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A Middle Stone Age occupation site at Porc Epic cave, Dire Dawa (east-central Ethiopia)

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Abstract

This paper describes the results of the 1974 excavations at Porc Epic Cave, Dire Dawa. Following a summary of Dr M. A. J. Williams' interpretation of the stratigraphic succession and geological history of the cave and its contained deposits, the cultural sequence is described and an explanatory model presented. The 1974 excavation showed the Middle Stone Age layers to be sealed under a massive dripstone, except in the front part of the cave where erosion and later deposition had produced the seeming mixing of Middle and Later Stone Age artifacts observed by the 1933 excavators. Artifacts are associated with comminuted and often burnt bone round what appear to be hearths. Tools consist predominantly of points, scrapers and edge damaged blade and flake forms. The specialized nature of the retouched and utilized tools, together with the relative inaccessibility of the cave and the comminuted nature of the bone waste, suggest the possible use of the cave as a hunting camp at seasons when game migrated into the escarpment from the Afar Plains. The wide-ranging habits of the occupants are attested by the presence of obsidian and basalt artifacts, the raw material for which is not found in the immediate vicinity of the site. On the basis of the human jaw fragment discovered in 1933, the Middle Stone Age occupants of the cave are said to show both neanderthal and non-neanderthal features. Hydration dates for obsidian artifacts from the Middle Stone Age deposit indicate that the cave was occupied between about 61,000 and 77,500 bp. These results confirm that the Porc Epic occurrences are of comparable age to those from Middle Stone Age localities in other parts of the continent.

Résumé

Cet article décrit les résultats des fouilles de 1974 à la grotte du Porc Epic, à Dire Dawa. Suivant un résumé de l'interprétation de la succession stratigraphique compilé par M. A. J. Williams et l'histoire géologique de la grotte et de ses dépôts, la séquence culturelle est décrite et un modèle explicatif est présenté. La fouille de 1974 a révélé que les couches du Middle Stone Age ont été scellées sous une épaisse couche de concrétion calcaire, sauf dans la partie avant de la caverne où l'érosion et une déposition ultérieure ont produit le mélange apparent des outillages du Middle et du Later Stone Age observé par les fouilleurs en 1933. Les industries sont associés à des fragments d'os souvent brûlés, autour de ce qui semble être des foyers. Les outils consistent surtout de pointes, de grattoirs et de formes de lames et d'éclats à bords endommagés. La nature spécialisée des outils retouchés et utilisés, ainsi que l'inaccessibilité relative de la grotte et l'aspect fragmenté des restes osseux, suggèrent l'usage possible de la grotte comme camp de chasse durant les saisons de migration du gibier vers l'escarpement des plaines des Afars. Les déplacements des occupants sur un vaste terrain sont attestés par la présence d'outils en obsidienne et en basalte, deux matériaux qui ne sont pas trouvés dans les environs immédiats du site. En se fondant sur un fragment de mâchoire humaine découvert en 1933, les occupants de la grotte au Middle Stone Age semblent démontrer des traits néanderthaliens et non-néanderthaliens. Les dates obtenues par la méthode d'hydratation des pièces en obsidienne provenant du dépôt du Middle Stone Age indiquent que la grotte fut occupée entre environ 61,000 et 77,500 bp. Ces résultats confirment que les activités dans la grotte du Porc Epic sont d'un âge comparable à celles des localités du Middle Stone Age trouvées ailleurs dans le continent.

Part I

Earlier Stone Age (ESA) artifact assemblages and the nature of the preferred occupation localities during the earlier Pleistocene in Ethiopia are becoming better known and more satisfactorily dated as a result of several recent studies on the high plateaux (Chavaillon *et al.* 1979; Clark and Kurashina 1979; Kurashina 1978) and in the Rift (Corvinus 1976; Corvinus and Roche 1976; Harris 1983; Roche and Tiercelin 1977; Clark *et al.* 1984; Merrick and Merrick 1976; Chavaillon 1976). Considerably less, however, is known of the Middle Stone Age (MSA) activity areas and the associated archaeological occurrences.

Good studies of obsidian quarry and workshop localities in association with volcanic centers at Gadamotta and Kulkuletti in the Lake Zwaai basin (Wendorf and Schild 1974) and at Kone' in the southwest corner of the Afar Rift (Kurashina 1978) show the nature of the flaking concentrations and other probable activity areas. A stratified sequence of deposits with 'Middle Stone Age' artifacts exists also at Melka Kunture on the Ethiopian Plateau south of Addis Ababa (Hours 1976) and occasional artifacts occur also in the fluvial sediments overlying the Plio-Pleistocene sedimentary sequence at Gadeb on the Southeast Plateau (Clark and Williams 1979). Others again are found eroding from alluvium at Modjio (M. A. J. Williams pers. comm.) but none of these are primary context sites and only at Melka Kunture has excavation been carried out. At the north end of Lake Tana a cave or deep rock shelter at the top of a steep hill close to the town of Gorgora was partially excavated in 1943 by Moysey (1943) and yielded a stratified 'Middle Stone Age' sequence with Later Stone Age (LSA) artifacts in the overlying layers. This is clearly a site reoccupied over a long period of time, perhaps a base camp, and would well repay further study. The artifact assemblage was described by Leakey (1943) but no quantitative details are given and the collection available to him was probably selected.

The only other MSA occupation occurrence yet studied is that from the Porc Epic cave at Dire Dawa, a site which, although known since 1933, received little attention until recently because of the believed disturbed nature of the occupation deposits. This paper is concerned with our own investigation of the cave in 1974 and the analysis of the excavated MSA assemblages.

Location

Porc Epic cave is situated some 2 km south of the town of Dire Dawa lying at the foot of the escarpment rising from the southern Afar plain and straddling the mouth of the Laga Datchatou (Fig. 1). The cave is located near the top of the hill called Garad Erer that rises very steeply from the narrowed wadi floor on the east side, and a stiff climb through thorn-bush and prickly pear is necessary to reach it 140 m above the wadi bed. It is also possible, though no less difficult, to reach the cave by means of a climb down a fissure from the top of the vertical, 9 m high cliff face above it.

Although the cave is not easily accessible, it commands a view of a great expanse of lower lying, open terrain to the north and of the wadi bed leading southwards into the escarpment. This wadi system is the major access route today for traffic onto the plateau. The plains and the lower slopes of the escarpment are covered by xerophytic vegetation while the plateau supports montane grassland and evergreen forest with *Podocarpus* and juniper. There are two rainy seasons, the lesser rains falling in April and the main ones in July and August. During the dry winter months from September to March the temperature on the plateau approaches freezing at night and there is a corresponding lowering of temperature in the Rift also. During the rains, the Gugure (Somali) pastoral nomads range westwards, following the base of the escarpment almost to the Awash river 140 km to the west, and lesser distances to the north and east into the southern parts of the Afar plains. In winter, when the temporary water supplies have dried up, they concentrate with their herds of cattle, small stock and some camels, in the wadis of the escarpment and live in symbiotic relationship with the Kotu (Oromo) cultivators of the region. This pattern of seasonal movement is important since, on the basis of the studies carried out in the Awash National Park (Robertson n.d.) we believe it follows the older pattern of game movement in the same region, at least so far as the gregarious grazing animals are concerned. Game can be expected to have moved up the sheltered escarpment wadis to the permanent springs and water sources in September/ October at the beginning of the winter and out again into the plains with the coming of the rains in April/May. During the time of the Last Glacial maximum in high latitudes, temperatures are known to have been at least 6°C lower than they are today so that such seasonal movements probably assumed then even greater significance for man and beast.

Since Porc Epic is the only cave in the area suitable for occupation, it may well have been a preferred vantage place for hunters watching for the migrating game animals in the fall and spring.

Geology

The escarpment in which the cave is situated exposes a repeating sequence of pre-Cambrian granites and Mesozoic sandstones and limestones, the resistant limestone forming massive cliffs while the more easily eroded granites and sandstones floor the intervening valleys. The escarpment is drained to the north by systems of wadis that have cut across the East/West striking step faults forming a series of limestone cliffs in which there are caves. Porc Epic cave, so called by the first authorized excavators in 1933, or—to give it its local name *Derer* (meaning 'high')—faces west looking onto the wadi. It is some 14 m wide and 3 m high along the drip line. The walls converge at the back (the east) and the roof also slopes so that the main area for occupation—about 115 m^2—is towards the drip line.

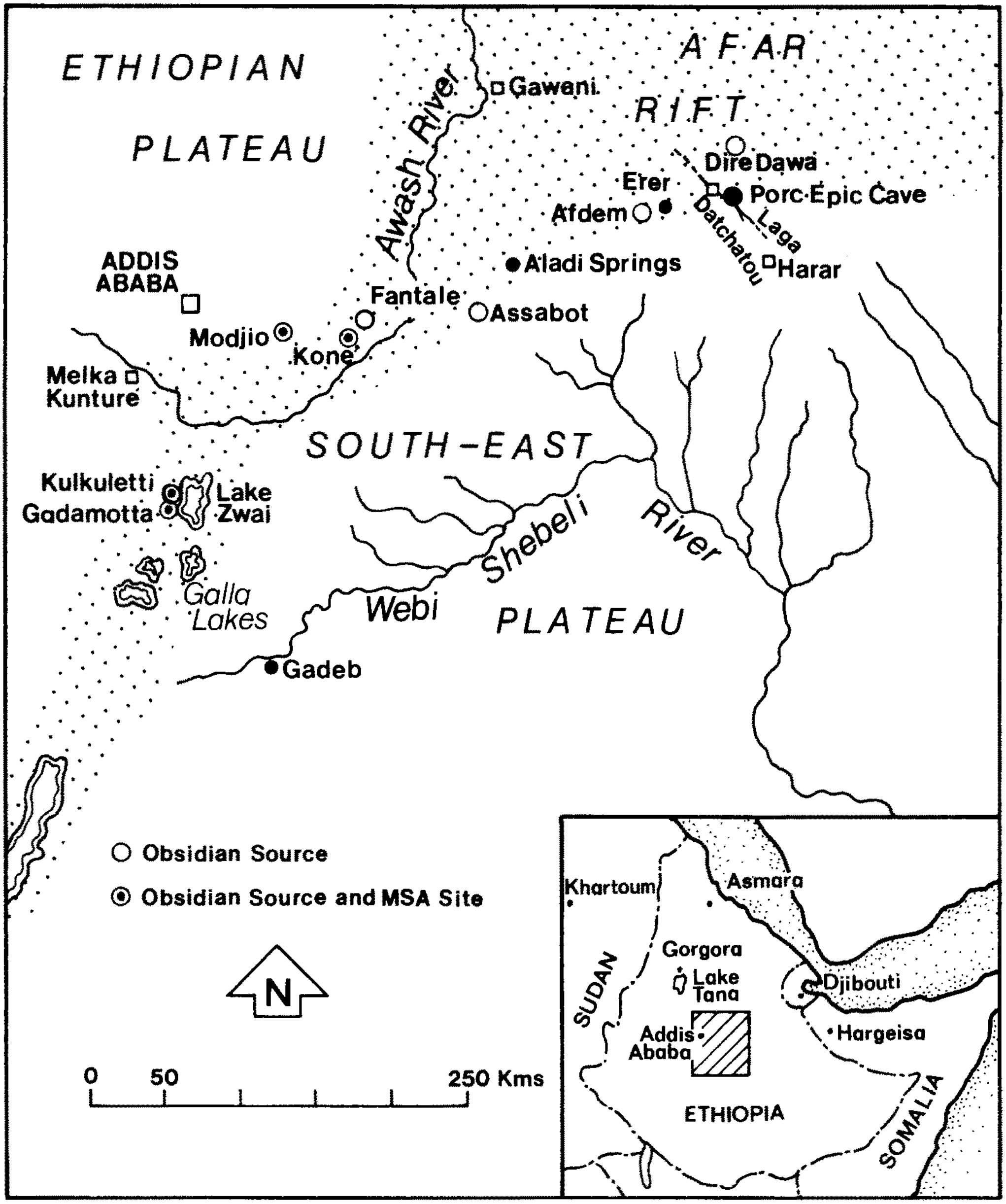

Figure 1 Locality map to show the position of the cave in relation to the Afar Rift and Southeast Plateau and other sites and obsidian sources referred to in the text.

The cave is now dry but in the past it was sufficiently wet for massive dripstone to form (cover photograph); there is also evidence that at some time a small stream flowed into the cave from above. The stratigraphy we obtained from our 1974 excavation has been interpreted by Dr M. A. J. Williams of the School of Earth Sciences, Macquarie University, New South Wales.

