Metallurgical sites of South Sinai (Egypt) in the Pharaonic Era: New Discoveries

Pierre Tallet, Georges Castel, Philippe Fluzin

Abstract
Since 2006, a joint mission from the Institut français d'archéologie orientale and the Université de Paris Sorbonne (Paris IV) has been investigating a specific region in the south-west of the Sinai peninsula that was the scene of intense exploitation of copper resources by the Egyptians from the very earliest periods of Pharaonic history. Within the context of this research, the remains of numerous metallurgical workshops from different periods have been surveyed. The aim of this article is to present the two most significant discoveries made in this field. To the west of Wadi Nasb, the discovery of a battery of intact furnaces that had been abandoned in antiquity without ever having been used, has allowed for precise observations regarding the construction techniques, ventilation system and the furnace load maintenance of these copper ore smelting units. Reproductions of these furnaces were then put to work as part of an experiment to demonstrate the main characteristics of their functioning. A second site at a locality known as Seh Nasb proved to be a major source of information as to the importance of this mining zone to the Egyptian state during the Old Kingdom. Here, a massive installation of some 27 batteries of furnaces, of a total cumulative length of nearly one kilometre, involving at least 3000 smelting units, reflects the nearly industrial scale of ancient operations in the exploitation of copper in the region.

Résumé
Depuis 2006, une mission conjointe de l'Institut français d'archéologie orientale et de l'Université de Paris Sorbonne (Paris IV) étudie une région bien délimitée, au sud-ouest de la péninsule du Sinaï, qui a été intensément exploitée pour ses ressources en cuivre par les Égyptiens, et ce dès les périodes les plus anciennes de l'histoire pharaonique. Dans le cadre de cette recherche, les vestiges de très nombreux ateliers métallurgiques de différentes époques ont été relevés. L'objectif de cette étude est de présenter les deux découvertes les plus significatives qui ont été faites dans ce domaine. À l'ouest du Wadi Nasb, la découverte d'une batterie de fours intacte, qui avait été abandonnée dans l'Antiquité avant sa mise en service, a permis de faire des observations précises sur les fours de réduction du minerai de cuivre, leur technique de construction, leur système de ventilation et de maintien de la charge. Des reproductions de ces fours ont pu être réalisées ensuite et mises en service pour mettre en évidence les principales caractéristiques de leur fonctionnement. Un second site, au lieu-dit Seh Nasb, donne quant à lui une information capitale sur l'importance de cette zone minière sous l'Ancien Empire. À cet endroit, l'installation massive d'un ensemble de 27 batteries de fours, sur une longueur cumulée de près de 1 km, et comportant un ensemble d'au moins 3 000 unités de réduction, renvoie une image quasi industrielle de l'exploitation ancienne du cuivre dans cette région.

METALLURGICAL SITES OF SOUTH SINAI (EGYPT) IN THE PHARAONIC ERA: NEW DISCOVERIES

P. TALLET, G. CASTEL and P. FLUZIN*

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Keywords: *South Sinai; Old Kingdom; Furnaces; Malachite; Copper.*
Mots-clés : *Sud-Sinaï ; Ancien Empire ; Fours de réduction ; Malachite ; Cuivre.*

INTRODUCTION

Since 2006, a programme of archaeological surveys has been underway as part of a partnership between the Institut français d'archéologie orientale (IFAO) in Cairo and the Université de Paris IV Sorbonne, the aim of which is a general study of Egyptian presence during the Pharaonic era in an important mining area situated in the south-west of the Sinai peninsula, directly above the modern coastal towns of Abu Zenima and Abu Rodeis. During this survey, numerous installations connected to the local production of copper have been discovered and studied. This has led to a completely

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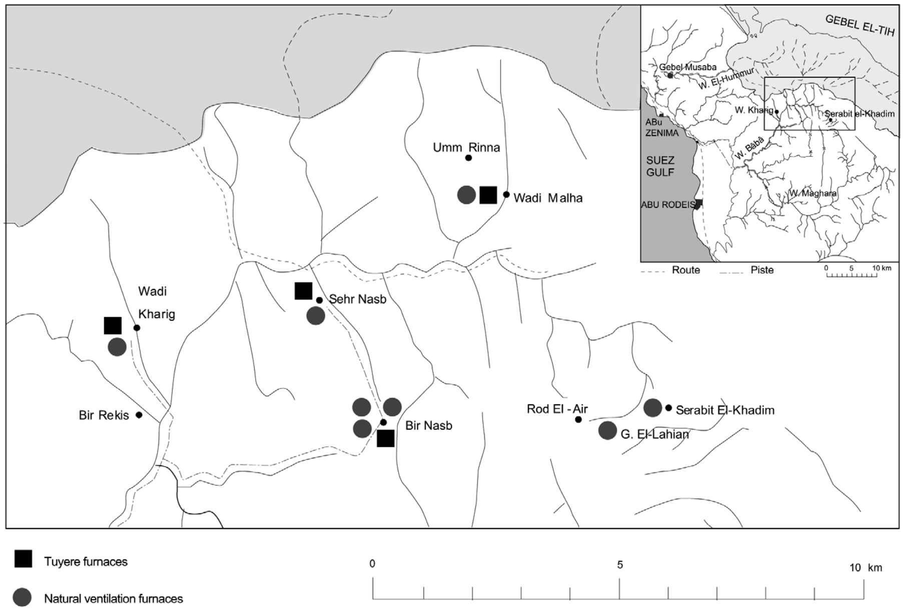

