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ASWAN
1st cataract
Hisn al-Bab
Egypt
RED SEA
Afyeh
Wadi el-Allaqi
Gebel Adda
2nd cataract
Wadi Gabgaba
Amara West
Sedeinga
Sai
3rd cataract
Tombos
Sudan
ABU HAMED
Nile
El-Ga'ab
Basin
H29
5th cataract
KAREIMA
4th cataract
Abu Sideir
Napata
Wadi Abu Dom
Dangeil
ED-DEBBA
Gala
Abu Ahmed
Wadi Howar
ATBARA
Meroe
Qalaat Shanan
Atbara
Wadi el-Melik
Wadi Muqaddam
6th
cataract
Jebel Sabaloka
OMDURMAN
KHARTOUM
KASSALA
Eritrea
Blue Nile
MODERN TOWNS
Ancient sites
WAD MEDANI
GEDAREF
White Nile
SENNAR
KOSTI
N
Ethiopia
0
250 km
South
Sudan
Azaza

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Contents

The Kirwan Memorial Lecture

Reports

Miscellaneous

Obituaries

Front cover: Excavations in progress in the *Kerma Ancien* cemetery at site H29 in the Northern Dongola Reach (photo D. A. Welsby).

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Kirwan Memorial Lecture

Quarrying for the King - the Sources of Stone for Kushite Royal Monuments

Abdelrahman Ali Mohamed

Introduction

In the past archaeological research in the Middle Nile Valley, and elsewhere in the Sudan had been focused on the identification and excavation of sites along with the dating and restoration of monuments. Little attention had been focussed upon studying the sources of raw material from which these monuments have been built, and their methods of extraction. However, Adams did describe the Kushites monuments from an architectural point of view (Adams 1984, 255). On the other hand Hinkel (1977, 10) outlined the methods of transport of the quarried rocks for the construction of the pyramids of Meroe. Recently, some research has been undertaken on quarrying in the northern Sudan (Harrell 1999) and in the Butana (Becker 2000, 65-73).

Due to the importance of provenance studies relating to the material used for constructing Kushite royal monuments for understanding the methods of their construction together with their importance in planning for the restoration and conservation of these monuments we launched a research project in 2002 in the area between the Third and Sixth Cataracts. This was designed to study the sources of stone used for the construction of Kushites royal monuments. Moreover, the documentation of the quarry sites is essential due to the fact that they are being directly endangered by development projects. An example occurred recently in the area of Napata when the important and extensive quarries of Khor el-Harazawin were damaged by the construction of the Kareima-Nawa highway (Plate 1).

A combined geological and archaeological survey was launched in the study area, which resulted in the recording of 40 sandstone quarries and five granite quarries, many hitherto unknown. The characteristics of these quarries were studied and fresh rock samples were taken from their active faces, which bear traces of tool marks. The collected samples from both the quarries and the monuments were studied by thin section petrography and scanning electron microscope analysis.

Plate 1. The Kareima-Nawa highway cutting through the Harazawin quarries.

Field studies revealed that there are two types of quarries in the Middle Nile Valley:-

(1) Sandstones quarries, which are related to the Nubian Sandstone Formation, dated to the Cretaceous. They are of two subtypes: open (Plates 2 and 3) and underground (Plates 4 and 8). The open quarries characterise the Napatan region while both types were represented in the region of Meroe.

(2) Granite and granodiorite quarries linked to the basement complex of the Nile Cataracts and dated to the pre-Cambrian. It should be noted that all these quarries are open ones (Plate 5).

Methods of Extraction of sandstones blocks

A/ Open Sandstone quarries

The following are the procedures followed by the ancient quarryman:

Plate 2. Open quarry at Musawwarat es-Sufra 3.

Plate 3. Open quarry at Umm Ali 1.