Stratigraphy and Depositional History (Figs 2 and 3)

The cave was first dug in 1929 by Henri de Montfried and Père Teilhard de Chardin (1930) and again in 1933 by Teilhard de Chardin and Paul Wernert (Breuil, de Chardin and Wernert 1951).[1] The Abbé Breuil studied the paintings which are all in a later, schematic style and very faded (Breuil 1934). He also found a human jaw fragment described by Vallois (1951) as exhibiting an ensemble of primitive characteristics which he compared with those of the classic Neanderthalers and related early forms of *Homo sapiens*. He considered the Dire Dawa specimen, as it is called, to represent an Ethiopian 'neanderthaloid'. The specimen is a well mineralized but damaged part of the body of the right side of the mandible between the third molar and the lateral incisor. On the exterior surface the beginning of the ascending ramus is present and the anterior part extends to the symphysis. Two premolars and three molars are present but the crowns are badly preserved and the enamel is missing.

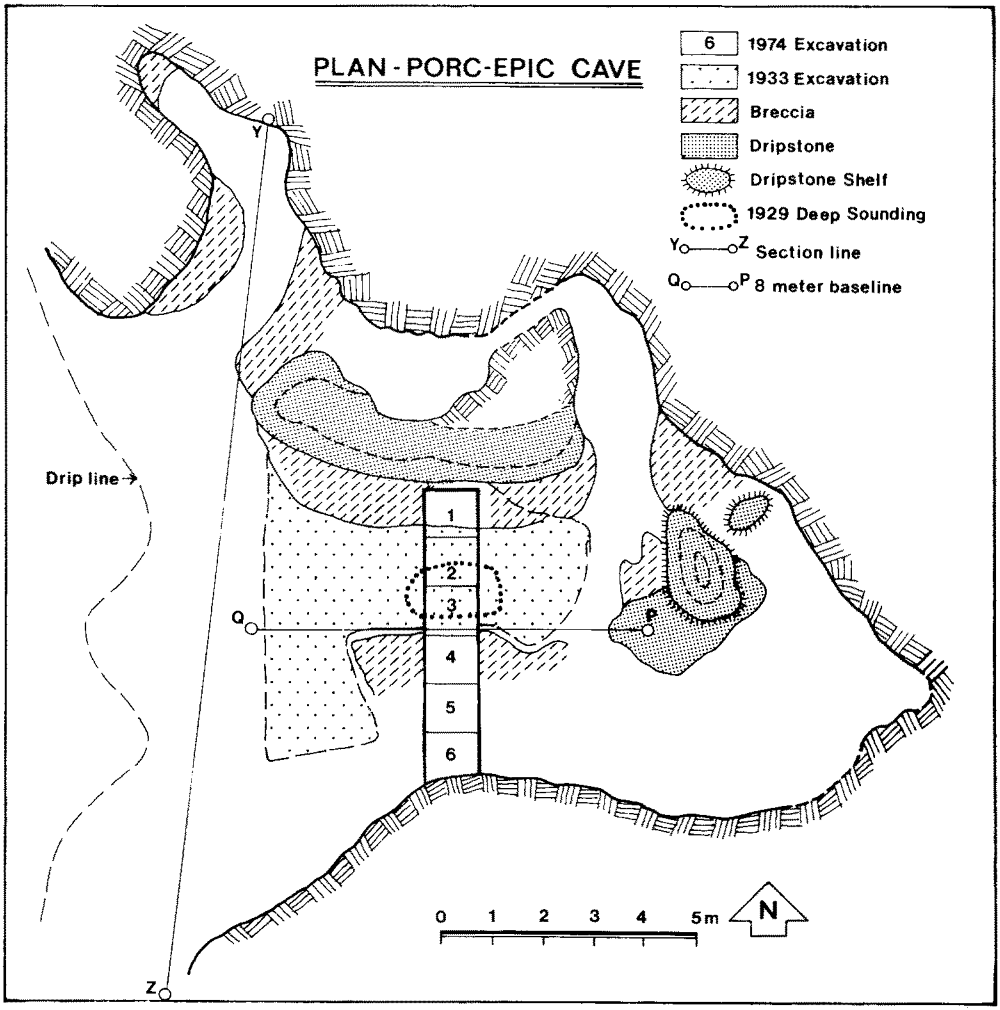

Figure 2 General plan of Porc Epic cave showing the 1933 excavation and the 1974 trial trench.

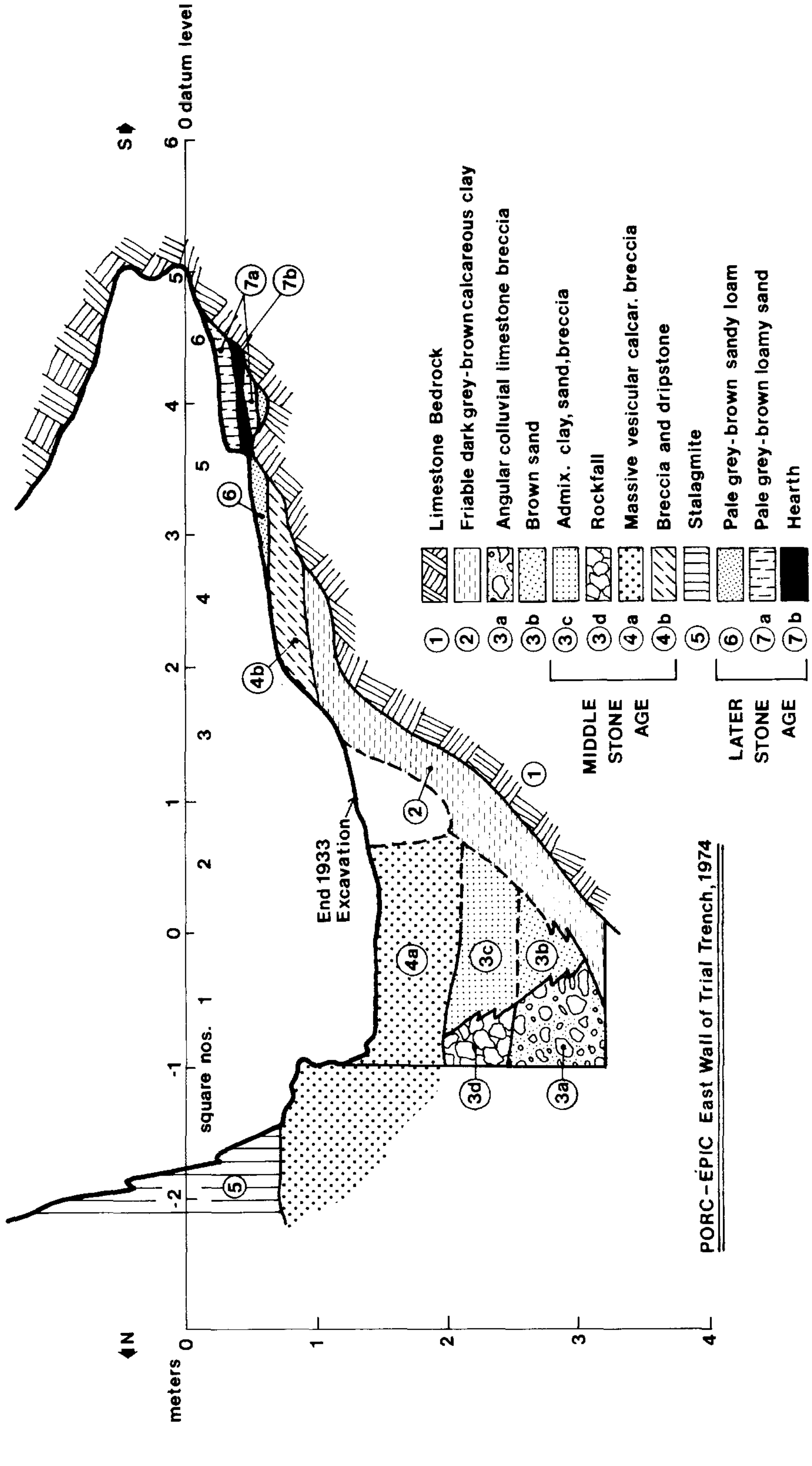

Figure 3 Section exposed in the east wall of the 1974 excavation.

The excavators thought that the occupation deposits had been disturbed because potsherds were found towards the base of their dig mixed with MSA artifacts. The assemblage was, therefore, interpreted as either an example of mixing of evolved Middle and Late Stone Age assemblages by natural agencies, or a form of Neolithic and so relatively late. In 1974 we rediscovered the cave after an eventful climb during which we stuck ourselves full of prickly pear. It was clear that the cave still had considerable potential since an exposed section showed a mass of breccia with bone and tools that passed beneath a dripstone curtain.

The 1933 excavation was still discernible in 1974 (Fig. 2). Clearing and sieving the back fill produced over 4000 artifacts and a trial excavation was accordingly planned. This took the form of a trench (1 m × 6 m) across the floor from south to north where the cave breccia passed beneath the curtain of stalagmite; our trench also cut across the 1933 trench.

The stratigraphic sequence and cave history (Fig. 3) is as follows:–

1. The cave was formed by solution and collapse.
2. Within it accumulated >2 m of grey-brown, calcareous clay with some 50 cm of angular rubble and a wedge of sand—evidence of stream activity. The vesicular structure and faecal pellets suggest that termites may have been active in the cave at this time. As we learned from the later, 1975, excavation, the MSA occupants appeared in the cave in the middle of this deposition.
3. The grey-brown clay passed upwards into ~50 cm of sand, clay and calcareous cave breccia with roof-fall deposits of limestone rubble. One of these overlies the initial MSA occupation floor which was present in the 1975 excavations at a depth of 2.3 m below datum.
4. Over this lay *ca* 1.5 m of indurated, coarsely laminated calcareous cave breccia which contained the main MSA occupation. Between this underlying breccia and the main dripstone curtains (see 5 below) were three transitional flow-stone horizons. Only the lowest of these contained MSA artifacts and fossil bone. The upper MSA horizons had already been cemented as breccia by lateral seepage before the main and overlying dripstone formation began, and a distinct difference can be seen between the breccia cementation in which $CaCO_3$ progressively pervaded the existing loamy matrix and the, perhaps seasonal, deposition of the layered dripstone skins.
5. The dripstone, which contained no bone or artifacts, sealed the breccia containing the MSA assemblage. Presumably the cave had been abandoned by this time, probably because it was too wet. The MSA deposits are more indurated near the walls and rear of the cave. However, at the entrance, during Phase 4 or shortly after, the less consolidated silty marl, of which only the upper part contained tools, suffered some minor erosion followed by carbonate deposits and a major roof collapse along the drip line.
6. As the cave became drier again, dripstone formation ceased. Round the walls, where it was protected by the dripstone cover, the breccia was not eroded. In the center and towards the entrance, however, where the deposits were unprotected and less consolidated, they were removed by a small stream, often to a depth of as much as a metre. In this formed a younger, post-dripstone fill of brown loam that sometimes abuts on or grades into the hard breccia and in which a few, presumably derived, MSA artifacts occur.
7. Occupation of the cave was resumed during late prehistoric times during the deposition of a 20–25 cm layer of fine sands and loam with interstratified hearth material. This

deposit everywhere unconformably overlies the older cave deposits and contains microliths and pottery; the paintings are believed to be contemporary with this layer.

It was thus quite clear from our excavated section that the MSA artifacts were sealed and stratigraphically distinct everywhere in the cave except at the entrance. There, post-dripstone cutting and filling had resulted in the natural mixing of LSA and residual MSA artifacts. In fact, a neat trap had been laid for the 1933 excavators.

In 1975, one of us (K.W.) carried out further excavations in the cave. These were visited by Dr Williams who confirmed that the new sections bore out the findings of the smaller, 1974 excavation. Unfortunately, due to circumstances beyond our control, it has not yet been possible to analyse the material from the 1975 dig. It seems unlikely, however, apart from the additional information the increased amount of fossil bone can be expected to provide, that the findings will materially alter those based on the 1974 work reported here.

The Later Stone Age

This was found in the topmost deposit—the fine sands and loam—and there were also, on typological grounds, a number of LSA artifacts in the 1933 excavation backfill as well as 27 potsherds; no potsherds were recovered from our own dig, however. The assemblage is dominated by microliths, small scrapers and *outils écaillés*. The shallow nature of the deposit suggests only temporary and sporadic use of the cave at this time and because of the presence of the potsherds the assemblage may well be quite late. This is perhaps confirmed by the carbonized seeds preserved in this horizon—mostly endocarps of *Ziziphus* sp. together with cowpea (*Vigna unguiculata*) and *Pisum sativum*, both domesticated legumes used in Ethiopia today.