Fig. 1 – *Sinai peninsula (Abu Zenima and Abu Rodeis region) with sites of metallurgical furnaces.*

updated vision of such metallurgical activities during different periods of the Pharaonic history. Furnaces for smelting copper ore using a forced-air intake (tuyere furnace), corresponding to a level of technology that seems to come into being from the New Kingdom (*ca* 1500 BC) and continues in use until the Roman period, have long been recognised, notably in the region of Bir Nasb, where there are remarkable accumulations of slag.[2] The same form of installation has been observed at several places during our survey, most notably at Wadi Kharig, Seh Nasb and at Wadi Malha (fig. 1). However, the most important discoveries concern furnaces employing natural ventilation that date back to the earliest periods of Egyptian history, which were in use in this area at least from around the 5th Dynasty (*ca* 2500 BC) and were probably still employed during the Middle Kingdom (1900-1800 BC).[3]

These installations have been observed at Gebel Musaba, Wadi Kharig, at several spots in Wadi Nasb, on the heights of Gebel el-Lahian and on the plateau of Serabit el-Khadim, site of the great turquoise mines of the Middle Kingdom (fig. 1). Some of them are spectacular, the largest of which at Seh Nasb might encompass almost 3000 smelting units (see *infra*). At other places, the furnaces themselves have disappeared but their position on the ground can be identified by scattered blocks of stone that made up the construction and that are still covered with copper slag adhering to the surface. This is notably the case for a battery of units that lay to the east of Bir Nasb, on the western slope of the mountain a few metres below a pass marked with inscriptions from the Middle Kingdom. The blocks from the demolition of this complex have now spread over an area of nearly 100 m². In order to better understand the working of this type of furnace, we have chosen to present the best preserved structure that we have discovered in the western sector of Wadi Bir Nasb.

2. Petrie, 1906, gives this account (p. 27): "in the Wady Nasb, there is an enormous mass of slag from copper smelting, about 6 or 8 ft. high, and extending apparently over about 500 ft. along the valley, and 300 ft. wide […] this mass of slag […] may amount to 100,000 tons […]". See also Rothenberg, 1987.
3. This technology goes back even further in Egypt since comparable furnaces, working on the same principles have been discovered in Wadi Dara (Eastern Desert) from a time corresponding to the first Dynasty (*ca* 3100-2900 BC), that is, at the very beginning of Egyptian history: *cf.* Castel et Pouit, 1997 : 101-112; Pouit et Castel 1999 : 131-144; Castel *et al.*, 1996: 15-31.

Fig. 2 – *Initial state of battery 062 before excavation.*

METALLURGICAL INSTALLATIONS TO THE WEST OF BIR NASB

One of the best preserved batteries is located to the west of Bir Nasb, on a rocky outcrop above the Bedouin village. In fact, this sector shows two distinct installations standing about 50 metres apart. The first of these (071) has been destroyed by the simple fact of its prolonged use. The stones that composed the uprights of these bloomeries have been shattered by heat and are scattered over the slope below the structures. The second group, however, appears to have never been used, which would explain its exceptional state of preservation. Scorched sandstone blocks indicate that it was built upon the site of a previous installation of a similar function. It is situated on a small rocky platform, the geology of which presents layers of crumbly, stratified sandstone topped by a crust of hard, compact sandstone some ten centimetres thick. The battery is set upon this sandstone crust on the north slope of the mountain facing the prevailing wind. Three or four overturned courses of stones give the initial impression of a collapsed wall (L. 17 x W. 0.50 x H. 0.40 m) (fig. 2). This wall is in fact made up of some 15 identical rectangular structures, which we shall call caissons, of unmortared stone lined up one after the other along the platform running about 60° off North. The front section of each caisson is pierced at its base by two small rectangular openings. Each caisson is a bloomery that was intended for the smelting of malachite ore but which was never used since there are no visible traces of fire inside. Before these caissons were finally abandoned they were clearly filled with small stones most probably as an attempt to shore them up for later use. We emptied two of these, F4 and F8, in order to understand the architecture, construction and functioning (fig. 3).

