

# A Bronze Age Quarry in Eastern Crete

Jeffrey S. Soles

University of North Carolina  
Greensboro, North Carolina

*The sandstone quarry at Mochlos is one of four major quarries in eastern Crete that were worked during the New Palace Period of Minoan civilization (ca. 1700–1450 B.C.) to produce large ashlar blocks for nearby Minoan sites. At that time sandstone, or ammoudha, as it is known locally, was especially valued as a building material, partly because of its distinctive color and texture, but mainly because of the ease with which it could be cut, and the stone was used extensively for exterior façades, for walls around interior courts, and for other architectural features of the more important buildings on these sites. This article describes the quarry at Mochlos in some detail, including the quarrying techniques employed, and argues that the destination of the stone from the Mochlos quarry was the Minoan palace at Gournia. The article ends with a comparison of the four ammoudha quarries in eastern Crete.*

## Introduction

During the summer of 1979 the University of North Carolina at Greensboro began a survey of the coastal plain that lies across from the small island of Mochlos on the north coast of the Greek island of Crete (FIG. 1). This plain extends along the coast, mostly to the east of Mochlos, for a distance of ca. 4.5 km. It is isolated from the interior of Crete by the Ornos Mountains which ring the plain on its east, west, and south, rising abruptly to a maximum height above sea level of 1237 m. The plain is nowhere more than 1 km. in width. It opens towards the sea and the island of Mochlos which lies about 160 m. offshore. Through much of antiquity the plain and the island were apparently connected by a low isthmus, one that would have provided excellent shelter for sea traffic as well as a bridge for land traffic from island to adjacent plain.

This area has been investigated by several archaeologists in the past. In 1908 Richard Seager, an American archaeologist, excavated on the island of Mochlos and uncovered an important cemetery of the Early Bronze Age, dating ca. 2600–2000 B.C., as well as settlement remains of the Middle and Late Bronze Age, dating ca. 1700–1450 B.C., and the Roman period, dating from the 1st century B.C. to the 4th century A.C.<sup>1</sup> Since Seager's

initial discoveries, other archaeologists have done some limited work in the area and have uncovered additional remains in the adjacent coastal plain, some of which parallel in their chronological span the antiquities that have been uncovered on the island of Mochlos. The settlers on Mochlos were active in the plain and relied heavily on its natural resources, for, while the island of Mochlos is solid rock, with little soil cover and no water source, the plain is rich in agricultural land and is provided with an abundant supply of water fed by the springs and streams of the Ornos Mountains.

The survey begun in 1979 has several objectives. Its immediate goal was simply to locate and examine the ancient remains that are known to have been located in the plain, both those that have been excavated and those that are still exposed to view. Its long-term objective is to produce a series of studies that will treat those remains in as much detail as possible in an attempt to establish the relationship between the island settlements and the activities that were being carried out in the adjacent plain. The project is being conducted in conjunction with a study of the ancient remains on the island of Mochlos.<sup>2</sup>

To date it has been possible to study only one site in the plain in detail: the site of the ancient quarry that is

1. R. B. Seager, "Excavations in the island of Mochlos, Crete, in 1908," *AJA* 13 (1909) 273–303; *Explorations in the Island of Mochlos* (Boston and New York 1912).

2. For a detailed map of the island, further discussion, and bibliography, see J. S. Soles, "Mochlos. A New Look at Old Excavations. The University Museum's Work in Crete," *Expedition* 20 (1978) 4–15.

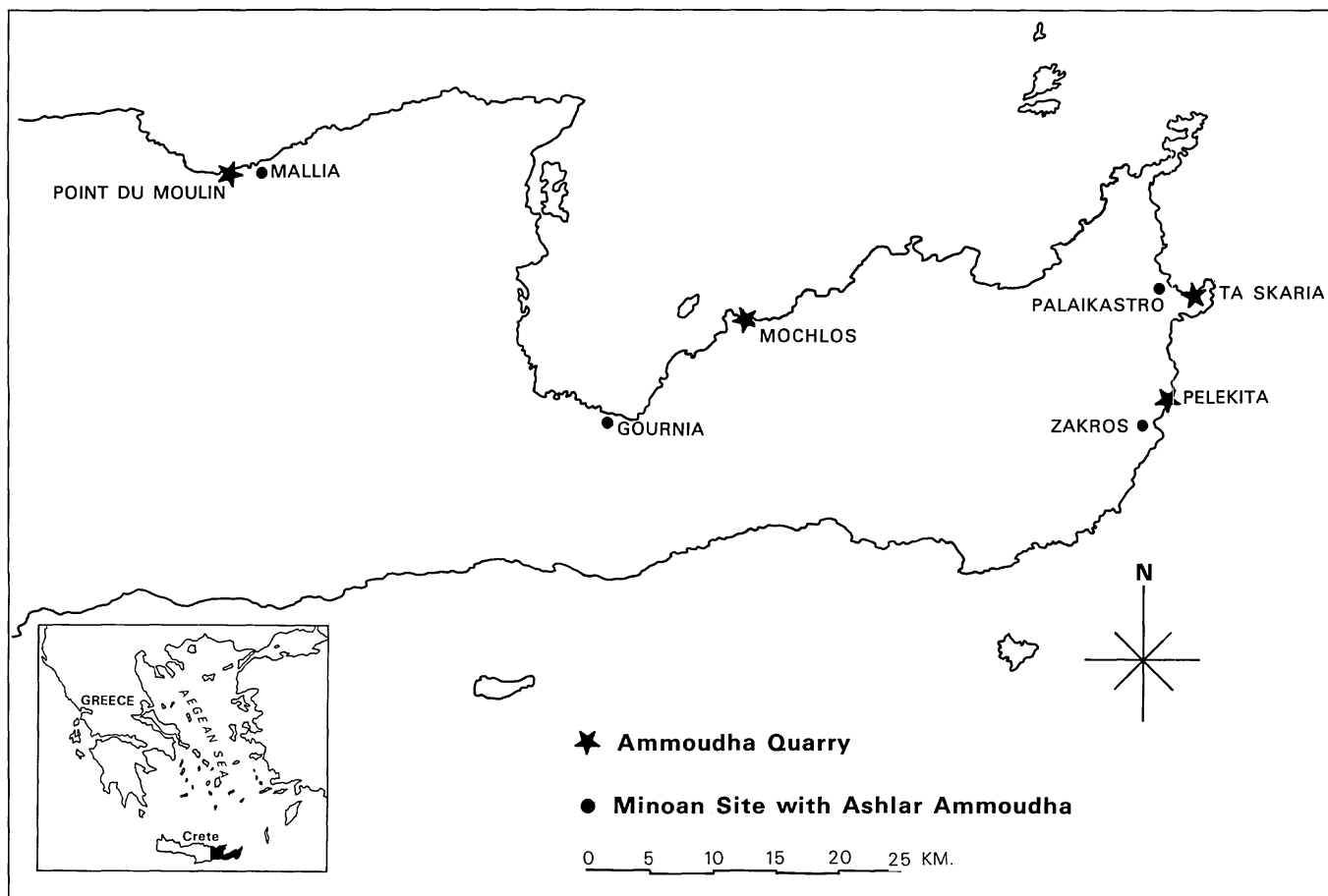


Figure 1. Location map of the major sandstone quarries in eastern Crete. Inset of Greece.

the subject of this paper. This quarry was first noted by Richard Seager who did not describe it, but who noted that ashlar blocks were removed from it and that it must have been worked during the Roman period since ashlar masonry was found in Roman buildings on the island and not in any of the Late Bronze Age buildings.<sup>3</sup> Recently the quarry was noted again by J. W. Shaw who suggested that it may have “furnished material for the refurbishing of Minoan buildings” on Mochlos.<sup>4</sup> It seemed that a closer examination of the quarry, as well as the neighboring sites where its stone might have been used, was called for in order to establish exactly when, and by whom, the quarry was worked. It also seemed likely that such an examination would produce useful information about ancient quarrying techniques at the same time that it would establish more clearly the relationship of the quarry to the settlements on Mochlos. In

3. Seager, 1909 op. cit. (in note 1) 275.

4. J. W. Shaw, *Minoan Architecture: Materials and Techniques*. AS-Atene 49 (1971) (Rome 1973) 40 note 3.

the course of the study, it soon became apparent that the quarry played a more important role in antiquity than anyone had realized.