The LSA assemblage will not be considered here.

The Middle Stone Age

1. Assemblage from the 1933 backfill (Table 1)

The 4278 artifacts recovered were analysed and we were surprised to find that the percentages of the various artifact classes were sufficiently like those from our own excavation as to make it seem that this was not a biased sample. Shaped tools comprised about 4% (about 88% of the shaped tools being points and scrapers); modified/edge-damaged pieces totalled 1.5% and unmodified waste, including cores, 94.3%.

Table 1 Inventory of Middle Stone Age artifacts recovered in 1974 from the infilling of the 1933 excavation, Porc Epic Cave.

Shaped Tools—4.2% of all artifacts			
Points	*N*	*% of Points*	*% of Shaped Tools*
Bifacial	14	20.00	
Unifacial	32	45.71	
Levallois	6	8.57	
Unfinished	10	14.28	
Broken	8	11.42	
Total	70		38.89

Scrapers		% of Scrapers	% of Shaped Tools
Denticulate	13	14.60	
Straight side	5	5.61	
Double side	1	1.12	
Convex side	11	12.35	
Concave/convex	2	2.24	
Concave side	2	2.24	
End and side	5	5.61	
End	5	5.61	
Convergent	6	6.74	
Transverse	3	3.37	
Subcircular	1	1.12	
Inverse	1	1.12	
Core	1	1.12	
Notched	10	11.23	
Broken	23	25.84	
Total	89		49.44
Burins		*% of Burins*	
Angle on break	2	13.33	
Technical	13	86.66	
Total	15		8.33
Naturally backed blades	5		2.78
Biface-like piece	1		0.56
Total Shaped Tools	180		

Modified/Edge-damaged—1.50% of all artifacts

			% of Modified/ Edge-damaged
Flakes and blades	58		90.62
Haematite chunks with rubbing facets	6		9.37
Total Modified/Edge-damaged	64		

Unmodified Waste—94.3% of all artifacts

Cores	*N*	*% of Cores*	*% of Waste*
Levallois	41	42.70	
Discoid	6	6.25	
Single platform	22	22.91	
Opposed platform	8	8.33	
Multi-platform	1	1.04	
Broken	18	18.75	
Total	96		2.38
Flakes	942		23.35
Blades	238		5.90
Proximal fragments (striking platform and bulb of percussion present)	516		12.79
Angular waste	1571		38.94
Core trimming flakes	18		0.44
Fire cracked pieces	470		11.65
Chunks	105		2.60
Haematite	78		1.93
Total Unmodified Waste	4034		
Total all artifacts	4278		

2. The 1974 Assemblage (Table 2)

The 1 m × 6 m trench was dug in arbitrary 10 cm spits measured from a permanent datum point. In order to increase sample size, the finds from two of these spits were analysed together, i.e. in 20 cm spits. MSA artifacts and bone occurred only in the breccia and rockfall layers and most of the finds were, not surprisingly, in the deeper central and northern parts of the excavation; to the south, the floor rises steeply and the deposits thin out.

The total number of artifacts recovered was 5146 and the density of specimens by grid square and unit depth is recorded in Figure 4. Densities fall off at the top and again below 2 m with the greatest concentration between 96 cm and 1.4 m; 43% of all worked stone was in

Table 2 Inventory of Middle Stone Age artifacts from the 1974 excavation, Porc Epic Cave.

Shaped Tools—4.02% of all artifacts

Points		*N*	*% of Points*	*% of Shaped Tools*
Parti-unifacial		9	11.39	
Unifacial		25	31.64	
Parti-bifacial		12	15.18	
Bifacial		12	15.18	
Unfinished		19	24.05	
Fragmentary		2	2.53	
	Total	79		38.16
Scrapers			*% of Scrapers*	
Convex side		11	17.74	
Notched		9	14.51	
Straight side		7	11.29	
Inverse		7	11.29	
Convergent		6	9.67	
Denticulate		4	6.45	
Double side		3	4.83	
End and side		3	4.83	
Nosed		3	4.83	
Concave		2	3.22	
Miscellaneous		7	11.29	
	Total	62		29.95
Burins			*% of Burins*	
Angle on break		9	40.90	
Dihedral		5	22.72	
Inverse		1	4.54	
Lateral		1	4.54	
Technical		6	27.27	
	Total	22		10.62
Becs		11		5.31
Backed pieces		9		4.34
Composite tools		2		0.96
Fragmentary		22		10.63
	Total Shaped Tools	207		

Modified/Edge-damaged—8.38% of all artifacts			
			% of Modified/ Edge-damaged
Blades	74		17.17
Flakes	111		25.75
Fragments	180		41.76
Miscellaneous modified	31		7.19
Haematite with rubbing facets	34		7.89
Grinder	1		0.23
Total Modified/Edge-damaged	431		
Unmodified Waste—87.6% of all artifacts			
Cores		*% of Cores*	*% of Waste*
Levallois	43	42.15	
Discoid	6	5.88	
Single Platform	17	16.66	
Opposed Platform	6	5.88	
Multi-platform	5	4.90	
Platform at right angles	6	5.88	
Fragmentary	19	18.62	
Total	102		2.26
Whole blades	235		5.21
Whole flakes	654		14.51
Side-struck flakes	284		6.30
Proximal fragments	791		17.54
Angular waste	2262		50.18
Haematite	180		4.00
Total Unmodified Waste	4508		
Total all artifacts in breccia	5146		

square 4. Figure 5 shows the density figures for retouched tools, in particular points and scrapers; again, the greatest density occurs between 1.1 m and 1.4 m below datum. The counts for points and scrapers combined with a qualitative study of the attributes of retouched tools suggest that no significant changes took place throughout the time that the MSA occupants used the cave. The 1975 excavation showed that workshop and other activity areas—such as grid square 4—were sometimes associated with concentrations of fire-fractured chert, implying that they may have been directly connected with hearths. This might also suggest that some of the chert was being heat treated.

The inventory table (Table 2) shows that of the 5146 artifacts recovered, 4.02% are shaped tools, 8.38% are modified/edge-damaged pieces and 87.6% are unmodified waste. Apart from the greater number of modified/edge-damaged pieces, this breakdown is very like that of the assemblage from the 1933 back fill.

LEVEL [CM B.D.]		SQUARE (1m) 1	2	3	4	5	6	TOTALS
1	29–68					113 2.2	31 .6	144 2.8
2	68–96		1933 EXCAVATION		407 7.9	276 5.4		683 13.3
3	96–110	22 .4		165 3.2	483 9.4			670 13.0
4	110–120	22 .4		66 1.3	966 18.8			1054 20.5
5	120–140	302 5.9		579 11.3	358 7.0			1239 24.1
6	140–160	297 5.8		114 2.2				411 8.0
7	160–180	292 5.7	383 7.4	6 .1				681 13.2
8	180–200	11 .2	231 4.5			BEDROCK		242 4.7
9	200–220	5 .1	12 .2					17 .3
10	220–240	0 0	5 .1					5 .1
TOTALS		951 18.5	6 1 12.3	930 18.1	2214 43.0	389 7.6	31 .6	5146

Figure 4 Total Middle Stone Age artifact distribution by grid squares and unit depths: 1974 excavation.

Raw Material

Chert from the local Jurassic limestones was by far the commonest (80%) and ranges from a microcrystalline structure to a heavily textured macrogranular component. Of these cherts 99% are of the replacement type, and the variation in texture, composition and colour is due

LEVEL [CM.B.D.]								POINTS	SCRAPERS	OTHER TOOLS and FRAGMENTS
1	29-68					0 1 0	0 0 0	0	1	0
2	68-96		1933 EXCAVATION		2 2 5	2 4 6		4	6	11
3	96-110	2 0 0		1 0 4	2 2 9			5	2	13
4	110-120	0 0 0		1 1 2	20 19 14			21	20	16
5	120-140	0 3 3		15 1 7	1 9 9			16	13	19
6	140-160	9 3 2		2 0 1				11	3	3
7	160-180	6 1 0	10 5 3	0 0 0				16	6	3
8	180-200	1 2 0	4 7 0			BEDROCK		5	9	0
9	200-220	1 0 0	0 1 1					1	1	1
10	220-240	0 0 0	0 1 0					0	1	0
							TOTALS	79	62	66

Figure 5 Densities of Middle Stone Age shaped/retouched tool forms by grid squares and unit depth: 1974 excavation.

to the degree of replacement and to the specific chemical environments. The remaining 1% of the chert was of a more chalcedonic type and, since several of the flakes made from this material show an abraded, cobble cortex, it is believed to have been obtained in the form of erratics from the escarpment wadis.

The basalt used (7.9%) varies from crystalline forms to more afinitic varieties, the latter being preferred. The obsidian (5.5%) is all of good quality. It is not known from where the fine-grained basalt and obsidian were collected. None occurs in the immediate vicinity of the cave or of Dire Dawa. The obsidian must have come from sources in the southern Afar (Fig. 1) and this is also the most likely source for the basalt. A source of poor obsidian is known about 40 km to the east of Dire Dawa but this would not have been suitable for artifacts (W. H. Morton pers. comm.). The most likely sources are the extinct volcanoes of

Afdem *ca* 95 km or Assabot *ca* 140 km west of Dire Dawa. A source is known and has been sampled on the latter mountain.

The remaining materials—quartz (1.9%), oolitic cemented sandstone, limestone (0.6%) and quartzite (0.5%)—were only sporadically used. They are all likely to be of local and relatively close origin from the escarpment hills and wadis. The quartz cobbles that occur in abundance in the main wadi do not seem to have been used, however.

The materials used for the shaped tools reflect the percentages of raw materials in the total assemblage in that 80% of them are made from chert, 6–8% from basalt and obsidian and the remainder from the other materials. No time trend change in the proportions in which these raw materials were used is discernible except in respect of quartz, 68% of which is found in grid square 2 at the 1.8–2.0 m level. It is possible, however, that trends of preference in raw material might have become apparent had the area of the excavation been larger.

Several pigment-producing materials were also carried into the cave and make up 4.1% of the raw materials. These comprise soft and friable red and yellow ochres, hard, red haematite and hard and dense specular iron. They are found in all levels but only above 2.0 m and occur as small, angular, abraded fragments, pebbles and lumps of which 34 (15.9%) show one or more areas of faceting and striations due to their having been rubbed on a grindstone to produce pigment. Of special interest here is the cast of a fossil ammonite completely replaced by pigment-producing materials. In addition, some 90% of these pieces show the alteration, cracking and fracture patterns indicative of their having been heated in a fire. Presumably such 'heat treatment' resulted in the production of different coloured paints.

Physical Condition

Seventy-one per cent of the assemblage is in mint condition and only 1.1% is abraded or weathered. Over 25% of the artifacts show characteristics of heat fracture and they are distributed throughout the excavated area. Unfortunately we found no definite hearth areas in 1974 and not enough charcoal to provide a reliable date.

Analysis of the Flaked Stone Assemblage

Table 2 shows the breakdown into the main artifact categories. With some 4% of shaped tools, 8% of edge-damaged artifacts and 88% waste, the site can be considered as a 'normal' manufacturing and activity area.