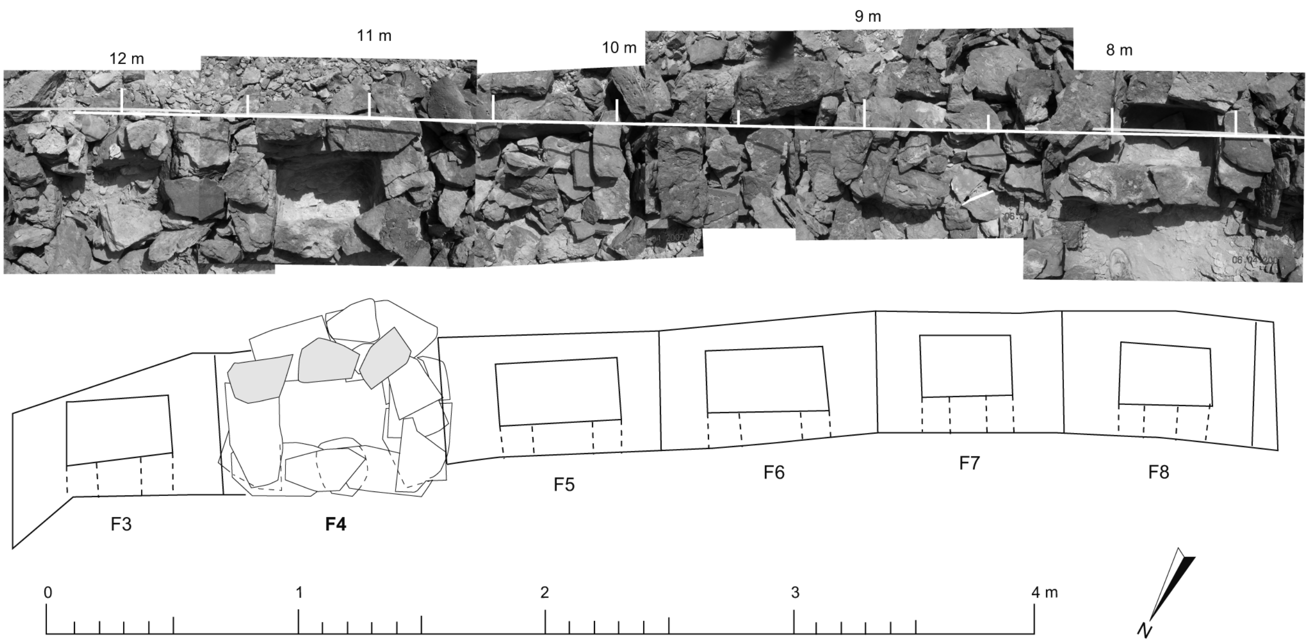

Fig. 3 – *Detail of battery 062.*

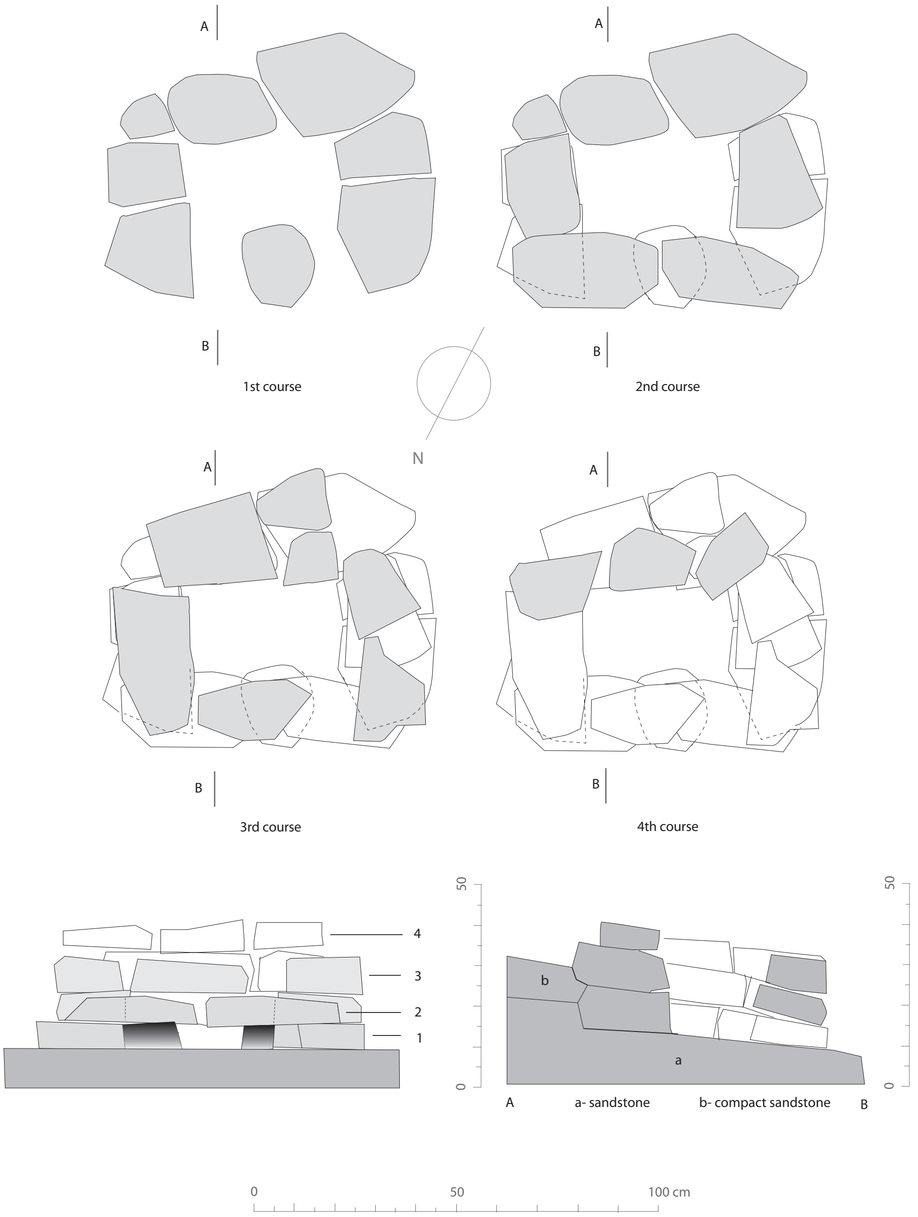

Fig. 4 – *Plans, elevation and section of furnace F4 of battery 062.*

The stones used in the construction of the caissons are flat, of a similar thickness and width but of slightly varying length. Smaller stones are wedged in around the larger. All this material comes from the surface crust, as it is confirmed by a pile of blocks left lying to the east of the battery and most probably intended for further construction. The caissons are rectangular, with internal dimensions of 40 x 28 cm and a maximum preserved height of 32 cm. The walls are composed of a single row of stones, each row made of three or four courses. The stones are placed flat, one on top of the other, without mortar. However, the placing of each course is staggered and the corner stones are overlapping (fig. 4). The north wall of each caisson that forms the façade of the furnace is facing towards the prevailing wind and features two small rectangular openings in its base (W. 14 cm; H. 8 to 10 cm; depth 15 cm), each one covered by a lintel (fig. 5). The latter is laid upon a lateral wall of the caisson and upon a cube-shaped block lying in the centre of the façade and acting as a pillar. The internal walls of the caisson are not coated with

Fig. 5 – *Angled view of furnace F4.*

Fig. 6 – *Reconstruction of furnace F4.*

any lining, nor are those blocks from the old dismantled bloomeries. The caissons, though fragile because of the slight thickness of their walls and the absence of mortar between the stones, owe their stability to the fact that they are built into the battery. Relatively abundant pottery sherds taken from the surrounds of this installation allow perhaps to date it to the Middle Kingdom. Nevertheless, it is noteworthy that numerous other batteries of furnaces in the area built along the same lines, for example at Wadi Kharig, are clearly from the Old Kingdom, according to the associated archaeological material.

The discovery of these installations has allowed us for the first time to get an idea about the system that held the furnace charge in place during the functioning. It is a screen-wall pierced at its base by two ventilation vents, and it is only due to the abandonment of these furnaces before use that we have been able to find this screen-wall *in situ*. Most of the time, this component was destroyed during the functioning of these bloomeries.