**The Ammoudha Quarry at Mochlos<sup>5</sup> (FIGS. 2, 3, 4)**

The plain in which the quarry is located is described on the maps of the Greek Geological Service as fluvial terrace formed in the Pleistocene by torrential deposits of boulders, gravels, pebbles, sands, and other materials.<sup>6</sup> These deposits have been eroded from the surrounding mountains and at various points along the coast range 20–30 m. in depth. They overlie marine formations belonging to the Miocene that are predominantly conglomerates and sandstone. These are exposed at points along the coast where wind and sea erosion have cut the

5. *Ammoudha* is the local Greek name for the calcareous sandstone that outcrops over scattered areas of eastern Crete. It is sometimes also referred to as *ammoudhopetra*.

6. J. Papastamatiou, “Siteia Quadrangle, Crete,” Institute for Geology and Subsurface Research (Athens 1966). Scale 1:50,000.

Figure 2. Map of the *ammoudha* quarry at Mochlos.

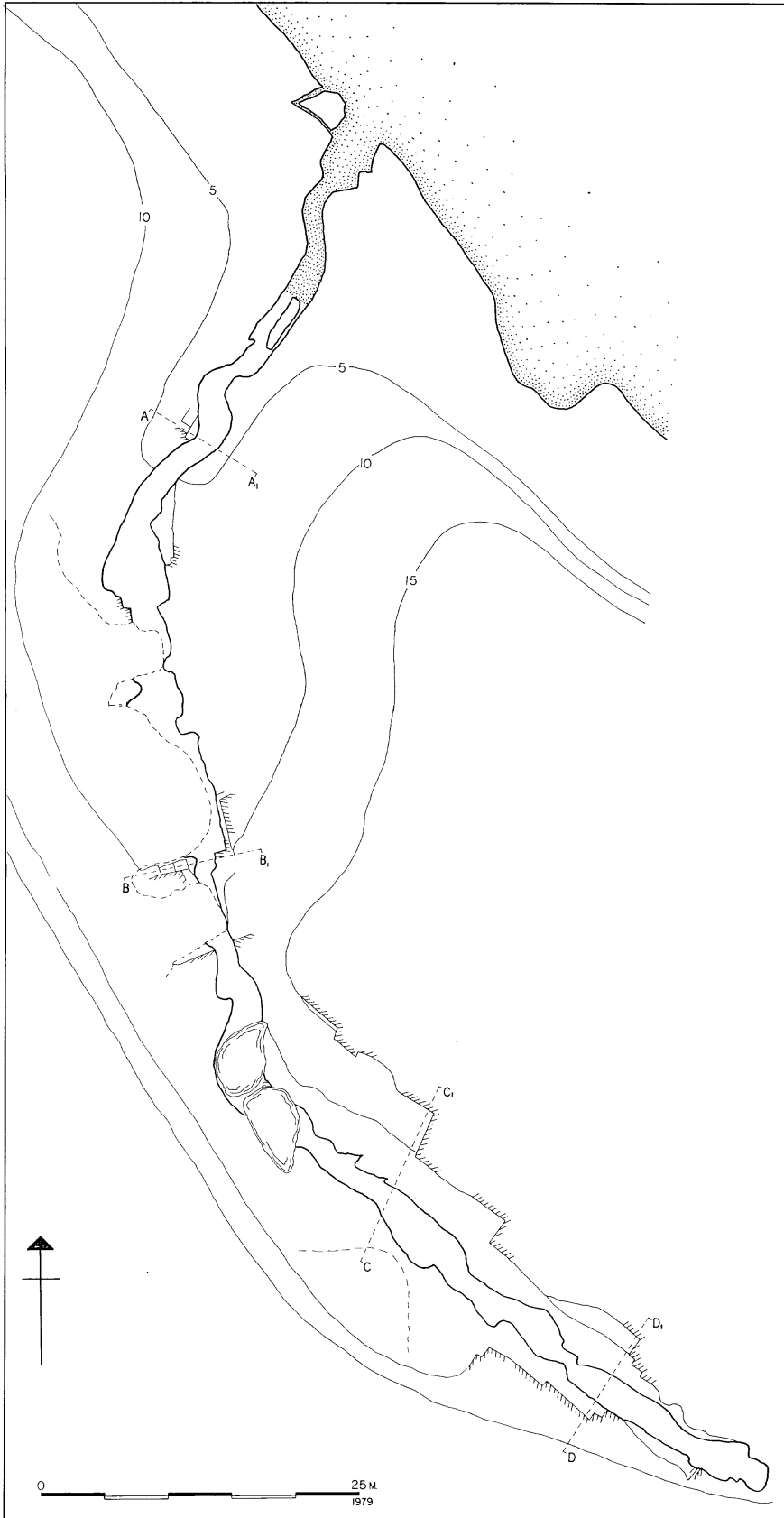




Figure 3. Ravine from the south.



Figure 4. Ravine from the NW.

overlying terrace back, causing it to drop sharply to sea level, and at several points throughout the plain where stream channels or larger rivers, dry except during the rainy season, have cut through the terrace to the marine formations beneath. The exposed sandstone in the ravine formed by one of these stream channels at the western end of the plain was quarried in antiquity.

This ravine is located about 200 m. to the east of the modern fishing village of Mochlos, diagonally across from the island of Mochlos at the juncture of the road that runs through the coastal plain and the westernmost of the roads descending to the plain from the main highway. It opens into the sea at its north and curves back from the coast towards the SE for a distance of ca. 100 m., rising from sea level to a height of ca. 20 m. above sea level at the point where it meets the coastal road. In recent years it has come to serve as the garbage dump for the neighboring village, and sections along its western side have been filled with garbage and with earth that apparently slid down when the coastal road was widened. These areas are indicated by dotted lines on the map in Figure 2. The bottom of the ravine is still exposed for the entire length of the ravine, however, and ranges 1–5 m. in width. Its floor is filled with rounded river stones.

At several points, starting ca. 25 m. from the mouth of the ravine and continuing all the way to its end, the sides of the ravine have been cut back to obtain large ashlar blocks of sandstone. These areas are indicated on the map by hatched lines. The cuttings are best preserved in four areas, and sections, looking up into the ravine towards the south or SE, have been drawn through the ravine at these points.