(1) To survey the selected area to find a suitable cliff face on a mountain or water course (*khor*) with steep rocky banks. Those cliffs with the minimum number of cracks or joints were sought. Sometimes during the survey test pits had to be excavated to evaluate the quality of the rock to ascertain its suitability for extraction. Some of these pits are recorded in the area to the south of Jebel Barkal. In the case of the region

Plate 4. Gallery quarry at Meroe to the east of the Northern Cemetery (photo D. A. Welsby).

of Meroe and Napata a regular vertical face of a new quarry was cut on the horizontal sandstone beds and strata so as to ensure maximum exploitation of blocks before a new set of blocks were extracted from behind. This enabled a large number of blocks at one level to be quarried simultaneously.
(2) To remove the sand, rubble and weathered rocks from the surface to reach the top of the fresh bedrock of a suitable cliff face.
(3) The principle technique of quarrying the sandstone involved the cutting of narrow separating trenches along the sides of a block in order to isolate it. The width of these trenches ranged from 200-300mm, then grooves or cylindrical holes were excavated underneath to insert levers, or prepared wedge holes along regular horizontal lines as in the

Plate 5. Split boulder in the hard stone quarry on Dabaki Island (photo D. A. Welsby).

case of extracting the ferruginous sandstone in the quarry of Abu Terabyia near Meroe (Plate 6). The extraction could be achieved in all directions against a sloping hillside as systematically as the movement of stones permitted.
(4) Quarried blocks were extracted from a particular layer or a group of selected layers within the sandstone formation. Due to the horizontal and extended nature of the beds, the same bed could be quarried in many locations in the region. An example of this is the fine-grained whitish sandstone layer, which has been quarried at Khor es-Sada in el-Kassinger and in Shebba. The pinkish sandstone layer is also quarried in Barkal Foug and Shebba.
(5) The vertical faces of quarries were cut out by means of a pointed metal chisel of 5mm diameter, of which traces are left on the active quarry faces.
(6) Finally the block is detached from the parent rock by means of rounded wooden levers of which traces are left on

Plate 6. Abu Terabyia.

the quarry faces of Jebel Suweigat where they are 100mm in diameter and 100mm deep.

(7) After the detachment of the last blocks the face of the quarry was left with a polygonal shape or a vertical face displaying the negatives of the blocks detached (Plate 7).

Plate 7. The quarry face at Khor el-Harazawin (photo D. A. Welsby).

B/ Underground sandstone quarrying

Due to the unavailability of suitable sandstone at the surface and due to the difficulty of removing the overlying rubble and debris of weathered rock, the region of Meroe is characterised by underground quarrying. The extraction of blocks started at the eyesight of the quarry man, the same way as in the open quarrying by preparing a regular roof for a gallery and then separation trenches are cut around the blocks. Then the process of quarrying proceeded downwards maintaining the vertical walls of the gallery. After the extraction of the uppermost line of blocks, the second line of blocks could be detached in the same way, more space being created. For preparing more galleries rectangular pillars were needed to support the roof (Plate 8).

Methods of Extraction of Hard Rocks

The oldest records of quarries in the Middle Nile Region come from the observations of early travellers and explorers in the 19th century, notably Hoskins (1835, 83) and Breasted

Plate 8. Interior of the gallery quarry at Meroe to the east of the Northern Cemetery (photo D. A. Welsby).

(1908, 14). The documented hard-stone quarries in the Middle Nile Valley are mainly situated in the areas of the cataracts where good quality granite outcrops. The famous hard-stone quarry of Tombos situated at the Third Cataract was extensively worked in antiquity; it was documented together with that at Daygah at the Fourth Cataract by Harrell (1999). The quarries yielded granite and gneiss. Other hard-stone quarries are known on Mograt Island and at the Sixth Cataract.

Methods of quarrying granite

(1) Selection of a large granite block devoid of fractures.

(2) The upper weathered epidermis of the granite is pounded away by a hard-stone tool to produce a depression revealing the fresh granite surface (Plate 9). This tool could be of diorite which is available in the area of the Third Cataract.