EXPERIMENTAL RECONSTRUCTION OF A FURNACE FROM BATTERY (062) AT BIR NASB

One of the experiments carried out on the Ain Soukhna site in order to recreate the operating chain of copper production in the Pharaonic era is a copy of a bloomery similar to those of battery 062 at Bir Nasb built in dry stones (fig. 6).[4] The measurements taken (temperatures, wind speeds) during a test smelt can be seen in fig. 7.

This experiment took place under irregular wind conditions (varying from 0 to 12.5 m per second, with an average of 4.4 m per second). It showed, first and foremost, that the furnace gains heat very rapidly, reaching 1180°C at the hottest point (front wall above the openings) only one hour after ignition, and that despite moderate winds at the beginning of the operation (fig. 7). Given the furnace considerable permeability due to the many gaps between the assembled stones, it is very responsive to fluctuations in the wind, especially in its frontal part. The correlations between wind speed and temperature are particularly significant and concomitant. After barely two hours of working, we measured a temperature of 1300°C that stabilised at around 1250°C. The maximum temperature being reached was 1334°C, which is much higher than that required to reduce an ore such as malachite. The operation of such a furnace requires close attention since the dynamics of the process are swift, especially if one does not want to waste the charcoal. Thus we were able to begin loading the ore after the furnace had been functioning for only one hour and 45 minutes. The furnace charge dropped very quickly—especially at the front of the furnace—this rate depending of the size of the charcoal and of the ground ore (varying from powder to chunks the size of a hazelnut). The low height of the structure probably accentuates this phenomenon. Thus, the successive stoking of ore and charcoal was done every 15 minutes. Regulating the process of reduction is possible but limited (given the porous nature of the furnace walls) by blocking more or less the frontal openings. We deliberately interrupted the experiment after 4 hours of activity because of its success.

4. Unfortunately, we could not get copper ore from Sinai for this experiment; copper ore from South Africa has been used in the process.