#### **Section A–A' (FIGS. 2, 5, 6)**

This area is quarried only on the western side of the ravine and only to a minor extent. At the line of the section, the stone is cut away in three steps, rising one above the other, parallel to the floor of the ravine. The second step, the narrowest, represents the remains of a quarrying channel (L. 1.07 m., W. 0.12 m.), which was dug along the inner western side of a block in order to free it. At the northern end of this channel, part of another quarrying channel may be observed running at right angles to it; it is the remains of a channel dug along the northern side of the block (FIG. 6, arrow). The width of the lower ledge, the length of the western quarrying channel (up to the point where it is crossed by the northern channel), and the distance above the western channel to the uppermost step give the approximate width, length, and thickness of a block removed from this middle step (L. 1.01 m., W. 0.66 m., Th. 0.30 m.). Another block was removed from the step immediately below. It would

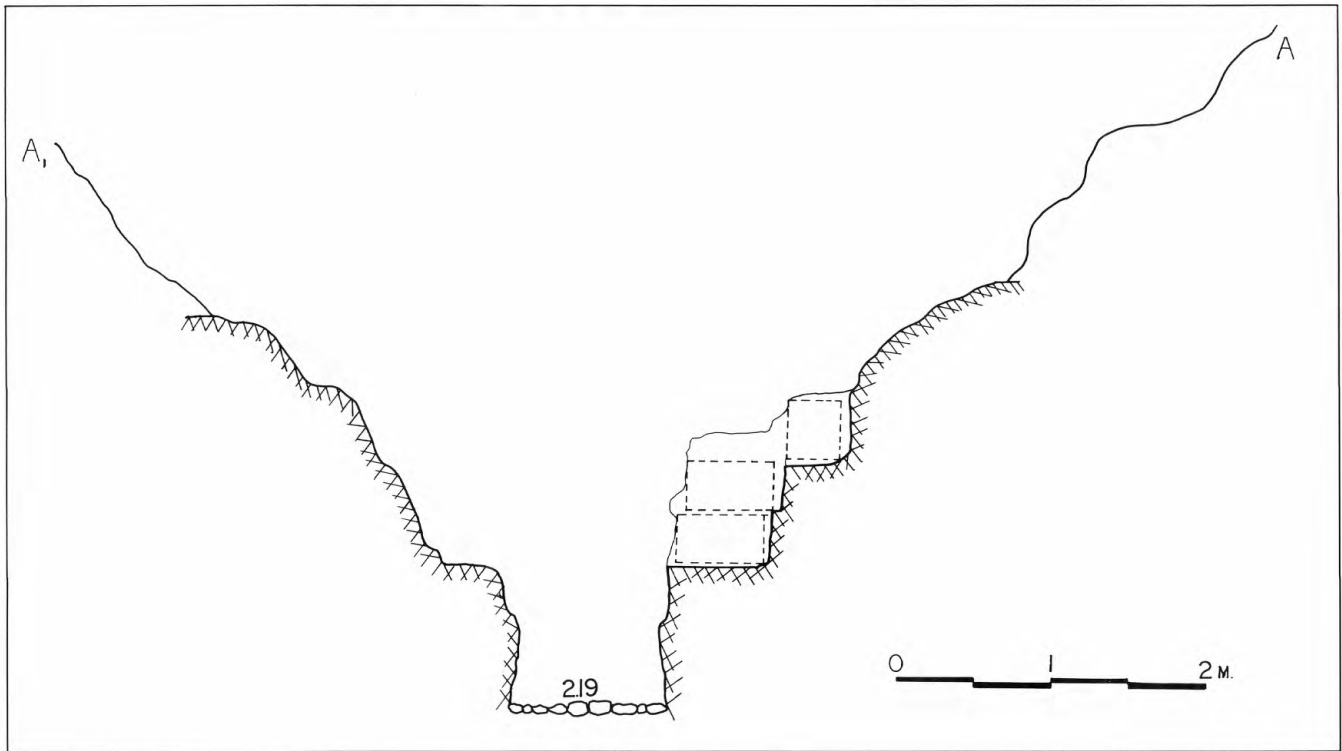


Figure 5. Section A-A' through quarry.

have had approximately the same width, a length equal to the length of the step itself, and a thickness equal to the distance between the lowest step and the middle step or western quarrying channel (L. 1.50–2 m., W. 0.66 m., Th. 0.34 m.). Still a third block, lying above these, somewhat to their north, was removed from the upper-

most step. This step represents only a corner of the removed block however; it was of indeterminate width and length, but of a thickness equal to the height of the step (Th. 0.41 m.). At least three blocks, therefore, were removed from this area; they are indicated in dotted lines on Section A-A'.

**Section B-B' (FIGS. 2, 7, 8)**

This area is quarried on both sides of the ravine, much more extensively than the area of Section A-A'. On the eastern side a single ledge has been cut back 2.50 m. to 3 m. above the base of the ravine. It extends for a distance of about 5 m., averages 1.30 m. in height and 0.55 m. in width. Several superimposed layers of blocks, the number depending on the thickness of the blocks, were removed along the entire length of this ledge. There is no indication of the size of these blocks, but the total amount of stone removed must have been about 3.58 cu. m. At the section on the western side of the ravine (FIG. 9), the face of the ravine has been cut back in three steps, and at least one block has been removed from each step. The lower step measures 0.72 m. by 1.08 m. and the distance from the lower step to the middle step measures 0.52 m.; a block of approximately these dimensions, therefore, was removed from this step. The middle step



Figure 6. View at Section A-A' from the east. Scale: 1 m.