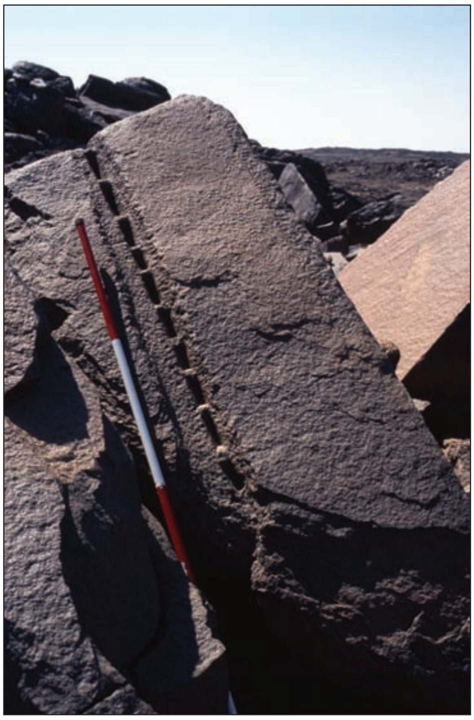

Plate 9. Boulder prepared for quarrying at Daygah (photo D. A. Welsby).

(3) This operation is followed by the cutting of a series of closely spaced, rectangular holes, 30-40mm wide in plan and trapezoidal in section tapering downward and with rounded corners, known as wedge holes (Plate 9). Clear evidence revealed that these holes were cut by the aid of a pointed metal tool.[1] Then, closely spaced wedges were places in these holes and by subsequent hammering on them the rock spilt into two or more parts. This technique is effective in the relatively fine-grained and compositionally uniform granite. This is known as *pointillé* technique. Sometimes to control the

[1] Harrell suggested that these wedges were made of iron (1999, 26). The cut wedge-holes have lengths ranging from 80-270mm, a width range of 30-40mm, measuring at the top 50-120mm, and were 20-30mm in depth. The rectangular holes are separated from each other by 30-50mm.

extraction of the blocks a series of horizontal and vertical wedge-holes were cut to provide regular separation (Plate 10).

Plate 10. Horizontal and vertical wedge-holes on blocks in the quarry on Dabaki Island (photo D. A. Welsby).

The technique of utilising lines of wedge-holes in the Tombos quarry was already dated by Harrell to the period 7th to 5th century BC. Such wedge-holes could be among the earliest known examples of the use of iron wedges in quarrying in antiquity. However, the earliest documented use of iron wedges in Egypt dates to the mid 4th century BC (Harrell and Brown 1999). The first evidence for the use of iron wedges is found in Greek quarries and dates to the early 6th Century BC (Waelkens *et al.* 1990, 62-63). However, the technology of iron working was adopted earlier in Kush, at least from the 7th century BC, as indicated by the presence of iron objects recovered in archaeological contexts in Taharqo's tomb (*c.* 664 BC), in the form of an iron spear, (Dunham 1955, 15 no. 19-3-95), and also at el-Kurru in the sandstone pyramid of an unknown king (Ku. 1(2); 19-4-241, 19-4-238 (362-342 BC; Dunham 1950, 24). Moreover, deposits of iron ore in the region are found mainly within the ferruginous strata which cap Jebel Barkal and as a cementing material for the conglomerate beds scattered in the region. It is worth mentioning that the iron working industry was certainly well established by the 5th century BC in Meroe (Trigger 1969; Török 1997, 34).

Tools

Traces of tool marks

No tools have been found in the area of quarries and there is some difficulty in identifying the nature of such tools from the visible traces appearing on the active faces of the quarries. The only tool marks which can be distinguished were left by a pointed or tapering chisel 50mm in diameter, in the form of diagonal, oblique, parallel continuous lines and herringbone pattern marks (Plate 11). The angle of inclination of these marks is about 45°; they are 50-100mm apart and their length is that of the quarried block. It is also noted that most of them were made from a right-handed working position which is dominant in all quarries. Chisels of 10mm in diameter were used for the dressing of some blocks. Traces of tool-marks on the active quarry faces can be classified as:

