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INDUSTRIAL TAXONOMY IN THE EARLY STONE AGE OF AFRICA

The aim of this paper is to investigate patterns of stone artifact variability during the Early Acheulian period of Africa using Olduvai Gorge and Sterkfontein as a case study. The questions asked are concerned principally with lithic industrial taxonomy during the early post-Oldowan period. Several techniques of pattern recognition are employed based on an analysis of attribute data. The rationale of the use of these techniques is set out in Stiles (1979).

The age of the assemblages under study is approximately 1.5 m.y. BP and constitutes the period of the earliest recorded incidence of biface manufacture (Leakey 1971; Hay 1976; Isaac and Curtis 1974; Stiles and Partridge 1979). Three industries have been defined for this period, the Early Acheulian, the Developed Oldowan B, and the Karari Industry (Leakey 1971, in press; Harris and Isaac 1976; Clark 1976). The meaning of lithic industrial taxa is considered and ways in which artifact and assemblage composition variability can be interpreted is discussed.

Specific objectives of lithic comparative analyses have often remained undefined by archaeologists. What can be gained by comparing stone artifact assemblages that are separated by hundreds or thousands of miles in space and tens of thousands of years in time? In this case three main questions are asked:

1. Is the Developed Oldowan B properly defined? If it is not properly defined, is there evidence to support a redefinition and for keeping it as an industrial taxon distinct from the Acheulian Industrial Complex? Would it be better viewed as a facies of the Acheulian?

2. Does the Sterkfontein assemblage belong with the Developed Oldowan B or with the Early Acheulian?

3. Where does the Karari Industry fit into Early Stone Age industrial taxonomy?

To answer the first two questions one must first see if the present definition fits the archaeological data, then the distinguishing features of the assemblages assigned to the two industries must be defined, and then one must determine to which group, if either, the Sterkfontein material most closely fits. The Karari material will be assessed by data available in Harris (1978). Assemblages in Bed II, Olduvai Gorge, are used because they are the basis upon which a Developed Oldowan B industry was distinguished from the Early Acheulian. Sterkfontein is included because this assemblage has been defined as both Developed Oldowan B (Leakey 1970) and Early Acheulian (Mason 1962, in press), and therefore offers a good comparative sample.

The Developed Oldowan B was defined by M. D. Leakey (1967, 1971) based on assemblages from Bed II at Olduvai Gorge. Two defined Acheulian assemblages, EF—HR and TK Lower Floor (TKLF), and two defined Developed Oldowan B assemblages, TK Upper Floor (TKUF) and FC West Floor (FCWF) were chosen (Leakey, in press). These assemblages were selected because each is made up of material excavated from a single occupation site, and therefore each represents a chronologically homogenous set of artifacts presumably produced by one social group of hominids. The other assemblages in Bed II are inappropriate because they are composed of material from several levels or vertically diffuse horizons and sometimes even from different locations mixed together. There is then no control over the effects of time or the possibility that more than one hominid social group was involved in the manufacture of the artifacts at any of these sites.

The methods by which prehistorians normally describe and compare lithic assemblages and decide on their industrial affinities involves an analysis of two levels of variability: 1. the percent frequencies of artifact categories and defined types and 2. the morphology and technical features of certain types considered to be taxonomically significant. In this study much more emphasis is placed on the second level of variability. I do not believe that percent frequencies of artifact-types are a valid criterion for the definition of industries because there are too many factors that affect the final assemblage composition that are not possible to attribute to culture tradition. Examples of such factors are the kinds of activities that were performed by the site occupants, length of occupation time, nature and availability of raw material, whether the site is single or multiple occupation, whether there has been a mixture of material from different time periods due to stratigraphical problems, depositional processes, or excavation errors, the tendency for assemblages to be composed of samples of the total number of artifacts actually present at a site, due either to incomplete excavation of the site and/or conscious sampling of excavated material and, finally, variations between archaeologists in concepts of types. All of these factors affect the final percent frequencies of artifact-types of any given assemblage and it seems to me, therefore, inappropriate to use them as industrial indicators. The percent frequencies of the Olduvai assemblages will be presented here for the explicit purpose of demonstrating that the commonly accepted definition of the Developed Oldowan B can no longer be supported.