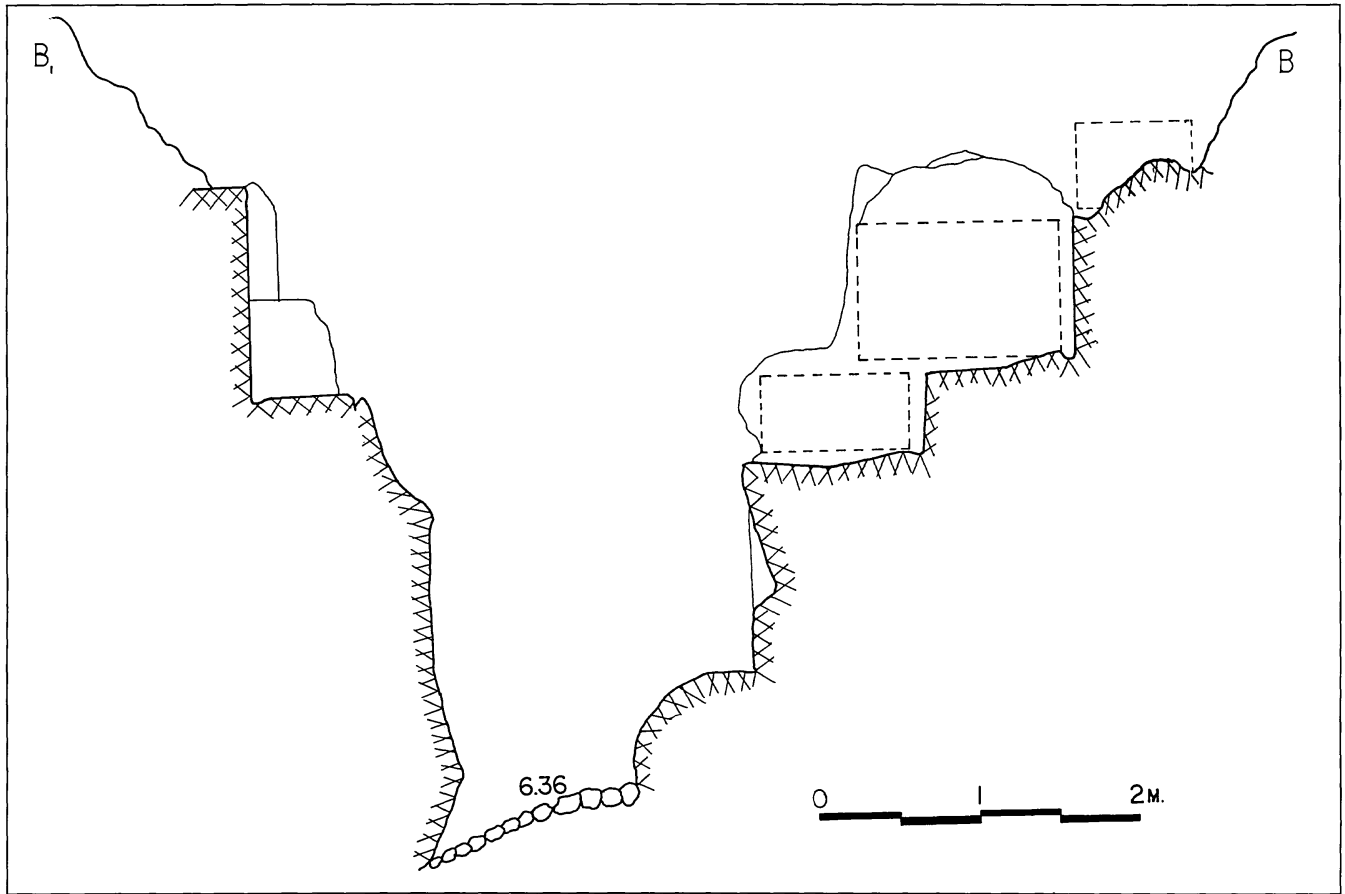


Figure 7. Section B-B' through quarry.

measures 0.69 m. by 0.93 m. and the height of the rise to the uppermost step measures 0.85 m. The block removed from this step, however, may well have extended out over the block beneath; so it is possible to obtain only the width and thickness of the removed block (W. 0.69 m., Th. 0.85 m.) Traces of quarrying channels, 0.06 m. wide, are preserved around the inner (south and west) sides of this step, and it becomes clear that the width of the surrounding quarrying channel must be taken into consideration in estimating the size of a removed block. The uppermost step is of special interest since one section of the block cut out by quarrying channels and removed from this step has broken off and remains in situ. The quarrying channels are still preserved along the south and west sides of the block, each 0.14 m. wide and 0.08 m. deep. The northern limits of the block are missing, but it appears to have been 0.94 m. long. Still another step was quarried immediately to the south of this section alongside the ravine; any steps to the north have been obscured by the dirt slide.

#### Section C-C' (FIGS. 2, 10, 11)

Only the north side of the ravine is quarried here where it is cut back in two great ledges, the upper rising 2.70 m. above the lower. While the lower ledge does not display any of the small steps that are found in Sections A-A' and B-B' and in other parts of the quarry, it is clear that the whole ledge has been cut back, as is indicated by the right angle at which it is cut into the ravine, by the vertical face and level bed of the ledge, and by traces of a quarrying channel along the inside of its bed. This lower ledge extends a considerable distance on either side of Section C-C' and has a length of approximately 20 m., a width averaging 2 m., and a height of 4.40 m. at its eastern face where no ledge is cut back above it. From these dimensions, it is possible to estimate the total amount of stone removed at 176 cu. m., and it is clear that the greatest amount of stone was removed at this point in the quarry.

The upper ledge here extends to the west of the section



Figure 8. View at Section B-B' from the east. Scale: 1 m.

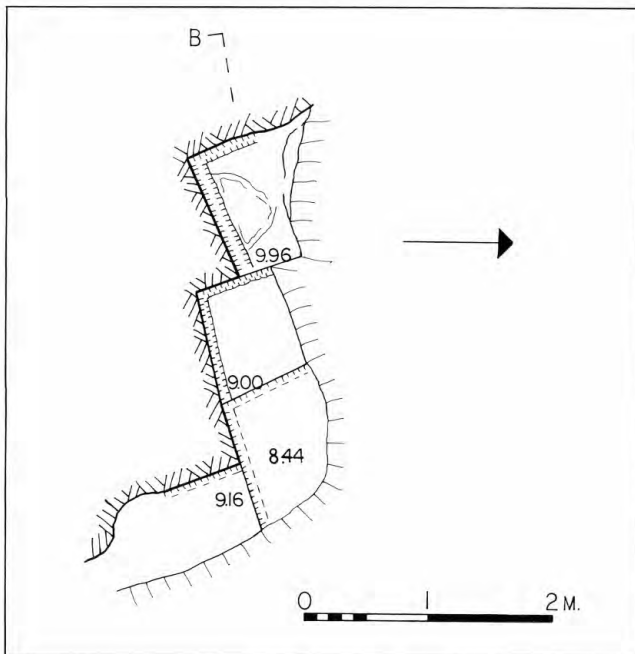


Figure 9. Plan of the western side of Section B-B', showing quarrying channels.

for a total distance of 15 m. It varies in width 3–5.30 m., and in height 0.50–2 m. It would have yielded a smaller amount of stone than the lower ledge. Its inner north face preserves the small steps characteristic of other parts of the quarry. The irregular vertical cuttings along this face suggest that the lengths of some of the blocks removed here were considerable. The best preserved is a projecting block near the middle of this side which was not completely cut out. It measures 2.27 m. in length and 1.15 m. in height; blocks of similar size were apparently removed on either side of this projecting block.

#### Section D-D' (FIGS. 2, 12)

At this section the ravine is again quarried on both sides. On the south a single ledge is cut back 3.16 m. above the floor of the ravine. It extends along the south side of the ravine for a distance of 11 m., averages 1.90 m. in width and 2.80 m. in height; it is possible, therefore, to calculate the total amount of stone removed from this ledge at 58.52 cu. m. At the east end of the ledge, just at Section D-D', and midway along the ledge, the inner south face of the ledge is cut back in three places, 0.82 m., 0.72 m., and 0.55 m. respectively (E-W); these cuttings represent the approximate widths of the blocks removed along the ledge and indicate that three rows of blocks, lying parallel to one another, were extracted. Along the eastern side of the easternmost cutting the remains of a quarrying channel may be observed.

On the northern side of this section, the ravine has been cut back with two ledges, the lower rising a maximum of 2.16 m. above the floor of the ravine, and the upper about 1.24 m. above the lower. Only the rear half of the lower ledge appears to have been quarried for sure. The rock face that rises above it at its eastern end is cut back twice, each cutting about 0.60 m. in width, and these again appear to represent the approximate widths of two rows of blocks removed along this ledge, one behind the other. As in Section A-A', a small step, 0.12 m. wide, in the north face of this lower ledge preserves the remains of a quarrying channel that was cut along the northern side of a block removed at this point. It indicates a thickness of 0.44 m. for the lowest block. The overall length of the ledge is ca. 7 m. and its width averages 1.20 m. The upper ledge measures about 5 m. in length and averages 1.20 m. in width and 2 m. in height. The total amount of stone removed from these two ledges then is ca. 39.22 cu. m. About 0.60 m. above the upper ledge, a quarrying channel, 0.14 m. wide, was cut at right angles to the ledge, and represents the beginning of a third ledge which was never cut out.