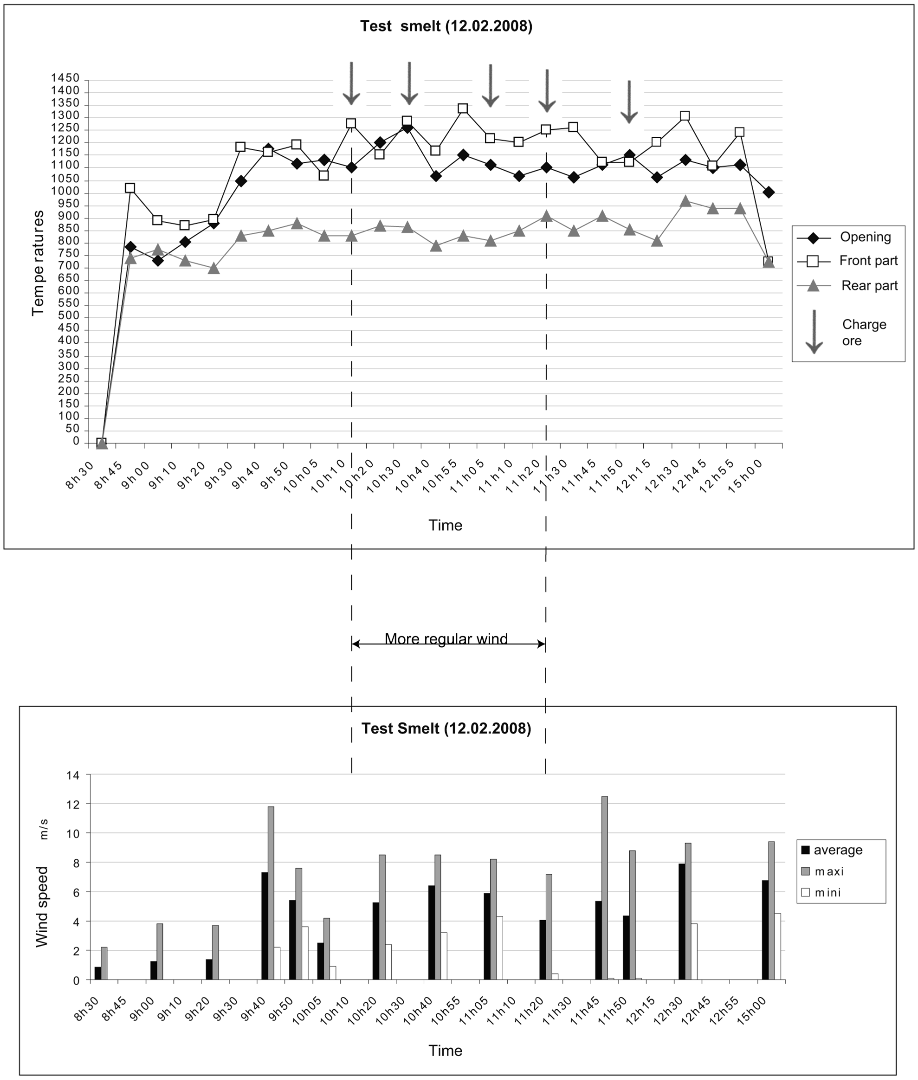

Fig. 7 – *Table of temperatures and winds during the smelting experiment.*

The copper metal was recovered, on the one hand, in the form of bigger or smaller runnels that formed mostly in the front section of the furnace in the axis of the openings (fig. 8), and on the other, as prills of varying sizes, from a few millimetres to more than one centimetre. The ratio of metallic copper as compared with the ore introduced was fairly good : 36.2% in four hours. Depending on the type of stone used, we observed cracking and shattering due to the thermal shock, notably at the front part. Repair and changing of stones was needed after each smelting process. However, we noticed that the proportion of slag formed was extremely low. This little, dry stone bloomery, despite its simplicity, seems to be relatively efficient and fast, depending on the wind strength and the type of ore being used. A choice of form (large upright slabs) and kind of stones used could considerably improve efficiency, should these elements be available. But from a functional point of view, the use of such furnaces in large numbers does not appear surprising, especially when one considers the easiness of their construction in relation to the quantity of metal it is possible to produce quickly.