Shaped Tools

Points These are the most significant tools forming 38.2% of the shaped tool category. They are made on flakes, usually from discoid and Levallois cores, more rarely on blades; a representative sample is illustrated in Figures 6 and 7. They are predominantly lanceolate and sub-triangular—both long, narrow and short—broad in plan form with a smaller number of narrow and broad foliate points. The majority are symmetrical but asymmetric examples also occur (e.g. Fig. 6:1). They have been sub-divided here (Table 2) according to the degree of unifacial and bifacial retouch they exhibit. Flaking platforms and bulbs may be left unretouched or may be removed by trimming. Some 15% of the points from the 1974 excavation have had the proximal ends retouched to facilitate hafting. This reduction may be

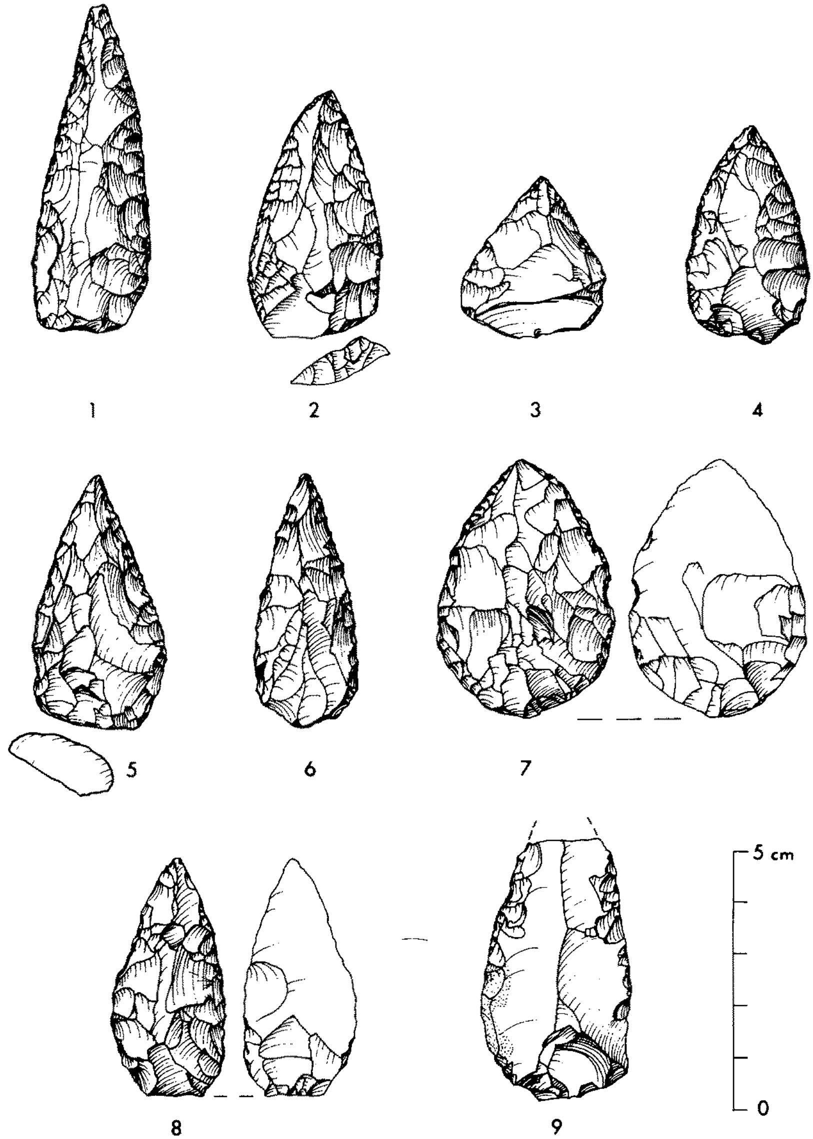

Figure 6 Middle Stone Age Unifacial Points. (Nos in parentheses denote level.)
1. Asymmetric, long triangular, unifacial point; plain striking platform and triangular cross-section. Chert. 61×23×8 mm (4). 2. Leaf-shaped, unifacial point; faceted striking platform. Plano-convex cross-section. Chert. 51×25×9 mm (4). 3. Short triangular unifacial point; faceted striking platform. Chert. 30×28×6 mm. (4). 4. Leaf-shaped unifacial point; striking platform removed by restricted retouch on ventral face. Obsidian. 41×23×6 mm. (5). 5. Sub-triangular unifacial point; striking platform plain, triangular cross-section. Chert. 47×25×11 mm (4). 6. Long triangular, parti-unifacial point; striking platform removed by proximal retouch on ventral face. Triangular cross-section. Chert. 48×19×9 mm. (6). 7. Broad, biconvex, bifacial point; striking platform removed by proximal retouch on ventral face. Some evidence of heat spalling. Chert. 50×34×10 mm. (8). 8. Leaf-shaped, parti-bifacial point; striking platform removed by proximal retouch on ventral face; sub-triangular cross-section. Chert. 45×23×9 mm. (6). 9. Long triangular, parti-unifacial point, distal end missing. Plain striking platform; large heat spall at proximal end. Chert. 50×29×9 mm. (5).

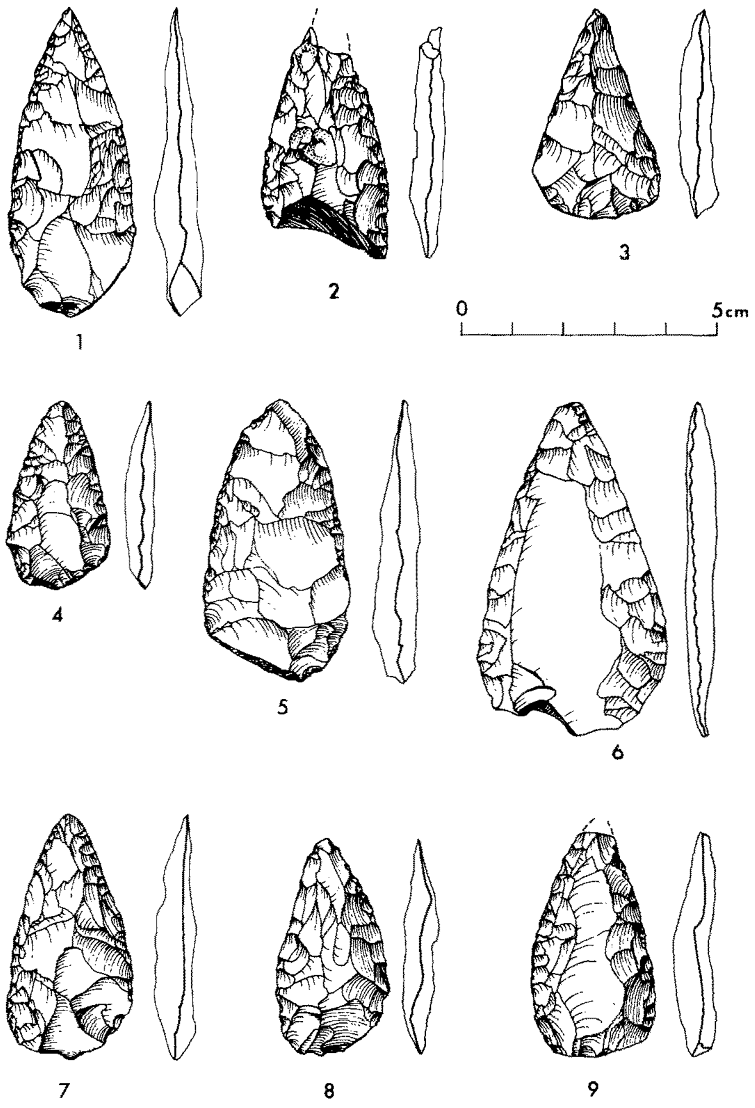

Figure 7 Middle Stone Age bifacial points. (Nos in parentheses denote level.)
1. Lanceolate point, fully bifacially retouched, proximal end not reduced. Chert. 59×24×9 mm. (5). 2. Fragmentary lanceolate bifacial point extensively altered by heat producing potlid fracture and reddening. Chert. 47×24×6 mm. (4). 3. Short, sub-triangular fully bifacial point, the proximal end showing Emireh-type retouch. Basalt. 40×24×6 mm. (7). 4. Short, foliate point, fully bifacial. Obsidian. 36×21×5 mm (2). 5. Foliate point, fully bifacial except that the oblique cortex platform is retained. Chert. 54×28×8 mm. (7). 6. Parti-bifacial, sub-triangular point; oblique, plain, restricted striking platform. Basalt. 64×36×5 mm. (7). 7. Parti-bifacial foliate point preserving oblique, plain striking platform. Basalt. 47×24×8 mm. (4) 8. Parti-bifacial foliate point, striking platform removed by ventral retouch. Basalt. 41×22×11 mm. (4). 9. Parti-bifacial, sub-triangular point retaining the plain striking platform; distal tip missing. Chert. 43×24×7 mm. (5).

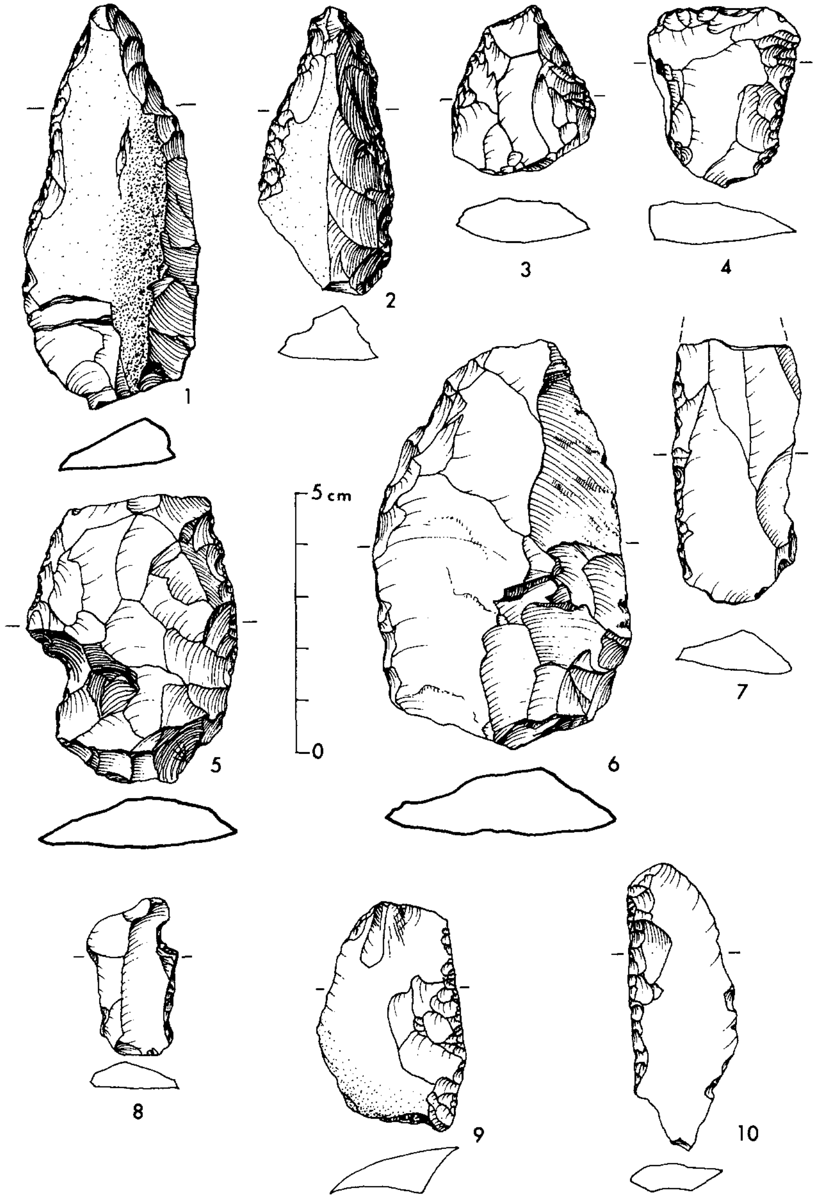

Figure 8 Middle Stone Age scraper forms. (Nos in parentheses denote level.)
1. Convergent scraper on cortex flake with plain striking platform. Basalt. 78×34×14 mm. (4). 2. Convergent scraper on cortex flake; plain striking platform. Chert. 54×26×11 mm. (2). 3. Double side scraper on flake with faceted striking platform. Chert. 30×28×9 mm. (4). 4. End and side scraper on flake with faceted striking platform. Obsidian. 34×29×9 mm. (4). 5. Single convex side scraper on proximal half of a radially prepared flake; platform reduced by ventral flaking. Heat spalling left proximal end. Chert. 56×40×9 mm. (4). 6. Single convex side scraper on end flake with dihedral striking platform. ?Welded tuff. 79×47×17 mm. (7). 7. Single straight side scraper on proximal blade fragment; faceted striking platform. Oolitic cemented sandstone. 51×24×8 mm. (10). 8. Notched scraper on proximal end of blade; faceted striking platform. Chert. 30×16×5 mm. (1). 9. Inverse single convex side scraper on end flake; point platform. Chert. 43×30×9 mm. (7). 10. Inverse, single straight side scraper on blade; point platform. Chert. 55×20×5 mm. (4).