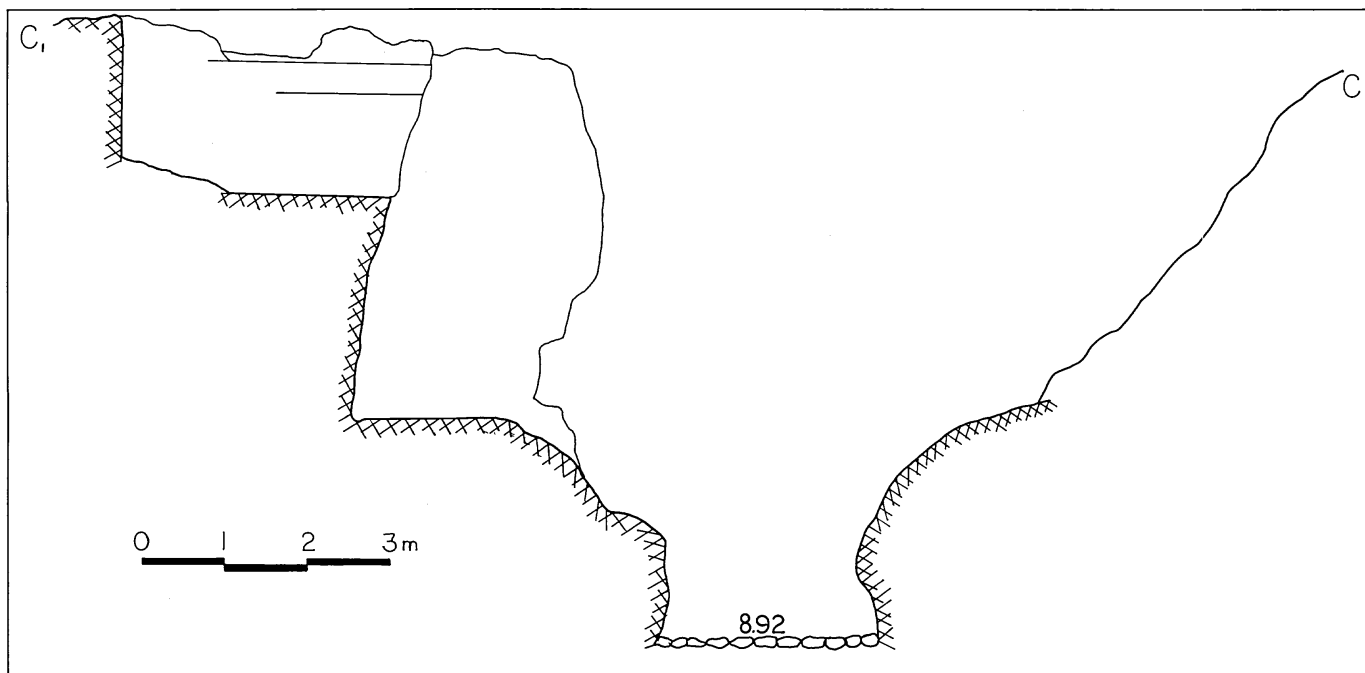


Figure 10. Section C-C' through quarry.

### Quarrying Techniques

Ancient quarrying techniques in Crete have been described most recently and most reliably by J. W. Shaw in his discussion of the Pelekita quarry at Zakros, another sandstone quarry in eastern Crete.<sup>7</sup> The techniques used in the Mochlos quarry appear to have been similar. As at Pelekita the quarry workers attacked the exposed sandstone with a pointed tool, probably a pick or adze, as Shaw has suggested, and began by digging narrow channels around the blocks they wished to remove.<sup>8</sup> *Am-moudha*, being soft and friable, could be cut back easily with such a tool, even a bronze tool, but, as Shaw has also suggested, the stone, which is highly porous, may have been soaked in water first to prepare it for cutting even more easily.

7. Shaw, *op. cit.* (in note 4) 30–35. For ancient quarrying techniques in general, see R. J. Forbes, *Studies in Ancient Technology VII* (Leiden 1963) 162–177. For Egypt: S. Clarke and R. Engelbach, *Ancient Egyptian Masonry* (Oxford 1930) 12–33, figs. 8–33; A. Lucas and J. Harris, *Ancient Egyptian Materials and Industries*, 4th ed. (London 1962) 63–92; H. Goedicke, “Some Remarks on Stone Quarrying in the Egyptian Middle Kingdom (2060–1786 B.C.),” *JARCE* 3 (1964) 43–48.

8. At Pelekita the vertical grooves left by such tools can be observed in the quarry faces (Shaw, *op. cit.* [in note 4] 32–33); at Mochlos similar grooves may be observed, but it is not always clear whether these are natural or man-made. The best example is located on the quarry face at the eastern end of Section C-C' (L. 0.14 m., W. 0.03 m.).

At Mochlos the workers began cutting their channels along the innermost sides of the ravine and along the highest part of the exposed stone and worked downwards and outwards from the center of the ravine, thereby creating the stepped ledges that are characteristic of the quarry. This approach had two advantages: first, the quarry worker needed to cut only three channels around his block (and only two after the first block had been cut away and removed) since the side toward the ravine was already free; second, once the quarry channels had been cut around the block and the block was ready to be freed, the quarry worker would have ready access to the side of the stone that must then be scored, probably with the same pointed tool, and wedged free, using some sort of chisel. A straight line, 0.05 m. wide and 1.72 m. long, which runs along the cut face of the stone at the eastern end of the upper ledge of Section C-C', may represent the remains of such scoring. It should be stressed that no traces of drill holes or of any kind of wedging holes exist in the quarry, or in any of the ancient quarries in Crete for that matter, and the quarrying methods described by Evans, Chapouthier, and Graham do not seem to have been used in Crete.<sup>9</sup>

9. Arthur Evans, *The Palace of Minos II* (London 1928) 233, fig. 131B; F. Chapouthier, *Les écritures minoennes au palais de Mallia, Études crétoises II* (Paris 1930) 87–88, figs. 32–33; J. W. Graham, *The Palaces of Crete* (Princeton 1969) 153. In the inscription that



Figure 11. View at Section C-C' from the south. Scale: 1 m.

Once the quarry workers had removed a set of blocks from the first ledge and had cut as far down into the ravine as they wished to, they would proceed to cut a second ledge behind the first, beginning once again on the side closest to the ravine and working outwards from the ravine's center. They might continue this second ledge as far down into the bedrock as the first and maintain a vertical face all the way down, in which case no trace of the first ledge would remain. This appears to have

Goedicke translates (op. cit. [in note 5] 45-48), after the block has been cut around, instead of wedges, fire is used to separate the block from the living rock at its base.

been the case on the south side of Section D-D' and also in the area cut just to the east of Section C-C'. In both these areas there is only a single ledge, but the substantial height of these ledges (in Section D-D' close to 3 m., and in C-C' over 4 m.), and their considerable depth, indicate that several ledges or layers of stone must have been cut out one behind the other. Little trace of these remains since each ledge was cut down the same distance as the one in front of it to form a level bed. On the other hand, the workers might cut the second ledge down only part of the distance of the first ledge. In this case, part of the original ledge would remain intact. It might be only a narrow step that remained, or a more substantial ledge, depending on how far back the workers cut the second ledge. In Section C-C', for example, after cutting several layers of stone out of the innermost ledge, all down to the same bed, the workers ceased to cut down as far as they had initially, thereby leaving a considerable part of the ledge behind intact.<sup>10</sup> In Section A-A', on the other hand, the lowest ledge was cut back almost as far as the ledge above it, but not quite, and a narrow step preserves the level of this ledge as well as the remains of the quarrying channel which was cut along the stone removed from the ledge.

Once the blocks were cut free of the bedrock, there is no indication that they were further worked or dressed while in the quarry itself. The only task that remained

10. The outer ledge, which because of its great width must also represent the remains of several steps or ledges, all cut down an equal distance, could have been cut down farther if the workers had so desired.