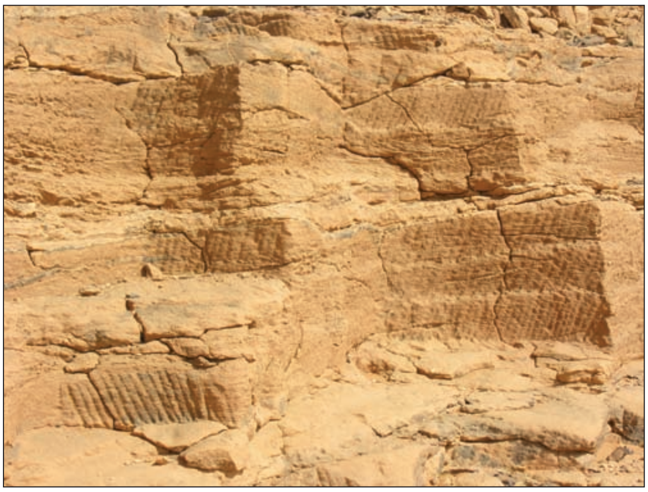

Plate 11. Tool marks on a quarry face near Musawwarat es-Sufra (photo D. A. Welsby).

(1) regular series of parallel inclined lines consisting of shallow grooves with gently curved traces representing the effect of a single cutting operation from a single position.
(2) The second group of traces present the same pattern as group 1 but their grooves are more pronounced.
(3) Longer sets of lines that alternate in direction after each layer of blocks, known as (herringbone pattern). This type of tool mark is characteristic of the 25th Dynasty and Napatan monuments, and they are also similar to the earlier New Kingdom marks.

Dressing of the quarried blocks

It has been noted that in the region of Meroe most of the quarried blocks and other structural elements were prepared at the quarry sites and may have had their final dressing near the monuments to be constructed. On the other hand, in the region of Napata only one dressing area is recorded at the western periphery of the quarries of Khor el-Harazawin. It covers an area of 15 x 20m, within which are a number of unfinished broken and weathered structural objects in various stages of dressing.

The shape and the size of blocks employed in the construction of the royal cemeteries of Kush was used by Reisner as a typological indicator (Reisner 1918). Dunham (1950, 123) also considered the size and shape of blocks in order to distinguish the types of pyramids. Measurements can be taken only from the blocks that are well dressed and have regular shapes. Blocks in the inner casement and the filling are left rough and are only crudely shaped. The inner faces of the blocks are also affected by bonding and adjustment, although in most cases the height of the stepping is often constant and equivalent to that of the regular stone courses.

Positioning and setting-out lines

Positioning and setting-out lines are observed on the surface of some blocks and columns in the form of two lines intersecting at right angles indicating the correct positioning and placement of the succeeding course. Setting-out lines for columns are observed on the cylindrical column drums of the Amun Temple (B 500) and they are used to fit and centre exactly the next drum. On the other hand setting-out lines for blocks are observed at many sites (Plate 12).

Plate 12. Setting out lines on the stepped courses of the small pyramid (Pyramid 1) in the Kushite cemetery at Kawa (photo D. A. Welsby).

During quarrying, some blocks were roughly cut and have a width of 523mm, which is equivalent to an Egyptian cubit (Welsby 1996, 100). However, at Khor el-Harazawin the blocks remaining on site measured 640 x 440mm.

Ordinary wall blocks were supplied to the construction site without a previously fixed and ordered length and the upper surface of the prepared block to be placed in a building course was pecked and roughened in order to adhere to the mortar bonding it to the next course. The roughly-hewn corners and joints of the blocks were both cut after setting them in their courses. This method resulted in extremely thin vertical and horizontal joints.

Dove-tail cramps

Dove-tail cramps are used to ensure the stability of a block in a building course and in antiquity they were made of wood or metal. However, in the study area none of these cramps have been found. Only the empty holes to fit the cramps were found in Sai Island, Tabo, Kawa and Barkal pyramids (collapsed pyramid Barkal N.6, in the 6th, 14th and 15th courses). The cramp hole in the sixth course of this pyramid was filled with the white mortar. Other cramp holes filled with mortar and clay are found in Kawa (Macadam 1955, 85). In the Kushite monuments also dove-tail cramps were used to fix two hemi-spherical drums of the portico of B.700 (Plate 13).