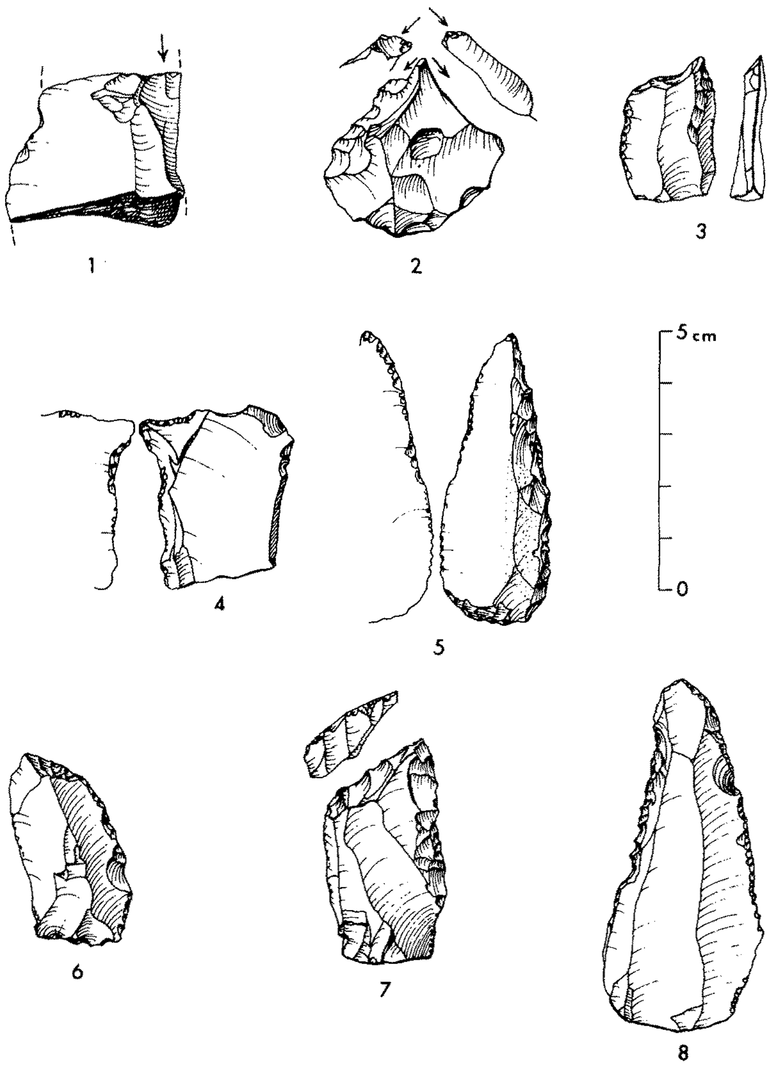

Figure 9 Middle Stone Age burins, *bec* and backed flakes. (Nos in parentheses denote level.)

1. Angle burin on break. Chert. 30×33×12 mm. (2). 2. Dihedral burin on proximal end of flake with faceted striking platform. Scraper retouch left lateral edge. Chert. 39×29×13 mm. (2). 3. Borer on short quadrilateral flake with plain striking platform. Chert. 27×18×12 mm. (2). 4. Borer on distal flake/blade fragment. Working edge formed by alternate notches. Chert. 31×30×5 mm. (4). 5. Subtriangular flake 'backed' by shallow retouch down right lateral edge and proximal end and with inverse and marginal edge-damage down left edge. Chert. 55×21×9 mm. (5). 6. Asymmetric convex backed flake; plain striking platform. Chert. 35×19×8 mm. (4). 7. Obliquely truncated flake with straight scraper retouch over distal half of right lateral edge. Chert. 42×21×8 mm. (6). 8. Partially backed atypical Levallois point with marginal edge damage along right lateral edge. Chert. 67×29×7 mm. (1).

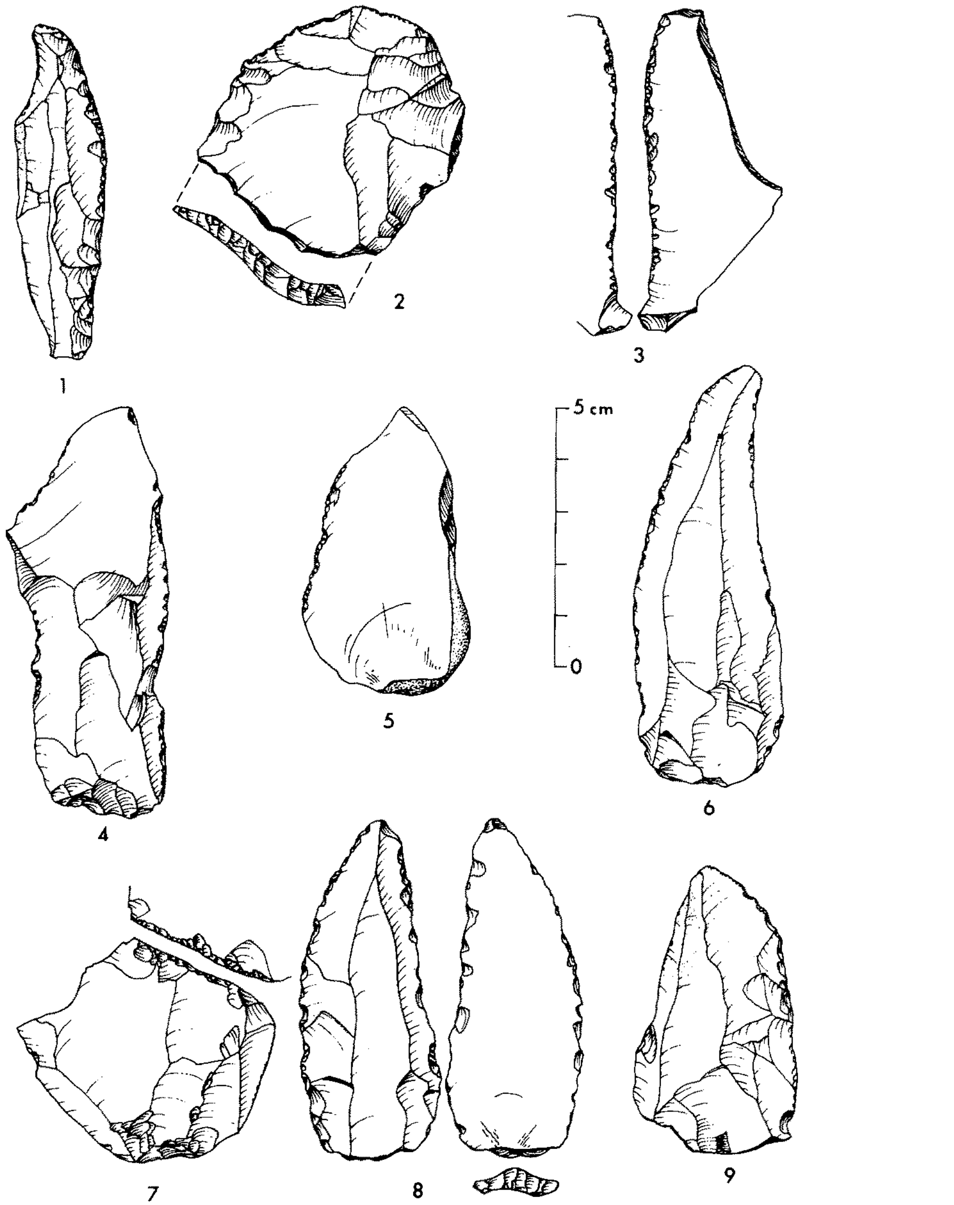

Figure. 10 Middle Stone Age flakes and blades exhibiting edge-damage on one or both lateral edges. (Nos in parentheses denote level.)

1. Blade with point platform and convex marginal edge-damage/retouch down right lateral edge on dorsal face. Chert. 64×17×4 mm. (8). 2. Radially prepared flake with multi-faceted striking platform and marginal edge-damage on left lateral edge and distal end on dorsal face. Chert. 48×43×9 mm. 3. Distal part of a flake or blade with marginal edge-damage on both faces of one lateral edge. Obsidian. 61×26×2 mm. (5). 4. Blade with restricted plain platform and discontinuous marginal edge-damage on both faces. Chert. 78×30×6 mm. 5. Cortex flake with cortex platform and marginal inverse edge-damage along most of one lateral edge. Chert 45×31×13 mm. (2). 6. Asymmetric blade with plain striking platform and discontinuous marginal edge-damage down both lateral edges. Basalt. 80×23×6 mm. (3). 7. Side flake with restricted plain striking platform and marginal retouch/edge-damage on both faces of one distal edge. Chert. 42×49×8 mm. (4). 8. Blade with multi-faceted striking platform and discontinuous marginal edge-damage on both faces of both lateral edges. Basalt. 65×26×6 mm. (1). 9. Sub-triangular flake with faceted striking platform and discontinuous marginal and dorsal retouch down right lateral edge. Chert. 54×31×10 mm. (8).

from the base or from one or both lateral edges at the proximal end, or a combination of these. In this the Porc Epic points are similar to those from the obsidian quarry and workshop site at Kone', *ca* 240 km to the west (Kurashina 1978:402), and those from Gadamotta and Kulkuletti in the Lake Zwaai basin (Wendorf and Schild 1974). The method as practised at Porc Epic has been illustrated by Perlès (1974:537, Fig. 2).

Points classified as partly unifacial and partly bifacial are those in which modification did not extend along the entirety of the edge margins. The sub-types grade from those showing only a little unifacial retouch to those fully retouched on one face, to those that are partly and fully bifacially trimmed. The extent to which a piece is retouched seemed in part to depend on the amount of thinning, especially at the proximal end, required to reduce the primary form to the required thickness. This, in turn, is a reflection of function and the way the particular category of tool was hafted. Unifacial forms predominate (58.6%). Retouched tools show an almost equal proportion of scaled to step flaking; the angle of edge flaking is discussed below. No significant differences in the length, breadth or breadth/length ratios of the sub-types could be detected in the sample available. Table 3 shows the means and standard deviations for length and breadth/length ratios of all points by stratigraphic level. For those levels with comparable sample sizes the means show no appreciable differences in maximum length. Since, however, the standard deviation shows evidence of reduction between Level 7 and Levels 4 and 5 which have comparable sample sizes, this may suggest a tendency towards greater standardization of the length of points in the upper levels. This trend is also apparent from the breadth/length ratios and, while these do not indicate a change in length, there does seem to be a tendency for points to become more elongate and for breadth to be reduced so that the values for the breadth/length ratios decline through time. Level 6 may be anomalous in that the standard deviations for both length and breadth/length ratios show a distinct decline but the sample is too small to be able to say whether or not this is significant.

Table 3 Table showing length and breadth/length ratios of measurable points from the 1974 excavation at Porc Epic cave.

	Maximum length (mm)			Breadth/length ratio		
Level	N	Mean	S.D.	N	Mean	S.D.
1	0			0		
2	2	42.50	2.12	2	.575	.049
3	5	43.80	12.93	5	.592	.129
4	16	47.56	10.15	16	.516	.142
5	14	44.29	9.59	14	.519	.068
6	6	46.33	5.01	6	.450	.069
7	13	47.23	13.23	13	.654	.143
8	4	42.50	6.61	4	.640	.042
9	1	44.00	0	1	.680	0
10	0			0		
Total	61	45.78	10.06	61	.556	.129

Scrapers (Fig. 8) account for 30% of the shaped tools but show less evidence of standardization than do the points. The primary form was usually a longish flake or fragment and the usual sub-classes are present: convergent, single and double side scrapers, end and side, notched scrapers and denticulates. There are also seven with inverse retouch and three larger, heavier specimens classed as nosed scrapers. The miscellaneous scrapers have no consistent pattern of edge trimming. Retouch, both scaled and stepped, varies from marginal to semi-invasive and edge angles in most cases exceed 60°. Lengths and breadth/length ratios for scrapers show no essential differences between the sub-classes. Denticulates are minimally represented.

Burins (Fig. 9) These comprise 10.6% of the shaped tools. The majority (9) are angle burins on a break (Fig. 9:1). Five other examples are classified as dihedral burins though only one (Fig. 9:2) is convincing as having been intentional. Six examples, although exhibiting burin scars, have been classified as technical since they appear to be more accidental than intentional. In fact, informality is even more of an attribute of the burins than it is of the scrapers at Porc Epic and the burin scars are generally short and unconvincing.

Becs (Fig. 9) A total of 11 (5.3%) of *bec* or borer-like tools was recovered (Fig. 9:3, 4). They are made by notching and retouch (normal or alternating) to form a short awl-like point that could be used for piercing. They come from above Level 7 in the excavation and six of them are from Level 4 in grid square 3 at 1.1–1.2 m below datum.

Backed and Truncated Flakes Nine irregular and triangular flakes were recovered with evidence of steep backing on one lateral edge (Fig. 9:5–8). A main feature of this class is the edge damage or discontinuous retouch on the edge opposite the blunted back. One only is a classic backed flake form.