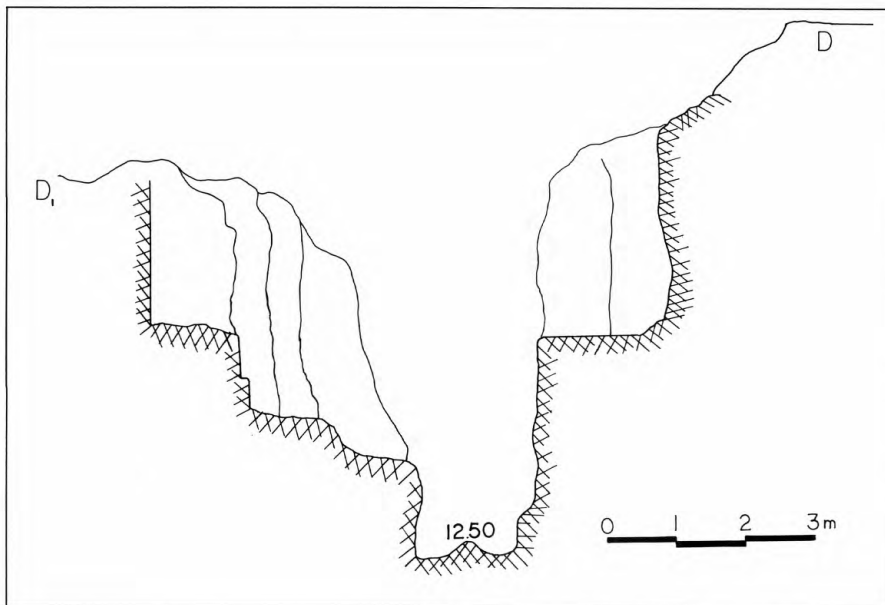


Figure 12. Section D-D' through quarry.

for the quarry workers was the removal of the stone from the quarry. This they accomplished by lowering the blocks into the ravine, probably using ropes and wooden supports placed at an angle to the sides of the ravine so that the blocks could slide down readily. The workers would then have dragged the blocks across the rounded river stones that line the floor of the ravine, perhaps using wooden rollers, until they reached the mouth of the ravine. This operation would have proceeded smoothly since nowhere is the floor of the ravine less than a meter wide, and the river stones and the natural slope of the ravine's floor would have facilitated the dragging of the blocks. At the mouth of the ravine, where sea water actually enters the ravine, the blocks could be loaded onto waiting barges or rafts and then hauled by ship to their destination.

### The Destination of the Quarried Stone

What was the destination of these stones? The large amount of stone quarried, over 350 cu. m.,<sup>11</sup> and the large size of several of the blocks cut,<sup>12</sup> suggest that the stone was used in a building or in buildings of some substance.

Richard Seager observed that the stone was used in the Roman houses on Mochlos and believed that the quarry was worked only in the Roman period. Indeed, a small amount of sandstone was used in Roman structures on Mochlos, but it is nowhere near the amount that was removed from the quarry, and the blocks belonging to these structures are small rectangular blocks that do not approach the dimensions of the larger blocks removed from the quarry.<sup>13</sup>

At the same time, some sandstone was used in Late Bronze Age buildings on Mochlos, and it is thus clear that the quarry was already being worked that early. This

stone is found in two places. Some squared blocks were used as building material alongside unworked stones in the rubble walls of the Late Bronze Age houses.<sup>14</sup> In that case, the blocks appear to have been damaged before being used in the wall. Part of a squared block was broken off, and the remainder was set in an earth mortar in uneven courses in the same fashion as the unworked stones in the wall. In no case were the blocks used in standard Minoan ashlar fashion with neatly squared faces laid in strict horizontal courses. The other and more extensive use of cut sandstone on the island is found in House D, which was remodelled late in the LM I period, ca. 1500 B.C. As a part of this remodelling ashlar sandstone blocks appear to have been laid in the floor of Room 9, and rounded sandstone blocks were used for the new column bases in that part of the house.<sup>15</sup> But once again, in neither case do the sizes of the blocks employed, or the total amount of stone cut, approach the size of the larger blocks or the total amount of stone removed from the quarry. Even the total amount of sandstone used in both periods, Late Bronze Age and Roman, is a small fraction of this quarried stone. It is certain, however, that the quarry was opened in the Late Bronze Age and that its stone was intended primarily for some other destination. Its use on Mochlos was incidental.

There is no evidence that this stone was used during the Late Bronze Age or the Roman period anywhere else in the immediate vicinity of Mochlos. The Late Bronze Age houses on the neighboring island of Pseira were made of field stones and schist slabs extracted locally, and the Roman houses that were erected a short distance to the east of Mochlos on the adjacent coastal plain had mostly river stones embedded in concrete. The only place nearby where both large quantities and large cut blocks of sandstone were used in either period is Gournia, which lies about 14 km. up the coast to the west of Mochlos (about 7 nautical miles). Late in the LM I period when (not coincidentally) the first cut sandstone appears on Mochlos, the small palace at Gournia was remodelled. It is not clear what prompted this remodelling, perhaps the damage caused by an earthquake, but the intention of the Gournia builders was to redesign the palace so that it would resemble the great palaces at Knossos, Mallia, and Phaistos more closely. Perhaps the most important means of achieving this goal was the introduction of ashlar masonry to certain key parts of the building. Large cut blocks of sandstone were used in three areas.<sup>16</sup>

11. This figure is an estimate and includes only the areas quarried on either side of the four sections: from A-A', 0.46 cu. m. (the lowest two blocks only); from B-B', (east) 3.58 cu. m., (west) 1.22 cu. m. (the lowest two blocks only); from C-C', (lower ledge) 176 cu. m., (upper ledge) 77.81 cu. m.; from D-D', (south) 58.52 cu. m., (north, lower ledge) 27.22 cu. m., (north, upper ledge) 12 cu. m. A small amount of stone was also cut from other parts of the ravine.

12. In length the blocks range from ca. 1 m. to just over 2 m., in width 0.60–1.15 m., and in thickness 0.30–0.85 m. The approximate dimensions of the blocks noted are as follows: at Section A-A', 1.01 m. × 0.66 m. × 0.30 m., 1.50–2 m. × 0.66 m. × 0.34 m.; at Section B-B', 1.08 m. × 0.72 m. × 0.52 m., 1–1.40 m. × 0.69 m. × 0.85 m.; between Sections B-B' and C-C' (on west), 1.58 m. × 0.60 m.; at Section C-C', 2.27 m. × 1.15 m. Compare the dimensions of the blocks from Pelekita, Shaw, op. cit. (in note 4) 34.

13. These blocks could, however, have been cut down from larger blocks and reused in the Roman walls. The best preserved examples are to be found in the western part of Block D in the settlement.

14. Several are located in Blocks A and B of the settlement.

15. Seager, 1909 op. cit. (in note 1) 293–295, figs. 14–16.

16. H. B. Hawes and others, *Gournia, Vasiliki and other Prehistoric Sites on the Isthmus of Hierapetra* (Philadelphia 1908) 24–25. Hawes mistakenly identifies this stone as "soft limestone".