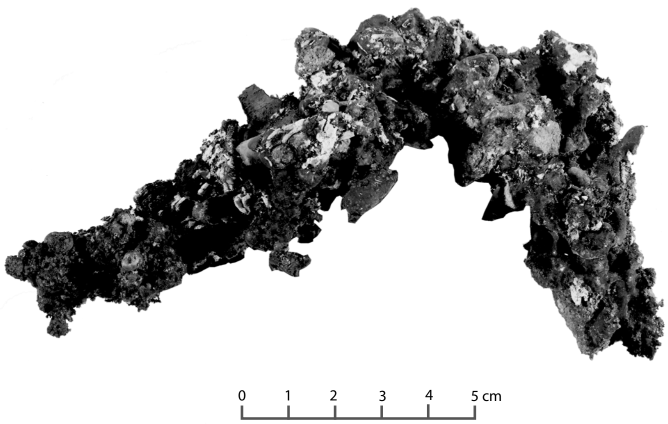

Fig. 8 – *Copper slags and prills as a result of smelting malachite ore.*

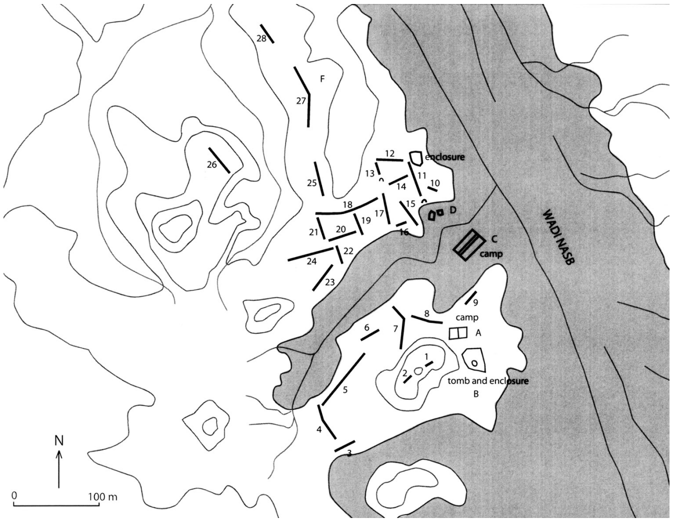

Fig. 9 – *Site map of Seh Nasb.*

A MASSIVE COMPLEX: THE INSTALLATIONS OF SEH NASB

Of all the metallurgical sites discovered in the mining zone of South Sinai, there is one that stands out owing to its sheer size. This is Seh Nasb, a complex located at the northern mouth of Wadi Nasb, at the junction of two important east-west and north-south transport axes (fig. 9). At this spot, on a small platform overlooking the wadi bed, a range of 28 batteries of furnaces has been discovered. The sizes of these installations are varied running from 11 to 80 m long. The total length of all these batteries put together is almost one kilometre, which means, according to the detailed study of certain of these elements, that there are probably more than 3000 individual furnace units. Such a development of metallurgical activity at this spot can perhaps be explained by the location of the site. The ore that was processed here clearly did not come from the mines that were in the immediate vicinity (which was indeed the case, for example, for the metallurgical workshops discovered at Wadi Kharig, and for those of Bir Nasb west, which were mentioned above).[5] As far as Seh Nasb is concerned, we are probably dealing with an important point where activities were concentrated, situated at a strategic spot where several routes leading to and from the mines converged. The layout of the site, on a well-ventilated platform close to sources of water and of the wood that could be used as fuel, no doubt played a role in the choice of this position.

5. No significant copper deposit has been so far reported in the immediate vicinity of the furnaces in Seh Nasb, at the entrance of Wadi Nasb—but further to the south in Bir Nasb, Abu Thor and in the Umm Bogma area.

The batteries of furnaces built on this spot functioned according to a method similar to those mentioned above. They differ, however, in the almost systematic dividing of the installations, set on both sides of a central axis. This form allows each one of these batteries to be ventilated from two directions. This aim to get an optimal ventilation can also be seen in the layout of the batteries themselves, in that they form a sort of grid square, facing all possible directions. The frequent variation in prevailing wind direction that we experienced during the time we spent on the site can probably explain this phenomenon. We noted that the wind can change from one day to the next, and even within the same day, depending on which face of the wadi is exposed to sunlight.

The large number of small-sized furnaces can be explained by the fact that they could be used to process any quantity of ore with a minimum of fuel, whatever the wind direction; the only condition being that the wind had to blow extremely hard and last a minimum of two hours.

The batteries are built of blocks of local sandstone. They are composed of furnaces set on either side of the same straight supporting wall, the width of which is constant (0.6 m) and the length varying from 10 to 80 m. Some 20 of the best preserved furnaces were excavated and studied in 2009. Here, we shall present the example of a series of seven units that belong to battery n° 27 of the site (fig. 10-13). Rectangular in shape, they appear as little caissons placed one next to each other on either side of the wall. In fact, they consist in a series of square hearths separated by stone partitions and open either to east

