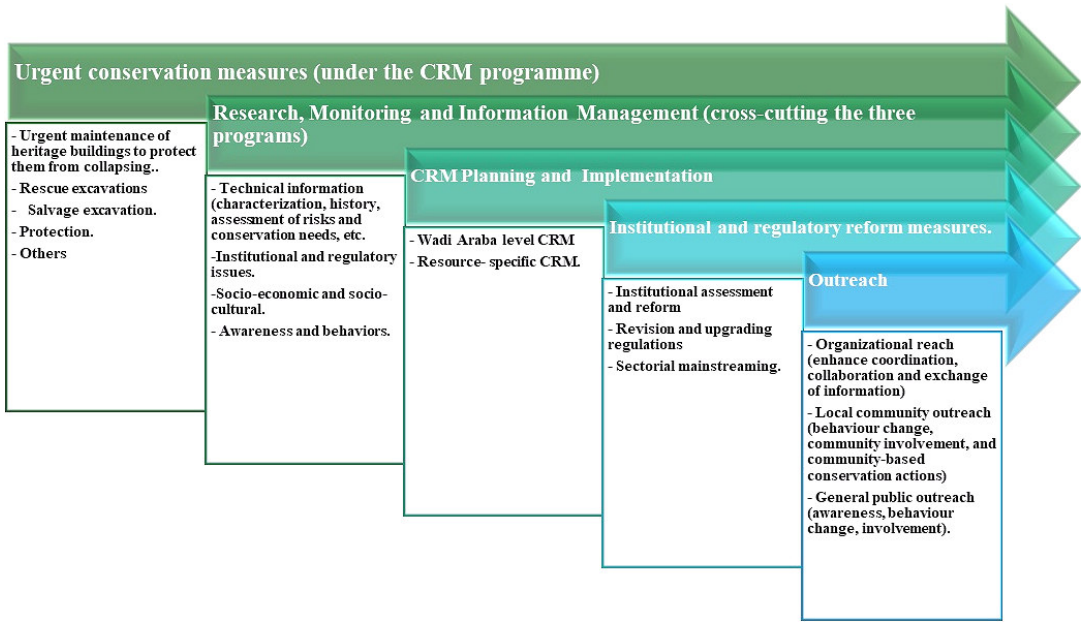

Figure 7. Logical framework of proposed response actions in Wadi Araba.

re-group and package proposed actions and response measures in three major interventions (programs), based on actions needed and approaches suggested to address the conservation and management of archaeological and cultural heritage resources. These recommended interventions can be summarized as follows:

• Regulatory and institutional reform of responsible authority, combined with mainstreaming conservation of cultural heritage in development sectors and regulatory systems of key stakeholding organizations.

• Planning and implementation of an integrated cultural resource management (CRM) strategy for Wadi Araba, and CRM plans for identified heritage resources. The strategy and plans need to apply a comprehensive set of management and conservation measures, including chance-finding and salvage procedures for addressing excavation and conservation requirements for resources that have not been explored yet.

• Outreach program targeting improved communication and collaboration among stakeholders, enhanced education of cultural heritage-related aspects, strengthened local community involvement in the conservation of such valuable resources, and public awareness of the value of cultural heritage resources and the need to conserve them.

CONCLUSIONS

There are several known sites in Wadi Araba with cultural and archaeological (metallurgical) significance in the history of early settlement of human beings in southern Levant and adjacent countries during the Chalcolithic-Bronze Ages.

The above records show a trend of continuation of settlement in Wadi Araba throughout the times, from prehistory to the Bronze Ages, Iron Ages, and Classical Ages, especially along the Elaf Quraysh Route and during the Islamic Ages. The study concluded and refers to the importance of the region as an attractive area for settlement, metal extracting, trade, and limited vegetation through history, etc.

It is reasonable to assume that this area has been the focal point for old civilizations from east to west and from north to south, in particular at Feinan, Khirbet Nahas and Wadi Khalid. Between Wadi Khalid and Wadi Ratiye several mines are still visible and were observed. Preliminary observations suggest their dating to the Early Bronze Age on the evidence of pottery and other datable materials. Wadi Fidan is a complex of sites of regional and international significance because it documents human activities at the very beginning of settled and metallurgical societies, along with the earliest use of copper mixing with tin to produce bronze alloy in the southern Levant region.

The remains of mining methods and techniques are still visible and can be seen on the walls of these mines, which reflects the progress of work achieved by an early man who produced and made a lot of artifacts, either tools or weapons, in the field of copper technology through his continuous efforts.

Urgent discussions are in progress for the proposal to include the Fidan area on the UNESCO World Heritage Tentative List.

The Wadi Araba copper mines and their associated buildings over the ages deserve not only preservation and consolidation, but also some degree of aesthetic and archaeological upgrading in cooperation with the local community and stakeholders, so that they can once again become a focal point of the whole Wadi Araba area in the southern Levant.

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