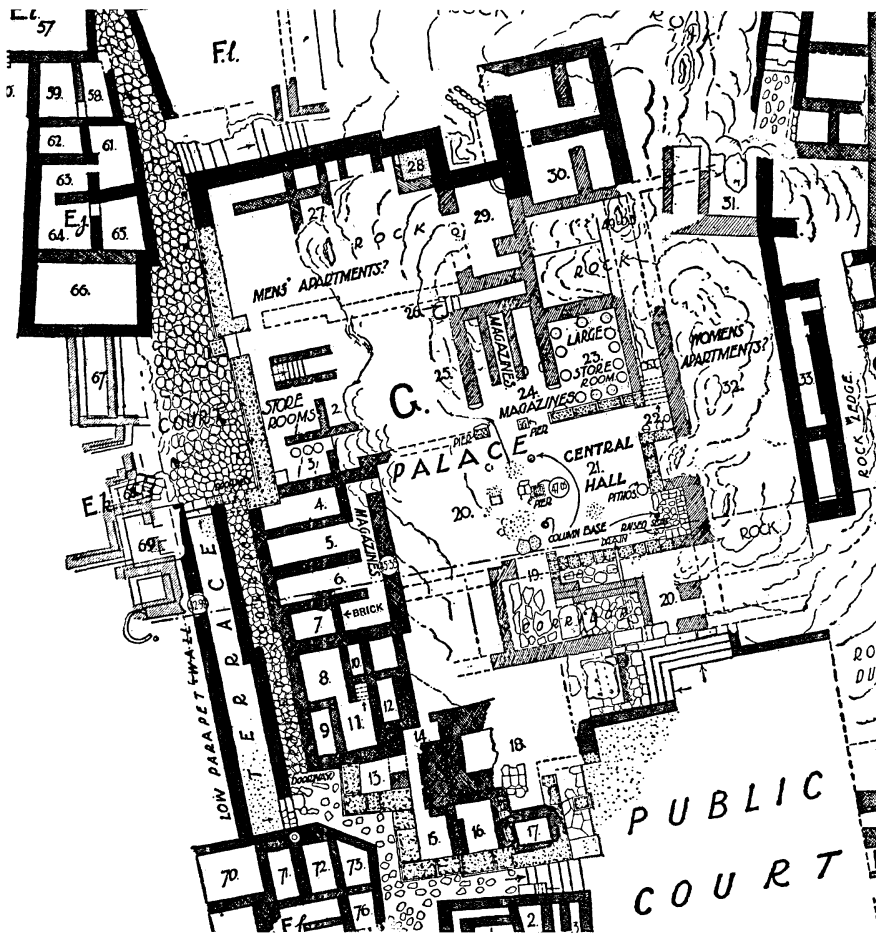


Figure 13. Plan of the palace at Gournia. Walls of ashlar *ammodha* are indicated by dotted areas; walls of ordinary rubble construction are indicated in hatched lines or black. Scale: 1:400.

They were used for the rebuilt western façade, with its “window of appearances”; they were used for the outer walls of a newly added extension at the sw corner of the building, which was to contain important public shrines; and they were used inside the building around a major court (FIG. 13).<sup>17</sup> The blocks in the west and sw façades are the largest, measuring 0.66 m. to 2.03 m. in length, 0.73 m. to 1.20 m. in width, and 0.48 m. to 0.76 m. in height (FIG. 14).<sup>18</sup> They were laid on a low projecting plinth in regular horizontal courses, and although only a maximum of two courses is preserved at any one point in these façades (max. H. 1.48 m.), they probably rose a total of four courses, about 3 m., to form the entire

17. This figure, which indicates these ashlar walls, is reproduced from Hawes, *ibid.*, Plan.

18. Most of these blocks are 1–2 m. in length; one at the north end of the western façade retains a quarrying channel at its top. Like all standard Minoan ashlar, the blocks were neatly dressed in front and on top and bottom, where they join other ashlar blocks, but in the rear they were only roughly cut to form a triangular or wedge shape where they back into rubble walling.

lower story wall as at Phaistos or Mallia.<sup>19</sup> Above this point, however, the wall would almost certainly have continued in mudbrick or rubble. It is thus possible to estimate the total amount of stone in these façades at something over 88 cu. m.

Inside the palace, smaller blocks are used around the court. The dimensions vary: L. 0.47–1.75 m.; W. 0.40–0.83 m.; and H. 0.46–0.62 m. Those on the north side of the court are used as orthostates set back on a low sandstone plinth, only one course high. On the south only the plinth remains, and the entire course of stones above is missing. On the east three courses of blocks are set without a plinth. These and the blocks on the north are preserved to their full height. Along the top blocks small, square dowel holes are cut for the insertion of wooden tenons and upright vertical timbers, indicating that above this point the wall continued in timber and

19. This at least would have been their total height along the western side of the palace, which lies exactly 3 m. below the floor level of the Central Hall, which is preserved to the east.



Figure 14. West façade of the palace at Gournia from the NW. Scale: 1 m.

mudbrick. If the south wall of this court resembled the north wall in construction and only one course of stone blocks was used here, too, the total amount of stone used in these three walls was about 13 cu. m. On the west of the court sandstone was used for the pillar bases, which are also marked with dowel holes on their tops and apparently also supported timber and mudbrick above, and for the column bases; the total sandstone here is just over 1.30 cu. m. The total amount of sandstone used in the remodelling of the palace, then, is just over 100 cu. m., a figure that falls well within the amount removed from the quarry at Mochlos.<sup>20</sup>

20. This amount is also an estimate. It is based on the following calculations and excludes paving slabs and part of the plinths, the complete thicknesses of which cannot be easily measured since they are set below ground level: West façade (15.68 m. × 0.80 m. × 3 m.) 37.63 cu. m.; West Court pilasters (0.92 m. × 0.60 m. × 3 m.; 0.96 m. × 0.60 m. × 3 m.) 4.05 cu. m.; Southwest façade (lower wall: 10.96 m. × 0.80 m. × 3 m.) 26.30 cu. m.; Southwest façade (upper wall: 10.80 m. × 0.80 m. × 2 m.) 17.28 cu. m.; Court pillars (0.85 m. × 0.85 m. × 2 m.; 0.72 m. × 0.68 m. × 2 m.; 1.12 m. × 0.36 m. × 2 m.) 3.24 cu. m.; Central Hall (north wall: 5.84 m. × 0.60 m. × 0.80 m.) 2.80 cu. m.; Central Hall (south wall: 6.96 m. × 0.60 m. × 0.80 m.) 3.34 cu. m.; Central Hall (east wall: 8.16 m. × 0.60 m. × 1.42 m.) 6.95 cu. m.; Central Hall pillars (0.84 m. × 0.60 m. × 0.51 m.; 0.64 m. × 0.60 m. × 1 m.; 0.60 m. × 0.60 m. × 1 m.; 0.65 m. × 0.44 m. × 1 m.) 1.29 cu. m. Total: 102.88 cu. m.

Elsewhere at Gournia the stone was used for Houses Ha and E1, which lie immediately to the south and SE of and adjacent to the palace. Here rather small and roughly worked blocks were used in the street façades; they were laid irregularly above rubble foundations, not in the monumental fashion that was used in the palace. The stone here may have amounted to no more than 20 cu. m. in all, and much of it may have come from cutting down the blocks used in the palace.

It would appear then that the remodelling of the palace at Gournia was the motive for opening the *ammoudha* quarry at Mochlos. This stone is not to be found in the immediate vicinity of Gournia, where limestones and conglomerates predominate, but because of its extensive and fashionable use at other important sites in eastern Crete—as at the palaces of Mallia and Zakros, and at scattered country villas where it is used in an identical fashion to form important façades and line interior courts—a source of identical stone had to be located for the successful remodelling of the palace at Gournia.