Fig. 10 – *View of battery 27 before being cleared of sand.*

Fig. 11 – *Elevation of the east face of battery 27.*

Fig. 12 – *View from above of battery 27.*

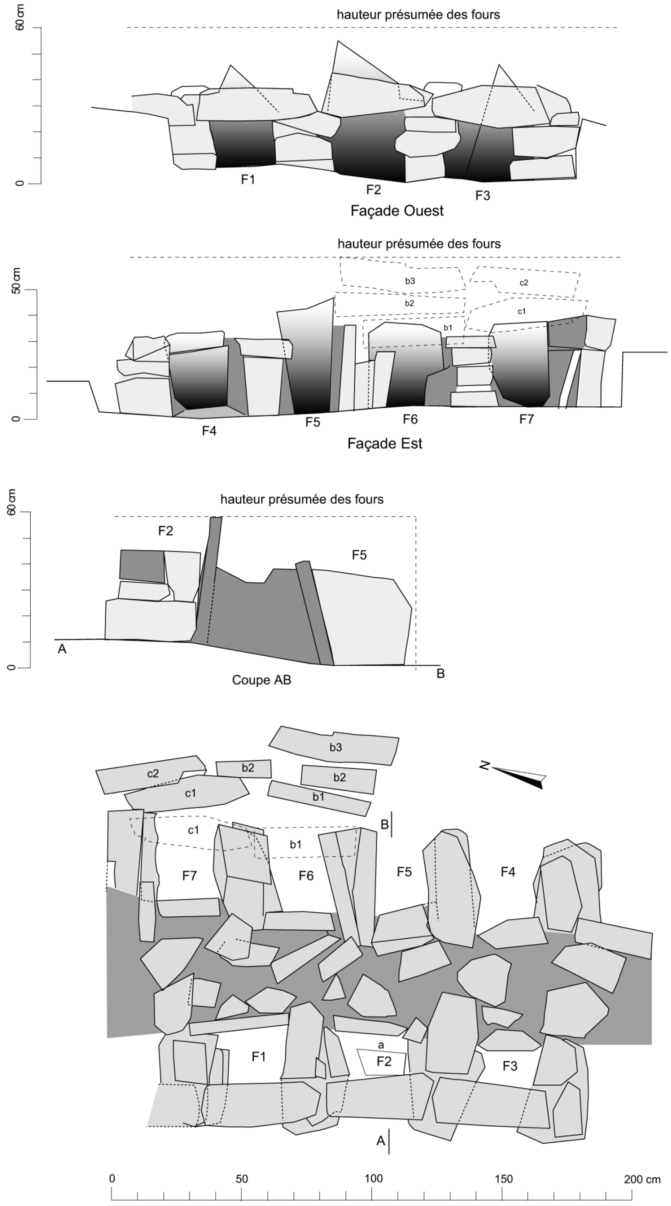

Fig. 13 – *Plan, elevations and section of furnaces F1 to F7 of battery 27.*

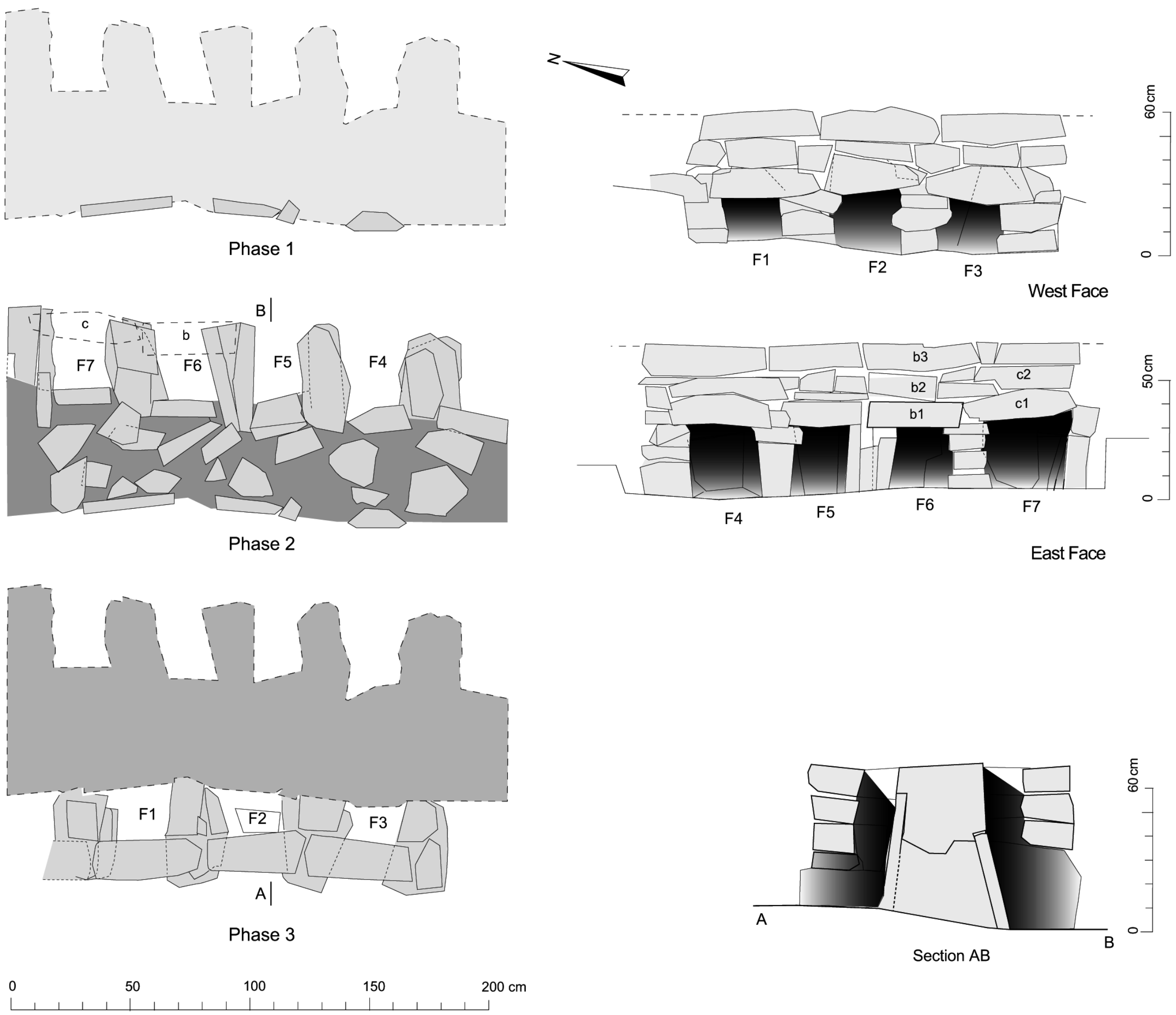

Fig. 14 – *Construction phases of furnaces F1 to F7 of battery 27.*

or west, depending on their situation. The front of each one, at ground level, has a rectangular opening topped by a lintel, and to the back, against the supporting wall, a vertical slab serves as the rear of the furnace. The vertical sides are generally composed of several courses of stones set into the wall. The hearths of these furnaces are sometimes covered with a clay lining, of which numerous scorched fragments still remain.

The construction of battery 27 described here as an example was undertaken in three phases (fig. 14):

– Phase 1: setting of vertical slabs running along a north-south line, this orientation being perpendicular to the winds that one is hoping to catch.
– Phase 2: a wall is built against the eastern side of this line of vertical slabs; a battery of furnaces open to the east (F4 to F7) is supported by this wall; the rear of these furnaces is made of a vertical slab, while the side uprights are set into the wall by up to 20 cm.
– Phase 3: a second battery of furnaces (F1 to F3) is built to the west against the wall and vertical slabs of Phase 1. This addition leads to three resulting consequences:
  – the slabs serve as the rear of the new furnaces;
  – the lateral uprights are not centred upon the slabs;
  – the lateral uprights are not (or barely) set into the wall.

If one takes into account the heights of the stone used for the rear of the furnace, and of certain lateral uprights found knocked over upon the ground (*e.g.* furnace F6), the height of the furnace is about 60 cm. The total width of the battery is around 1.2 m and that of the support wall is 0.6 m, meaning a total width of each furnace of around 0.3 m.

The furnaces F4 to F7 no longer have lintels. The height of the latter from the ground has been calculated as a function of the height of the lateral uprights that served as supports for the lintels (table 1).

Table 1 – *Battery 27 – Furnaces F1-F7 (measurements in cm).*

N°	Hearth L x W	Opening L x H	Lintel L x W x H	Left upright L x W x H (preserved)	Rear slab L x H (preserved)