PROCEDURE

For the first objective of deciding whether the Developed Oldowan B is properly defined, the stated criteria of the definition will be examined. This will involve a discussion and analysis of both percent frequencies of artifact-types and of a set of selected qualitative and quantitative attributes for certain artifact-types from the four Olduvai assemblages. A set of hypotheses will be generated to be tested by the data. The basis upon which the Developed Oldowan B is differentiated from the Acheulian will also be examined. The Sterkfontein artifacts will be compared to the Olduvai assemblages to ascertain to which, if either, they most closely resemble and a discussion will be made of the affinity of the material. The methods to be employed will include coefficients of variation, nonparametric statistical tests, and multivariate statistical techniques. Following the detailed comparative study involving the Olduvai and Sterkfontein assemblages, a comparative study will be made of selected Karari assemblages and other defined Developed Oldowan B and Acheulian assemblages where limited data is available from Gadeb, in Ethiopia (Clark and Kurashina 1979, in press).

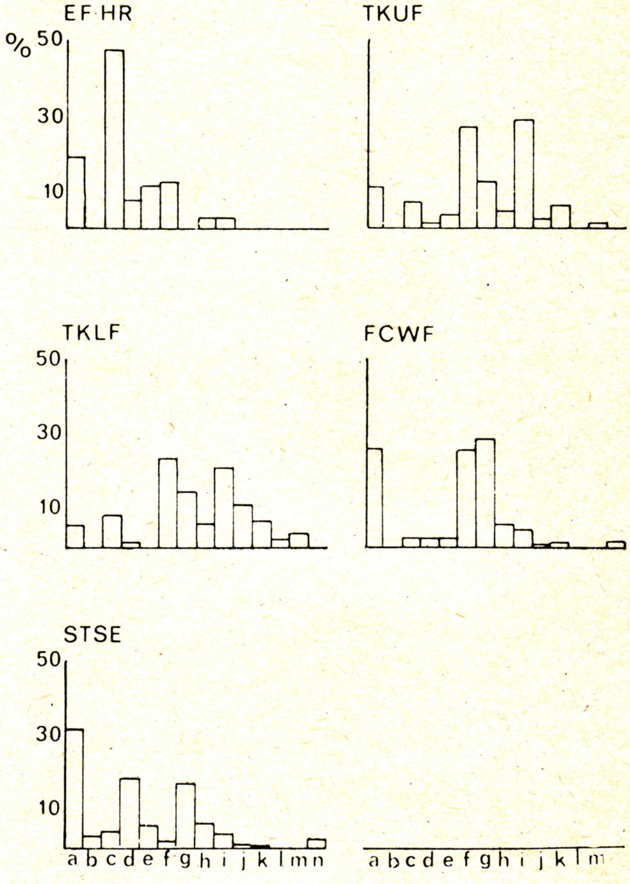


FIG. 1. *Assemblage composition of Olduvai and Sterkfontein.*

WHAT IS THE DEVELOPED OLDOWAN B?

M. D. Leakey (1971, in press) has stated that the Developed Oldowan B can be distinguished from the Acheulian by the following features:

1. A higher proportion and greater variety of light-duty tools is found in the Developed Oldowan.
2. A higher proportion of spheroids, subspheroids, and modified cobbles, nodules and blocks is found in the Developed Oldowan B.
3. Acheulian handaxes are larger than Developed Oldowan B handaxes.
4. Acheulian handaxes display less variation of morphological attributes than Developed Oldowan B handaxes.
5. Acheulian handaxes tend to be made on large flakes while Developed Oldowan B handaxes are not.
6. The makers of the Acheulian handaxes had the technological capacity to produce large flakes (> 10 cm) while the Developed Oldowan B makers did not.

These statements will be treated as hypotheses to be tested using the various statistical methods described below. In the context of the above discussion two alternative hypotheses concerning the interpretation of interassemblage variability can also be proposed for the relevant segment of the Early Stone Age of Africa: 1. there were two distinct cultural traditions beginning approximately 1.5 m.y. ago or 2. the Acheulian Industrial Complex, beginning about 1.5 m.y. BP, was marked by a high degree of variability in percent frequency of stone artifact-types and biface morphology.

ASSEMBLAGE COMPOSITION

Figure 1 shows the percent frequency of the artifact-types, using the system of classification devised by M. D. Leakey (1971). The raw data is presented in *table 1.* There seem to be no consistent features of assemblage composition that would serve to distinguish the Acheulian from the Developed Oldowan B. EF-HR shows a histogram considerably different from the others, characterized by a high frequency of bifaces and almost total absence of small tools. TKLF, the other Acheulian assemblage, had the highest proportion and widest range of light-duty tool types and a relatively high percentage of spheroids and subspheroids, which does not accord with Leakey's definition of the Acheulian being inferior in these respects.

Sterkfontein shows itself to be different in the following ways:

1. More choppers than any Bed II assemblage.
2. Many fewer spheroids and subspheroids than any Bed II assemblage.
3. It is the only assemblage with both proto-bifaces and bifaces.
4. More polyhedrons than any Bed II assemblage.
5. Lower proportion of light-duty tools than any site except EF-HR.