Two *composite tools* were recovered: a bec/burin and a scraper/burin.

Modified and Edge-damaged Pieces (Fig. 10) The majority are blades and blade-like flakes. When it is realized that there are 396 of these specimens, as compared with 207 shaped tools, it is evident that they are a significant class. The nature of the edge-damage mostly takes the form of discontinuous micro-chipping on both faces of an edge, as is consistent with use for cutting or slicing (Tringham *et al.* 1974). Figure 11 shows frequency polygons of maximum lengths of unmodified flakes, retouched tools and flake/blades showing edge-damage. It is evident that longer flakes and blades were selected for retouch into tools and for use, as compared with the unmodified examples. Figure 12 giving the frequency distribution of breadth/length ratios, again shows the similarity in form of the retouched and edge-damaged categories with a preference for the more blade-like forms in the edge-damaged class.

We also recovered a number of *miscellaneous modified pieces* exhibiting no consistent pattern and one sub-rectangular lower *grindstone fragment* of limestone showing one well-smoothed face and reddish alteration due to having been burnt. The rubbed pigment, definite evidence of the use of paint, has already been referred to.

Unmodified Waste

Table 2 shows the *core forms* almost half of which (42%) are Levallois cores and 5.8% are discoids. The Nubian type of Levallois point core which occurs at the Ethiopian obsidian quarry sites appears to be absent from Porc Epic. Levallois cores have a mean length value of 39.9±7.2 mm and the mean breadth value is 37.6±10.3 mm. They are relatively standardized in plan form, radial preparation, relative flatness and prepared platform. Flakes were also obtained by direct percussion from unprepared cores with single, double or multiple striking platforms. Most of the cores are too small to have produced the flakes in the assemblage and were almost certainly the rejected, worked out examples too small for further use.

Twenty-six per cent of the unmodified waste is made up of *whole blades* and *flakes*. As might be expected, the majority are end-struck flakes and blades but the preference for blades at Porc Epic may be paralleled again in the high proportion of blades at the obsidian quarry sites. When one compares flake form (Figs. 11 and 12) in unmodified flakes, tools and edge-damaged flakes it is apparent that there is a significant tendency to select the longer, blade-like examples for use and retouch. The primary form of 95.5% of shaped tools and 90.7% of modified/edge-damaged pieces is a blade or an end-struck flake. Platform type is recorded in 2456 cases. As might be expected, those with faceted platforms derived from Levallois cores are the largest class (45%). Plain (23.9%) and cortex (8.5%) platforms account for 32%, the remainder being restricted (12.4%), point (5.4%) or crushed (4.6%) platforms. It seems that restricted platforms tend to be the result of indirect flaking techniques and at Porc Epic the crushed platforms usually correlate with flakes in obsidian. There do not appear to be any significant differences in platform type frequencies between the stratigraphic levels, and facetted platforms predominate except near the top (Level 2) where plain platforms are in equal proportions.

The dorsal scar patterning is principally (36.6%) radial, though convergent (8.3%),

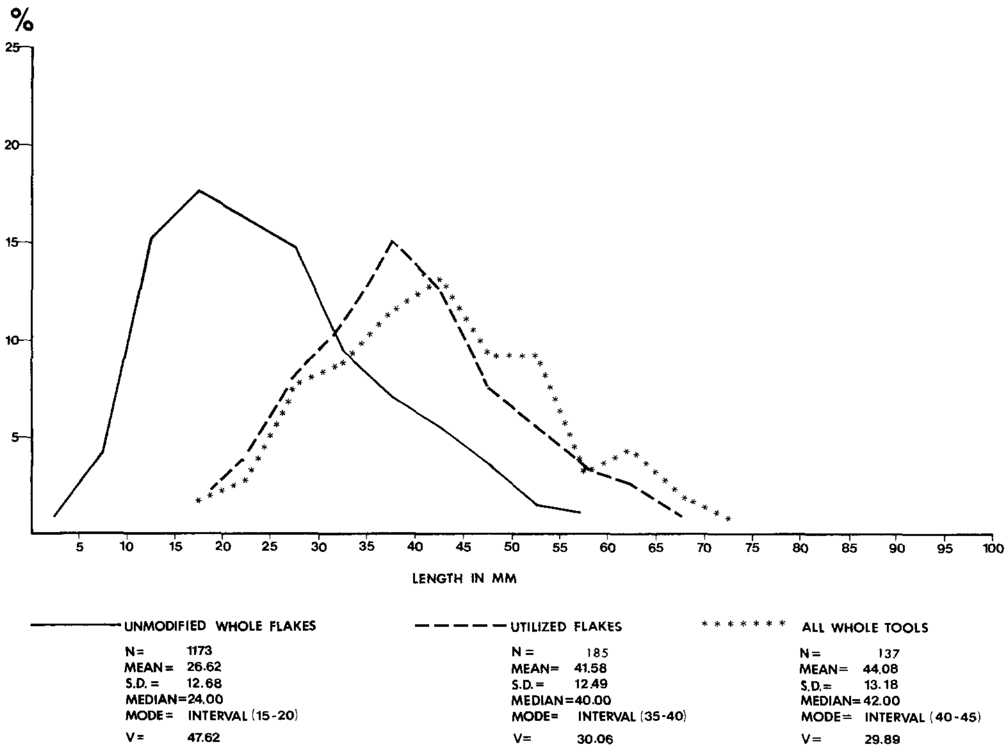

Figure 11 Frequency polygons of maximum lengths of artifact categories: Middle Stone Age, 1974 excavation.

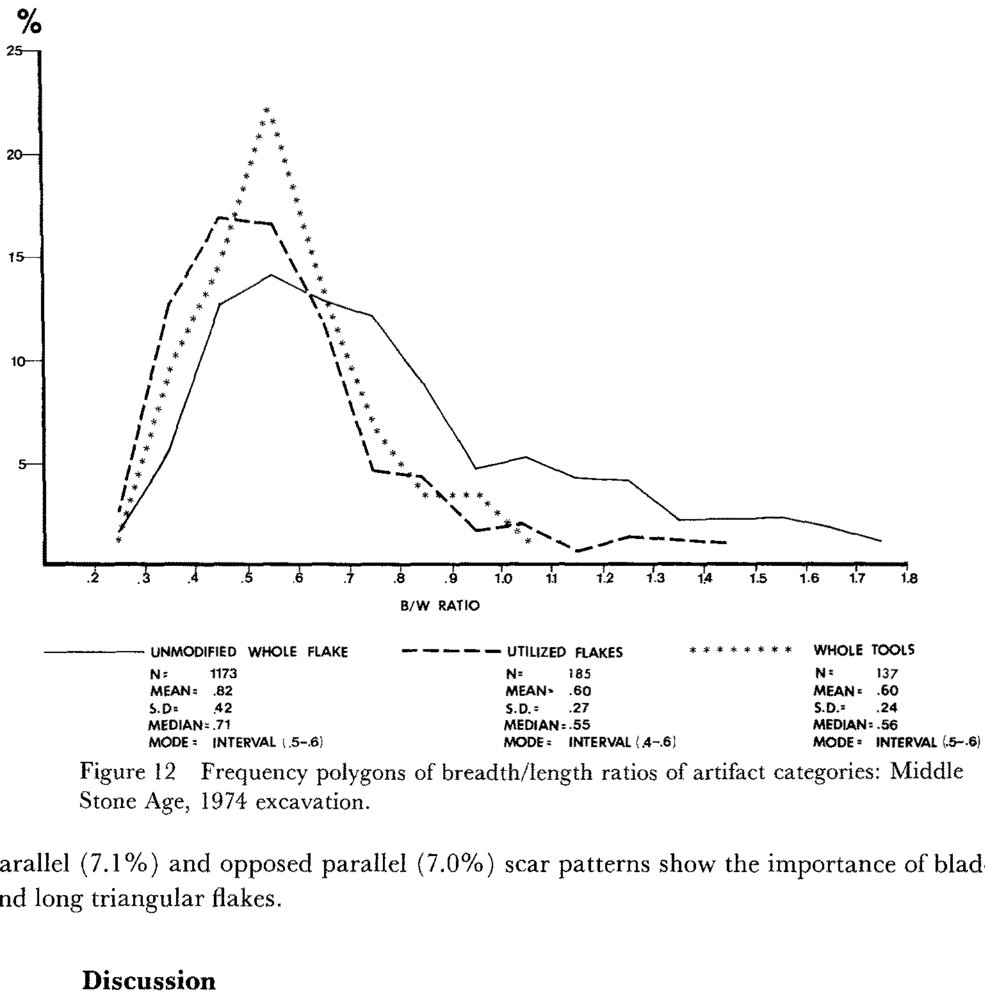

Figure 12 Frequency polygons of breadth/length ratios of artifact categories: Middle Stone Age, 1974 excavation.

parallel (7.1%) and opposed parallel (7.0%) scar patterns show the importance of blades and long triangular flakes.

Discussion

This analysis shows that, from beginning to end of the Middle Stone Age industry at Porc Epic there is no major shift in end-products or techniques. Retouched points, scrapers and edge-damaged artifacts were the three main types, though a larger sample might indicate that backed blades were also important. It was thought that measurement of edge angles might provide a further way of distinguishing quantitatively between points, scrapers and utilized pieces. Figure 13 shows the results of these measurements and it is clear that there is a distinct separation between the three classes of artifact. Could this, perhaps, result from selection for three different kinds of use? Only a larger sample will help to clarify this.

As already stated, the artifacts from the 1933 back fill appear to show the same general components and proportions as those of the *in situ* assemblage from the 1974 dig, except for the 1.5% of edge-damaged specimens from the 1933 fill as compared with the 8.2% from the 1974 excavation. Both assemblages contain an unusually large number of points, generally carefully retouched. This observation was also made by the 1933 excavators and by Perlès (1974) who did a technical study of the points and pointed pieces from that collection.

Table 4 and Figure 14 compare the composition of the industry from Porc Epic with those from three obsidian quarry sites at Gadamotta and Kulkuletti (Wendorf and Schild 1974) in

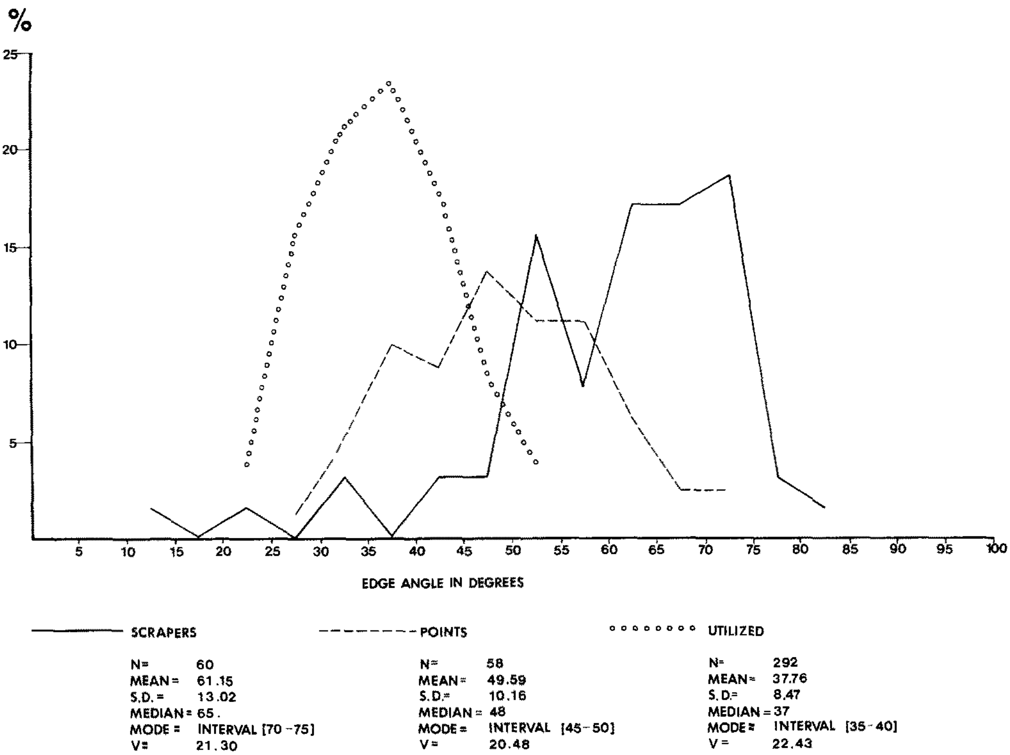

Figure 13 Frequency polygons to show measurable edge wear angles for certain Middle Stone Age artifact classes, 1974 excavation.

the Lake Zwaai basin and two at Kone' at the southwest end of the Afar Rift (Kurashina 1978). There is an overall similarity between these assemblages but that showing the closest resemblance to Porc Epic is the 8B site at Gadamotta which is also believed to be a living site concentration. The other sites are workshops and so have fewer shaped tools and modified or edge-damaged pieces. They do, however, have consistently more—between $2\frac{1}{2}$ and 11 times more—notched pieces. This raises the question, since the workshop sites are all in the open, whether these might have been produced by trampling or other natural causes.