F1	20/23 x 20	20 x 18	48 x 16 x 13	40 x 25 x 30	40 x 40
F2	20 x 20	20 x 20	40 x 18 x 10/18	50 x 25 x 30	30 x 50
F3	20 x 15	20 x 20	45 x 18 x 10/18	42 x 20/30 x 30	30 x 45
F4	20 x 20	20 x 20	missing	40 x 25 x 30	40 x ?
F5	20 x 20	20 x 22	missing	45 x 20 x 30	20 x 42
F6	20 x 20	20 x 20	collapsed 40 x 12 x 10	45 x 15/20 x 30	30 x 30
F7	20 x 20	20 x 20	collapsed 50 x 15 x 12	40 x 20 x 35	24 x 33

It was during the excavation and study of these batteries of furnaces that it became clear that there are roughly seven furnaces every two metres, and it was upon this that we based our global estimate of the number of smelting units originally present on this site—most probably a minimum of 3000. The ceramic finds associated with the installations of this sector have been dated to the Old Kingdom, and more precisely to the 5th Dynasty (*ca* 2500-2300 BC), which indicates without any doubt the strategic interest taken by the Egyptians in this region from the very earliest times of their history. The spectacular development of the Seh Nasb site during this period is most probably an indication of the utmost wealth of copper resources in this region, something that has previously been pointed out by several scholars.[6]

CONCLUSION

It is difficult at this stage of our research to go much further in our interpretations of the vestiges that we have discovered on the large site of Seh Nasb. In particular, it is impossible to know whether the complex of furnaces to be found on the site are the result of one—and especially huge—occupation, or if they are evidence of regular reinstallations of Pharaonic teams at the same location over more than a century. Given the absence of significant deposits of slag it is also impossible—as was the case for Bir Nasb—to propose an estimation of the quantity of ore that could have been dealt with on the site.

On the other hand, we can say that here we have a very good illustration of Pharaonic era work organisation. In the heart of what was most likely in antiquity the major area for the Egyptians' exploitation of copper, this site was probably chosen for its location in a well ventilated zone and especially as it stood at the conjunction of several routes.

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6. *E.g.* Rothenberg, 1987: 1-7.

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