Using the criterion of artifact-type frequencies, therefore, it is not possible to assign the Sterkfontein assemblage to either Early Acheulian or Developed Oldowan B. Furthermore, it is not even possible to make a clear distinction between the two industries at Olduvai itself. The first two hyptheses cannot therefore be supported.

We shall next examine the morphology and technical features of certain types in the assemblages using a series of quantitative and qualitative attributes. If two separate traditions existed, then this should be reflected by a consistent patterning of attribute values for artifact-types that is different between assemblages assigned to the two industries. In other words, if cultural conventions dictate the form of artifacts, then artifact classes of one cultural group should be distinguishable from the corresponding artifact classes of a different cultural group (Stiles 1979: 5). The attributes used are those listed in the appendix.

To review the analysis of all of the types here would be an extremely lengthy and a certainly boring endeavor, therefore only selected types were examined. These were: side choppers, bifaces, light-duty scrapers, and whole flakes. This provides a sample of the large and small artifact classes and these classes have been used by others as taxonomically important in assessing industrial affinity (Bordes 1961; Movius 1948; de Lumley 1969a; Bower 1977; Isaac 1977). I shall present here only a summary of the results of the univariate attribute comparative study, a more detailed discussion can be found in Stiles (1977).

The evidence from the comparative analysis showed that there were few differences between the artifact attributes of the two industries overall, and that the differences that do exist exhibit a haphazard pattern. These differences can be summarized as follows:

1. The Acheulian side choppers are larger and have longer working edges formed by a higher number of flake scars.

TABLE 1.

Assemblage Composition of Olduvai and Sterkfontein Assemblages.

Artifact Type	EF-HR		TKLF		TKUF		FCWF		STSE[1])	
	No.	%	No.	%	No.	%	No.	%	No.	%
a. Choppers	14	17.7	6	5.1	29	10.2	49	25.9	66	31.9
b. Proto-bifaces	0	0	0	0	0	0	0	0	8	3.9
c. Bifaces	37	46.8	9	8.0	18	6.3	4	2.1	10	4.8
d. Polyhedrons	5	6.3	1	0.9	3	1.0	4	2.1	39	18.8
e. Discoids	8	10.1	0	0	9	3.2	4	2.1	12	5.8
f. Sph./Subsph.	9	11.4	28	23.9	76	26.7	48	25.4	5	2.1
g. Mod. Battered Cob., Nod., Bloc.	0	0	17	14.7	35	12.3	54	28.6	35	16.9
h. HD Scrapers	3	3.8	6	5.1	13	4.6	11	5.8	14	6.8
i. LD Scrapers	3	3.8	24	20.5	78	27.4	9	4.8	9	4.3
j. Burins	0	0	12	10.3	6	2.1	1	0.5	2	1.0
k. Awls	0	0	8	6.8	15	5.3	2	1.1	1	0.5
l. Outils écaillés	0	0	2	1.7	0	0	0	0	0	0
m. Lat. Trim. Flks.	0	0	4	3.4	3	1.0	0	0	0	0
n. Sundry	0	0	0	0	0	0	3	1.6	6	2.9
	79		117		285		189		207	

[1]) *STSE — Sterkfontein*

2. The Acheulian handaxes tend to be longer, thicker, and to have longer working edges.

3. The Developed Oldowan B scrapers tend to have longer retouched edges and more retouch scars.

4. The Acheulian flakes tend to have a higher proportion of elongated flakes and more dorsal surface scars.

There are at least as many attributes that differ between EF-HR and TKLF, the two Acheulian assemblages, as between the Acheulian and Developed Oldowan B. This suggests that one population with a wide range of variability is being sampled and that the Developed Oldowan B and Acheulian are not distinct industries. Along with the assemblage composition comparison it would seem that the Developed Oldowan B definition is confused. This is due to the fact that M. D. Leakey (in press) reclassified assemblages that contained high proportions of spheroids/subspheroids and light-duty tools (TKLF and MNK Main Site) from Developed Oldowan B to Acheulian. This reclassification was based on handaxe morphology and technical features. Without it explicitly being stated, a redefinition of the Developed Oldowan B was implied. The definition now rests exclusively on features of the handaxes. These features are said to be due to cultural differences between the populations that produced the two different styles of handaxe (Leakey 1971: 272). If all of the statements made by M. D. Leakey concerning the differences in the handaxes of the two industries could be demonstrated as being correct, and if no other explanation than culture tradition could be found to account for these differences, then it might be possible to make a case entertaining the concept of two cultural traditions in the Early Stone Age of Africa.