We had hoped that an age for the dripstone that seals the breccia would provide a *terminus ante quem* for the MSA occupation. A sample from the core of the stalagmite submitted to Dr J. C. Vogel for analysis by both ^{14}C and Ionium methods gave disappointing results:

Pta-2600 (^{14}C) 4590 ± 60 bp
U-111 (Th–230) 6270 ± 1020 bp (max. age)

Dr Vogel comments 'The ^{14}C age may be slightly too high as a result of "carbonate dilution". The Ionium age is somewhat uncertain due to the presence of detrital Thorium-232, but it does serve to confirm the ^{14}C age.' It seems probable, however, that the formation of the dripstone may not have been contemporaneous with the termination of MSA occupation but is more likely to have occurred appreciably later. Its formation could be contemporary with one of the earlier Holocene wet periods on the basis of the age of 11,070 ± 160 bp for the tufa containing LSA artifacts at Aladi Springs west of Dire Dawa, that of 6670 ± 110 bp for a

Table 4 Comparison of the Porc Epic industry with those from other sites in Ethiopia.

(a) Main categories (%)

Site	Shaped tools	Modified/ edge-damaged	Flakes	Cores	Angular waste	Number
Porc Epic 1933	4.2	1.5	27.6	2.2	64.5	4278
Porc Epic 1974	4.2	8.2	22.7	1.9	62.8	5146
Gadamotta Eth-72-8B	3.8	—	20.4	0.6	75.1	9188
Gadamotta Eth-72-6	2.0	—	21.0	0.6	76.4	7362
Kulkuletti Eth-72-1	1.4	—	34.5	0.5	63.6	18,433
Kone' 5	0.7	2.3	10.1	0.1	86.8	3893
Kone' 5 Extension	0.5	1.0	13.8	0.4	84.3	37,692

(b) Shaped tools (%)

Site	Points	Side-scrapers	End-scrapers	Notched	Denticulate	Burins	Perforators	Backed flakes	Truncated	Other	Number
Porc Epic 1933	38.9	33.9	2.8	5.5	7.3	8.3	—	—	—	3.3	180
Porc Epic 1974	38.2	18.8	1.5	4.4	1.9	6.6	5.3	4.4	—	14.9	207
Gadamotta Eth-72-8B	32.3	16.7	0.3	12.7	4.6	2.3	0.9	—	0.9	29.4	347
Gadamotta Eth-72-6	24.0	23.3	4.0	10.7	6.0	2.0	0.7	2.7	1.3	25.3	150
Kulkuletti Eth-72-1	24.4	26.4	4.8	16.0	5.6	2.8	—	—	—	20.0	250
Kone' 5	—	7.4	—	44.4	14.8	—	—	14.8	14.8	3.7	27
Kone' 5 Extension	7.6	13.0	1.1	28.6	13.5	9.2	1.1	2.2	7.6	16.2	185

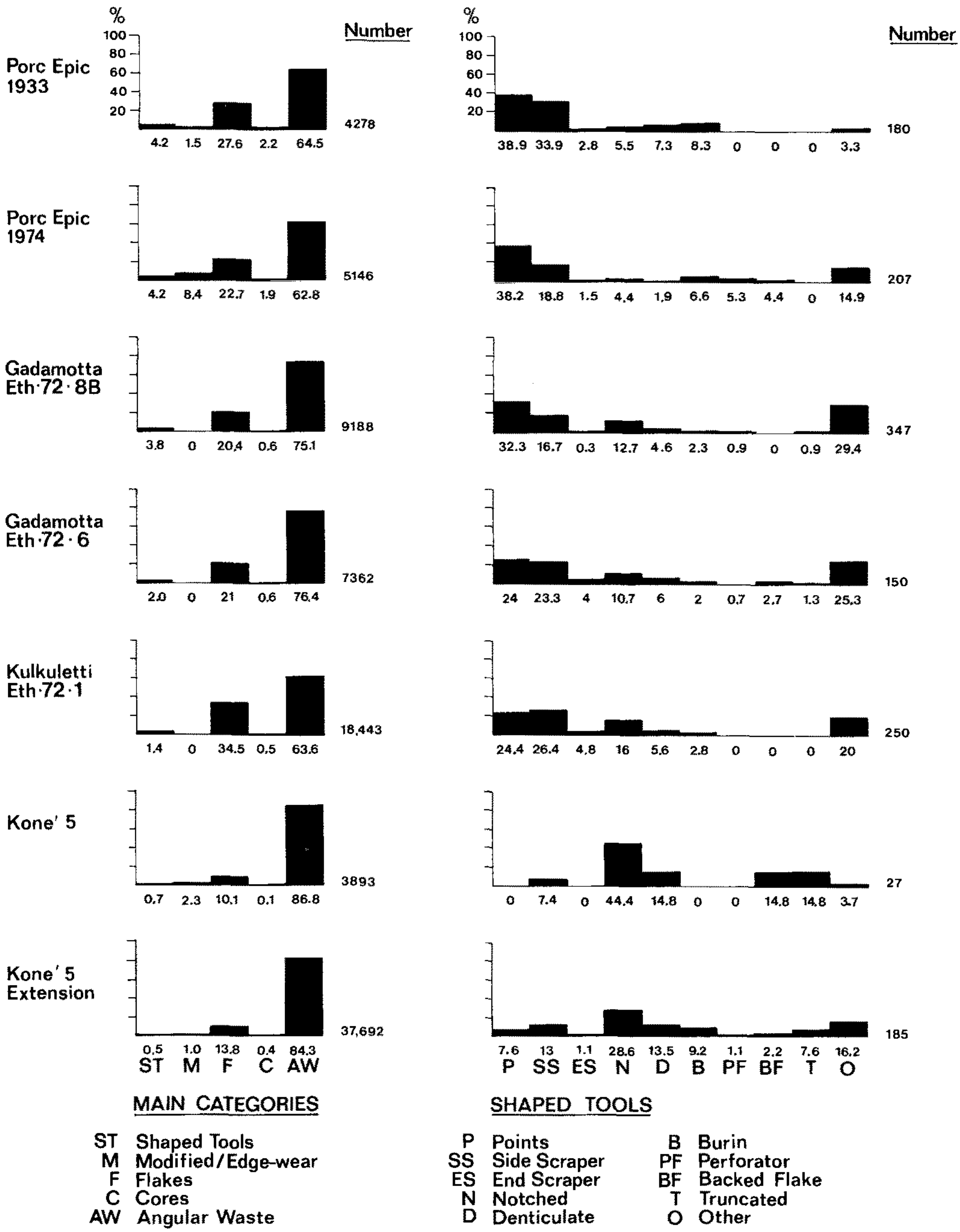

Figure 14 Comparison of Middle Stone Age lithic assemblages from Gadamotta, Kulkuletti, Kone' and Porc Epic. (After Wendorf and Schild 1974 and Kurashina 1978.)

shelly tufa between Aladi Springs and Erer, and 6810 ± 120 bp for the deposition of calcium carbonate at the bottom of the upper dark clay at Kone' which has LSA artifacts in the base (Williams, Bishop and Dakin 1977). Small flecks of charcoal obtained from the uppermost breccia at Porc Epic gave an anomalously young date of 5700 ± 110 bp (I–7971) so that it seemed that the age of the MSA occupation would still remain unknown. Now, however, the obsidian hydration dates obtained by Joseph Michels and Curtis Marean (Part II) give ages that are entirely compatible with a later MSA occurrence. The significance of these results will be discussed in Part II of this paper. The depth of deposit and the vertical spread of artifacts within it suggest that occupation lasted several millennia, and it would seem that the cave was repeatedly occupied for brief periods in connection with the same specific activity or activities. The specialist nature of the shaped tool component, the numbers of points with butts reduced for hafting, of scrapers, and of edge-damaged flakes for cutting, suggest that the cave may have been the regular camp of a group of hunters.

Fire cracked and spalled rocks and artifacts and calcined and cracked bone attest to the regular use of fire, perhaps for heat treating the local chert employed in tool making but certainly for cooking meat. Since the cave was occupied during the time of the early Last Glacial it might be expected that the warmth of a fire would have been welcome. Hearths were also used in the preparation of various coloured pigments from the appropriate rocks. Whether this pigment had a utilitarian use mixed with oil as body paint for warmth or to inhibit parasites, or whether it served a more esoteric 'ritual' purpose remains to be determined.

The time of occupation seems to have coincided with a relatively dry and cooler climate than that of the present day though the reduced evaporation rate can be expected to have resulted in an increased availability of surface water sources.

We have already noted that the cave, though not easy of access, would have been a good lookout place from which to watch the movement of animals into or out of the wadis and escarpment at the spring and fall seasons. The range of game animals available to the MSA occupants was very probably much like that still preserved in the Chercher Mountains on the plateau and in the escarpment today (Beadles and Ingersol 1968). Resident species include hare and other edible rodents including porcupine, *Hyrax*, reedbuck, bushbuck, greater and lesser kudu, grey duiker, dikdik, klipspringer, Dorcas gazelle, Waller's gazelle, warthog and bushpig, and these would have been available to a group occupying the cave at any season of the year. Migratory species include oryx, Soemmering's gazelle, Grevy's zebra, Swayne's hartebeest and elephant, and the Laga Datcharou would be a likely place to hunt them in their movements to and from the Afar Plains. During the summer rains the human population can be expected to have followed the large groups of game into the Rift. It might be thought that such a suggestion could have been confirmed by analysis of the faunal remains but, unfortunately, this has not yet been carried out. In 1974, most of the bone we recovered was so broken up as to be unidentifiable; much of it was also burnt. This strongly suggests the practice of bringing back the meat, or joints, from the kill to the cave, breaking the bones into small pieces by hammering and crushing the joints with the meat on them and then grilling or drying the meat over fires. Very few head parts were recovered: a few isolated teeth of bovids, including bushbuck and duiker, pig and zebra, but no other identifiable parts such as mandibles, limb bones or horn cores. In 1975, however, appreciably more identifiable bone was found and when work can be resumed on this it is expected that a great deal more evidence on the meat processing and butchery practices will become available. This should aid in testing the model presented here, namely that Porc Epic was the fall and/or spring camp of a 60–70,000 year old group of MSA hunters who used to carry butchered joints of meat back to the cave. In the summer rains the group left the cave to spread out into the Afar and move westward following the escarpment to the obsidian sources at Afdem and Assabot volcanoes.

Part II

Porc Epic Cave has been of considerable chronological interest ever since its initial excavation in 1933 which revealed a distinctive MSA industry associated with human remains, including a mandible fragment ascribed by Vallois to a 'neanderthaloid' type. Although the great bulk of lithic material is chert, there are some artifacts made of obsidian. Recent developments in obsidian hydration dating now make it possible to determine a calendar year date for artifacts directly through knowledge of the chemical composition of the artifact and of the air temperature in the general vicinity of the site. Three Porc Epic obsidian artifacts of uniform chemical composition were dated by this technique. The results, which are minimum age estimates, suggest that Porc Epic Cave was occupied in the Middle Stone Age at around 61,000 bp and also around 77,000 bp.

The dating sample

Artifacts from the 1974 excavation are stored in Addis Ababa and not available for dating. However, the Chicago Field Museum of Natural History possessed a sample collection from the 1933 excavation, consisting of 258 specimens of which 18 were obsidian. Glen Cole, Curator of Prehistory, kindly made available six obsidian specimens from that collection. Although their original stratigraphic provenience is not known, all are typologically characteristic of the MSA assemblage. The LSA assemblage at the site tends to consist of small, almost microlithic, pieces.

Compositional characterization of the specimens was accomplished by means of atomic absorption spectroscopy. Inspection of Table 5 will readily reveal that three chemically distinct geological sources were involved in obsidian procurement by MSA occupants of the cave.