The distance to Mochlos was not a major consideration since once loaded onto barges or rafts the stone could be shipped easily by sea, more easily, in fact, than overland from a source closer by, even if such a source had existed. The site of Gournia itself lies close to the coast, and the small beach and harbor located here would provide good landing space for the ships bringing in sandstone blocks. Once landed, the blocks could be hauled up the bed of the river that opens onto the beach and runs back along the western side of the settlement into the hills to the south. Where the river bed passes closest to the settlement, an earth ramp could be cut in its rather steep banks so that the blocks could be hauled up to the higher ground level above the river bed and across to the site. The stone would have been further cut and dressed on the site itself to meet the requirements of the building. The labor involved in this work was presumably divided between the settlers on Mochlos and those at Gournia. Because of the proximity of the quarry to the island of Mochlos, one assumes that the cutting of the stone in the quarry and the delivery of the stone to Gournia were among the occupations of the settlers on Mochlos.

#### Other Sandstone Quarries in Eastern Crete (FIG. 1)

The quarrying techniques used in the Mochlos quarry and the method of shipping the stone to its destination appear to have been standard procedures in the Late Bronze Age in eastern Crete. There are four major sandstone quarries that may now be identified in this part of the island and associated with major Minoan buildings. All of them are located directly on the coast a short distance from the site where their stone was used.

By far the largest and oldest of these is the quarry at the Point du Moulin, which provided ashlar masonry for the palace at Mallia.<sup>21</sup> It is located on the coast ca. 1 km. to the west of the palace, and was worked as early as the Old Palace period, ca. 1900 B.C., when ashlar

21. Chapouthier, op. cit. (in note 9) 87–88; H. and M. Van Effenterre, *Fouilles exécutées à Mallia, étude du site et exploration des nécropoles, Études crétoises XIII* (Paris 1963) Plans 1 and 2; Shaw, op. cit. (in note 4) 35–38.



Figure 15. Ridge of *ammodha* at Ta Skaria from the south. The arrows indicate the extent of the quarried area.



Figure 16. *Ammodha* quarry at Ta Skaria. Detail of cuttings from the sw.

sandstone began to be used at Mallia. The quarry extends for several kilometers along the coast wherever low outcroppings of sandstone appear.

The quarry at Pelekita is located about 5 km. to the north of Kato Zakros, and provided the stone for the palace that was built here in the Second Palace period, ca. 1700 B.C.<sup>22</sup> It consists of a large outcropping of sandstone that sits on top of hard limestone. The outer sides of this outcropping have been cut back, and, as a result, it is difficult to estimate from the quarry alone how much stone has been removed. The amount of stone found at Zakros, however, suggests that this quarry should fall somewhere between those at Mallia and Mochlos in size.

The quarry at Ta Skaria lies about 5 km. SE of Palaikastro. It was noted by R. C. Bosanquet in 1902 at which time it was still being worked and the stone from the quarry was described as "dark yellow freestone";<sup>23</sup> the quarry otherwise remains unpublished. It is located on a low ridge of sandstone that runs down to the sea and is flanked on the north and south by shallow river beds (FIGS. 15-16). The north side of this ridge and the opposite side of the north river bed were both quarried. Immediately below there is a small cove with a sandy beach where the stone could be loaded and transported up the coast to Palaikastro. Here sandstone was used for the ashlar façades of several large houses and for the causeways of the cobbled streets. The small size of the quarry at Ta Skaria, considerably smaller than that at Mochlos,

22. N. Platon, 'Ανασκαφαὶ Ζάκρου, *Praktika* (1968) 181-183, figs. 164 a-b; *Zakros, The Discovery of a Lost Palace of Ancient Crete* (New York 1971) 53-54, 85; Shaw, op. cit. (in note 4) 30-35, figs. 21-23.

23. R. C. Bosanquet, "Excavations at Palaikastro, I," *BSA* 8 (1901-1902) 315.

suggests that the stone may never have been used more extensively on the site.

Although all of these quarries are situated on the coast, they each show some important differences in their individual topographic features. The Mochlos quarry, for example, is the only one that is located inside a deep ravine. The sandstone outcropping at Pelekita rises vertically several meters and is isolated by the hard limestone on which it rests. The ridge of sandstone at Ta Skaria is considerably lower and more extensive, but not nearly as low or as extensive as the flat outcroppings that occur along the coast at Mallia. Because of these differences, the quarried areas also differ somewhat in appearance. Numerous small steps characterize the quarries at Pelekita and Ta Skaria, but at Mochlos they are less pronounced, found mainly at Sections A-A' and B-B'. The deep ledges that cut into the sides of the ravine at Sections C-C' and D-D' account for most of the stone that was quarried here, and the vertical faces of these ledges are characteristic of the quarry. At Mallia, on the other hand, there are no deep ledges and very few steps; instead, the blocks are cut out alongside one another on a fairly level plain. These differences, however, are not a result of different quarrying techniques. Quarrying channels were found in each quarry, and the same techniques were clearly used in each quarry.

The sandstone itself appears to show some variation within each quarry, particularly in color, in texture, and in porosity. The colors include browns and reds as well as a pale yellow. The size of the sand grains ranges from fine to slightly coarse and the porosity of the stone varies widely. C. Pareyn, in his analysis of the stone at Mallia, has also noted variations: one group of sandstone (the stone actually quarried for building material) was con-

siderably finer and more homogeneous than the rest.<sup>24</sup> Similarly, at Mochlos these variations and differences in quality may explain, at least in part, why the ravine was cut in so many different locations: the quarry workers sought areas where the stone was best suited to their purposes.

Shaw has suggested that the sandstone at Pelekita is more compact than that at Mallia because of finer sand grains and a stronger gluing agent.<sup>25</sup> Whether or not the differences between quarries are so distinct, however, is not certain. It would be useful, if permits could be arranged, to collect samples from the quarries and from the sites where the stone was used, for petrological or chemical analysis in the laboratory. Multiple samples would be needed, however, because of the apparent variations within each deposit.

One question that remains from this study of the Mochlos quarry is particularly intriguing. If the palace and houses at Gournia used only one third of the total amount of stone extracted from the quarry, as they seem to have, and if the amount of stone used on Mochlos itself is negligible, where was the remaining stone used? One suspects that somewhere along the coast to the east towards Siteia, or perhaps even farther afield in the Dionysiades, both poorly explored areas, another building, whether a small palace like that at Gournia or a country villa, was erected with sandstone from the Mochlos quarry in the Late Bronze Age when this stone was in such great demand. On the other hand, because of the extremely conservative nature of Cretan quarrying techniques, apparently unchanging over thousands of years, the quarry may have been reopened at a later time, perhaps in the Venetian period, or like Ta Skaria even in the 20th century. But it is doubtful if the stones cut were ever as large as those cut in the Late Bronze Age, or if the destination of the stone was ever for a project of such magnitude as the palace at Gournia.

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*Jeffrey S. Soles is Assistant Professor of Classics and Classical Archaeology at the University of North Carolina at Greensboro. He has been working at Mochlos since 1971 and has a particular interest in the topography, monuments, and history of eastern Crete.*

24. C. Pareyn in Van Effenterre, *op. cit.* (in note 21) 21–27; see also M. J. Becker, “Soft Stone Sources on Crete,” *JFA* 3 (1976) 361–374, who notes similar variations, particularly in the range of colors, in deposits of other types of stone.

25. Shaw, *op. cit.* (in note 4) 24.