Plate 13. Dove-tailed cramps on a column drum from the portico of B700 at Jebel Barkal (photo D. A. Welsby).

Geological and laboratory analysis

The collected sandstone samples were analysed using thin-section petrography in the laboratories of the University of Khartoum, and electron scanning microscope analysis was undertaken in the laboratories of the British Museum. Both analyses revealed the presence of two varieties of sandstone used in the building activities of the Kushite royal monuments in the Middle Nile Valley. They are mainly the quartz arenite and the sub-arkose characterised by whitish, brownish, yellow and grey colours, with fine to medium-grained textures. The major mineral components are quartz, feldspars and mica, the minor minerals being zircon, rutile, tourmaline and silver. The cementing material is mainly kaolin, clays, silicon oxides, iron and iron oxides.

Conclusion

Our research has allowed us to identify the provenances of the sandstone used to construct 50 monuments dated to the Kerma, Napatan and Meroitic periods. However, evidence of quarrying dated to the 19th Dynasty was also documented in the area.

Recent excavations at Jebel Barkal have revealed that the nucleus of the temple of Amun (B.500) was constructed in five phases of which the oldest, built from sandstone *talatat* blocks, is dated to the reign of Akhenaten, with the succeeding phases dated epigraphically to the reigns of Seti I and Ramesses II (Kendall 2009, 5). Moreover, the *talatat* blocks were quarried from fine grained greyish, yellowish sandstones obtained from the quarries of Khor el-Harazawin and Barkal Foug, while the whitish sandstones were extracted from the quarries of el-Kassinger. On the other hand, Kushite construction activities in temples and palatial buildings at Jebel Barkal were begun under Kashta and Piye, and with the establishment of the 25th Dynasty, a new political strategy of construction of temples began which led to large-scale building activities in Kush. The Kushites brought architects and artisans from Egypt where there was a long familiarity with the techniques of quarrying, going back to the 3rd millennium BC, to their centres in the middle Nile region. The large-scale construction of temples at Tabo, Sanam and Kawa required the application of new techniques to enable the extraction of a great quantity and high quality of sandstone which resulted in the changing of quarrying techniques from that which left a herring-bone patterning of tool-marks to the more practical technique which left an alternating parallel pattern of tool-marks. These great building activities could only be executed by permanent local staff trained to carry on the technologies adopted and shows how simple technology developed to satisfy the local demand for stone for a nation.

During the Meroitic period extensive building activities had been launched by the royal couple Natakamani and Amanitore, who commissioned great architectural projects in the two centres of the Kingdom of Kush and large quantities of sandstone were quarried by effective and simple techniques of exploitation, which reflect the fact that the Meroitic quarryman and artists knew how to absorb, adapt and combine foreign elements to create new works of special character. Moreover, the change in exploitation technique from open to underground quarrying indicates that the ancient quarryman was capable of solving the problems posed by the unavailability and inaccessibility of good quality sandstone near the surface. By choosing the underground quarrying method he applied his technical experience of quarrying and reduced the cost and time required to remove the overburden of the unsuitable weathered rock. This practice may indicate some technological advances in the quarrying technique of the Kushites.

It can be noted that quarrymen knew about jointing systems, bedding, layering and foliation. This is in addition to the knowledge of durability, strength, hardness and resistance to weathering which led to the extraction of a considerable number of good-quality blocks for use in the construction of Kushite royal monuments in the Middle Nile region.

The quarrying activities employed in the study area depended on many factors such as the availability and accessibility of good quality rock at/near the surface or underground, topography, colour, texture and durability of the rock, the distance of quarries from the construction sites and the distance from the Nile, which provided by far the easiest mode of transport between quarry and construction site.

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