Table 5 Chemical composition (expressed in %/wt values) of obsidian artifacts from Porc Epic Cave, Ethiopia

Laboratory No.	Field Museum No.	SiO_2	Al_2O_3	Na_2O	K_2O	Fe_2O^T	CaO	MgO	TiO_2
12017	220286	71.2	11.83	6.37	4.36	5.42	0.42	0.01	0.44
12018	220315	74.2	13.29	4.36	5.08	2.07	0.74	0.08	0.19
12020	220529	74.2	13.29	4.47	5.14	2.12	0.73	0.08	0.01
12022	220287	73.8	13.59	4.51	5.07	2.07	0.73	0.08	0.17
12019	220531	75.9	11.86	4.57	4.74	2.41	0.38	0.05	0.07
12021	220514	76.7	11.58	4.67	4.60	2.13	0.23	0.01	0.09

Few obsidian flows known to exist in the Afar Depression and in the Ethiopian Rift Valley have been compositionally analyzed. Analyses are available for three separate flows in the vicinity of Volcano Fantale (230 km west of the site) and one flow in the vicinity of the town of Modjio (320 km west of the site) (Mohr 1971:212–13) (Fig. 1). A comparison of Porc Epic obsidian with these flows reveals an altogether persuasive compositional affinity between

Porc Epic specimen 12017 and obsidian from Modjio, Shoa. The range of the obsidian trading network in the MSA may thus have been quite extensive.

No source affinity can be established for the other two Porc Epic groups at this time, although Volcano Fantale can be ruled out. The most likely candidates are obsidian flows in the Afdem area (some 100 km west of the site). There is also a chance that obsidian deposits occur among the siliceous domes and flows which Kazmin (1973) locates just 20 km northwest of the site.

Experimental procedures and results

Specimen 12022 was selected for the accelerated hydration experiment because the hydration rate thus established could be applied also to specimens 12018 and 12020 due to their compositional uniformity. The artifact was fractured by percussion and nine small freshly-surfaced flakes were selected for induced hydration in a one-liter, thermoregulated reaction bomb containing 500 ml of deionized water. The results are given in Table 6. Hydration measurements were taken (after thin sectioning) under transmitted, polarized light by means of an optical microscope equipped with a I–IV order quartz wedge, a 100× oil immersion objective and Vicker's image-splitting eyepiece.

Table 6 Porc Epic No. 12022 induced hydration.

Sample No.	Temperature	Duration	Micron Value	Standard Deviation
1	200°C	0.5 day	1.56μ	±0.05μ
2	200°C	1 day	2.90μ	±0.07μ
3	200°C	2 days	4.46μ	±0.06μ
4	200°C	4 days	5.35μ	±0.21μ
5	200°C	6 days	6.85μ	±0.13μ
6	250°C	4 days	16.09μ	±0.09μ
7	225°C	4 days	9.07μ	±0.15μ
8	175°C	4 days	3.32μ	±0.10μ
9	150°C	4 days	1.68μ	±0.10μ

Hydration measurements on samples 1 through 5 are plotted in Figure 15. A linear regression analysis was performed using the following data arrays:

x-array ($\sqrt{\text{time}}$) = 0.0000; 0.7071; 1.0000; 1.4142; 2.0000; 2.4494.

y-array (μ) = 0.00; 1.56; 2.90; 4.46; 5.35; 6.85.

This resulted in the determination of a rate of hydration of 7.95 μ^2/day @ 200°C, with a correlation coefficient of 0.99.

Hydration measurements on samples 4, 6, 7, 8, 9 are plotted logarithmically in Figure 16. A linear regression analysis was performed using the following data arrays:

x-array ($\frac{1}{T}$°K) = 0.0019115; 0.0020074; 0.0021134; 0.0022313; 0.0023632.

y-array (ln k) = 4.17; 3.02; 1.97; 1.01; −0.35.

The resulting *slope* determination (m) of −9780.48 can be converted to an activation energy value (E) by means of the equation

$m = -E/R$

where $R = 1.985\ C/mol^{-1}{}^{\circ}C^{-1}$ (gas constant)
thus $E = -mR$

which yields an activation energy of 19,414 cal/mol (81267 J/mol) with a correlation coefficient of 0.99.

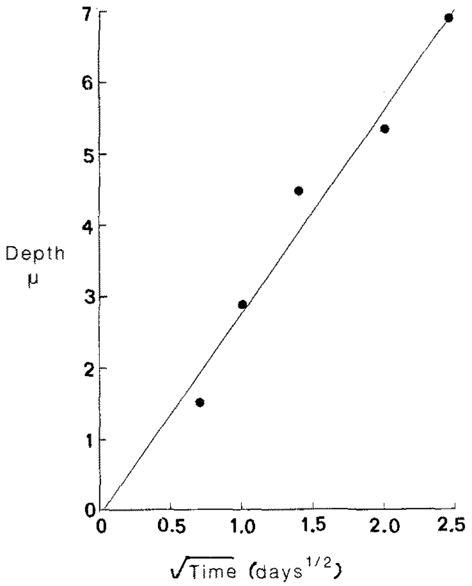

Figure 15 Porc Epic 12022 induced hydration at 200°C.

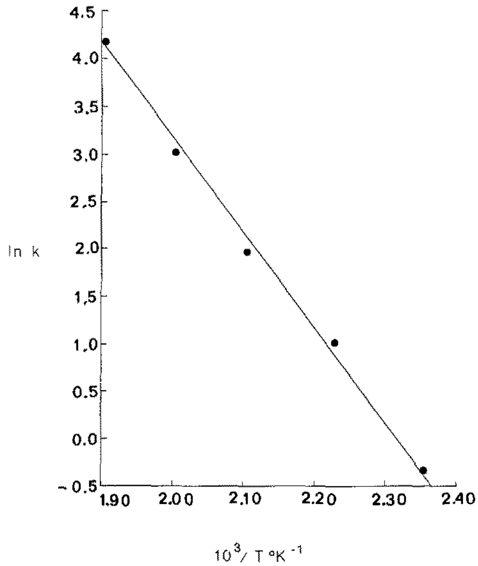

Figure 16 Porc Epic 12022 Arrhenius plot.

Effective hydration temperature

To determine the effective hydration temperature it is necessary to take into consideration fluctuations of temperature around the annual mean. This is because in endothermic (heat-absorbing) reactions, the rate of change of the reaction increases as a function of temperature. Richard Lee (1969) has experimentally derived a prediction equation that allows (average) monthly mean air temperature data to be used to determine the effective temperature:

$$T_a = -1.2316 + 1.0645\ T_e - 0.1607\ R_T \qquad (1)$$

where

T_a = mean annual air temperature
R_T = temperature range of T_a
T_e = effective temperature

using weather records from Dire Dawa (9°36′N; 41°52′E; 3804 m ASL) collected over 15 years as reported by Wernstedt (1972) we find that

$T_a = 24.2°C$
$R_T = 6.4°C$ (Dec. mean subtracted from June mean)

thus

$$T_e = \frac{(24.2 + 1.2316) + (0.1607 \cdot 6.4)}{1.0645}$$

which yields an effective temperature of 24.8°C (297.96°K).

Hydration rate calculation

The hydration of obsidian is a diffusion process and obeys the equation suggested by Friedman and Smith (1960):

$$x^2 = kt \qquad (2)$$

where x is the thickness of the hydrated layer, k is the hydration rate, and t is the time. The hydration rate is temperature dependent and follows the Arrhenius equation given by:

$$k = A \exp(-E/RT) \qquad (3)$$

or (working equation)

$$k' = k \exp\left(E/R\left(\tfrac{1}{T} - \tfrac{1}{T'}\right)\right) \qquad (4)$$

where k' = hydration rate @ T' (of the unknown)
k = hydration rate @ T determined by induced hydration (7.95 μ^2/day)
E = activation energy determined by induced hydration (81267 J/mol)
A = hydration constant
R = 8.317 J/mol^{-1}°C^{-1} (gas constant)
T = 473.16°K (200°C) (induced hydration temperature)
T' = 297.96°K (effective hydration temperature at Porc Epic Cave)

thus for Porc Epic Cave, Ethiopia

k' = 0.0000424 μ^2/day *or* k' = 15.47 μ^2/1000 yrs.

The dating of Porc Epic obsidian artifacts

Archaeologically hydrated surfaces of specimens 12022, 12018, and 12020 were thin-sectioned and examined microscopically as described earlier. A moderate amount of surface corrosion had caused pitting and other structural alterations that reduced the inherent clarity of the hydrated rim under normal illumination. However, when the sections were examined under cross-polarized light the hydrated rims were readily detectable. This is because obsidian, normally isotropic, undergoes strain due to the interdiffusion of hydronium ions (H_3O^+) with mobile alkali ions during the hydration process (Laursen and Lanford 1978). The hydrated layer therefore becomes anisotropic and exhibits the property of *strain birefringence.* It is this property that causes the hydrated layer to appear bright against a dark field when viewed between crossed nicols.

Although the hydrated rims of two of the specimens (12018, 12020) were partially exfoliated, it was possible to secure compatible measurements at an average of three separate hydration loci per section. Multiple measurements taken at each of the loci were averaged, yielding the following hydration values:

Artifact 12022	30.77µ ± 0.24	(standard deviation)
Artifact 12018	30.88µ ± 0.27	
Artifact 12020	34.64µ ± 0.35	

When converted to chronometric dates by application of the Porc Epic hydration rate we have:

Artifact 12022	61,202 bp ± 958 yrs (standard deviation).
Artifact 12018	61,640 bp ± 1083 yrs
Artifact 12020	77,565 bp ± 1575 yrs

However, the effective temperature of the Porc Epic region is a very important part of the rate calculation. Glacial periods with subsequent lowering of temperature will, therefore, slow the rate of hydration. Thus the dates given must be seen as minimum estimates. Research into this problem is currently under way. Preliminary calculations would put the true age of the specimens 20,000 years earlier than the dates listed above.

Discussion

These results are of the greatest interest. Not only do they provide minimum dates for the MSA occupation at Porc Epic showing that it is likely to have continued for more than 16,000 years but they also show that hominids with 'neanderthaloid' and some characteristics of modern man, were present in the Horn of Africa during the earlier part of the Last Glacial and were the makers of the Porc Epic form of the Ethiopian MSA. Since the point forms, in particular the sub-triangular and long foliate types, are also characteristic of the MSA assemblages from the Gorgora rock shelter at Lake Tana and the later Middle Stone Age of the northern part of Somalia, notably from Hargeisa, it might be suggested that these early populations of *Homo sapiens* were widespread throughout the Horn at this time. Since the brecciated deposit that contains the MSA at Porc Epic is in general not more than 1.5–2 m in thickness and some of this is made up of rockfall from the roof, the implication is that the rate of sediment accumulation—1.5–2.0 m in 16,000 years—was exceedingly slow, assuming that the minimum dates of 61,000 bp and 77,000 bp can be regarded as an approximation of the upper and lower limits of occupation. This would tend to confirm the sporadic, relatively brief and so probably seasonal occupation of the site. Had occupation been more regular and for longer periods, appreciably more deposition would probably have resulted.

Ages of from ~40,000 bp up to 100,000 bp or more have been obtained for MSA occurrences from southern Africa and elsewhere (Singer and Wymer 1982). In the Ethiopian Rift, potassium-argon samples of tuff that overlie the MSA horizons at Gadamotta suggest that the MSA there may be between 150,000 and 180,000 years old (Wendorf *et al.* 1975). This is in general agreement with the extrapolated dates for the beginning of the MSA at Klassies River Mouth and Border Cave in South Africa and implies that biface production had already been largely or completely replaced by light duty, technically more advanced MSA tool kits before, or by the beginning of the Last Interglacial. The new Porc Epic dates fall well within what are now thought of as the upper and lower limits of MSA technology in sub-Saharan Africa. Clearly, as soon as it is possible to resume research in Ethiopia, the next step is to date further obsidian samples from the 1974 excavations at Porc Epic, as well as samples from the excavated workshop floors at the quarry sites at Gadamotta, Kulkuletti and Kone'. The new hydration dating method is one of the most important developments for prehistoric studies in East Africa and Ethiopia where good sources of obsidian are to be found.

Endnote

1 Subsequent to the publication of the preliminary report of the 1933 excavations, part of the collection was purchased by Dr Henry Field of the Field Museum, Chicago, where it is now housed. This collection has been analysed twice: by Michael J. Mehlman, a graduate student at the University of Illinois at Champaign-Urbana, and by Gary Richards of the Graduate Program at U.C. Berkeley. They have generously made available their unpublished findings to the authors but, as the collection is presumed to be selected, their analyses have not been used here other than to confirm that there are no essential artifact differences from the 1974 assemblage.

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