Of the six criteria enumerated for differentiating the Acheulian from the Developed Oldowan B, those concerning proportions of artifact-types, hypotheses 1 and 2, cannot be supported. Hypothesis 3, which states that Acheulian handaxes are larger than Developed Oldowan B handaxes, has been verified. There is, therefore, an indication that the Developed Oldowan B could be redefined based on handaxes.

The question of the industrial affinity of Sterkfontein has not been answered. For some artifact-types the attribute values at Sterkfontein resemble Developed Oldowan B assemblages, for others Acheulian assemblages, and for others they resemble neither (Stiles 1977).

To assess whether the Acheulian assemblages display less variation of handaxe attribute values than the Developed Oldowan B handaxes, hypothesis 4, we shall compare coefficients of variation for selected attributes and also turn to multivariate methods of pattern recognition. If attribute values for one group of units display less variation than those of another group of units, then we could say that the former group contained more "standardized" units. If the Acheulian handaxes are indeed more standardized than those of the Developed Oldowan B, then they should show more successful clustering as obtained by a cluster analysis. Likewise, the Acheulian handaxes of each assemblage should be discriminated correctly by discriminant analysis more often than those of the Developed Oldowan B.

Multivariate statistical programs can also be used as a means of identifying the attributes that are the most important in discriminating artifact-types between assemblages and at the same time can be employed to assess the degree of discriminating power of those attributes. Principal components analysis is a valuable technique that can be used for this purpose.

A brief description of these three multivariate techniques is in order here.

MULTIVARIATE ANALYSIS

Cluster analysis is a numerical taxonomic method for classification. It has been used in many of the natural sciences as well as in archaeology for reducing non-homogenous data into groups. These groups are defined by a set of variables used to describe the cases. Clustering performs a display function for multivariate data similar to graphs or histograms for univariate data; it provides a multivariate summary, computed from a matrix of similarity or distance measures. Using these measures, cases most often alike are grouped together and cases similar to existing cluster members are successively joined to them, until all cases and clusters have been fused into one. This structure is represented by a dendrogram, or tree. Each case starts at the tip of a twig and the twigs join to form branches until all are joined in the trunk.

There are several agglomerative hierarchal procedures for forming the clusters and there are different measures of similarity or distance. In this case I have used average-linkage cluster analysis with the Euclidean distance measure (Doran and Hodson 1975: 177). The variables used were the same variables employed for handaxes in the univariate analysis (see appendix). The program employed was the BMDP 2M (Dixon 1975) on the CDC 6,400 at the University of California, Berkeley. If the Acheulian handaxes are indeed more standardized then they should form clusters more homogenous than those of the Developed Oldowan B. If Sterkfontein handaxes are of the Developed Oldowan type then they should tend to cluster with TKUF and/or FCWF.

Discriminant analysis is used to distinguish statistically between two or more groups of cases. These groups are defined beforehand, in this instance being comprised of the handaxes belonging to each of the assemblages under examination. To distinguish between the groups a set of discriminating variables is selected that measure characteristics on which the groups are expected to differ. Again, the same nine variables used in the univariate analysis and the cluster analysis were employed. The mathematical objective of discriminant analysis is to combine linearly the discriminating variables so that the groups are forced to be as statistically distinct as possible. Ideally, the discriminant scores for the cases within each group will be fairly similar. I say ideally because if the cases are not in reality similar then the discriminant scores cannot be made to be similar. In any case, the functions are computed in such a way as to maximize the separation of the groups.

At the same time that the classification functions are being calculated for each group, a posterior probability is computed for each case; each case is assigned to the group in which the value of the posterior probability is maximum. After all the variables have been entered, the program lists the discriminant scores and the classification posterior probabilities (N i e et. al. 1970). These two bits of information present a good picture of how well each case has been classified. If a large percentage of the cases is classified correctly, i.e. if the posterior probability assigns them to their original group, then it is demonstrated that group differences do exist. If many cases are classified into the wrong group it can be concluded that there is overlap in the variable values and the groups are not entirely heterogeneous. Therefore, if M. D. Leakey is correct in her stated distinguishing criteria the Acheulian assemblages should have a higher percentage of correctly classified handaxes than the Developed Oldowan B. FCWF was not included in this analysis as it was felt that there were too few handaxe cases to compute a statistically valid classification function.

Discriminant analysis was also employed to examine two aspects of the Sterkfontein handaxe variability. The program was run once with Sterkfontein as an unknown, whereby the computer assigned each of the handaxes to the Olduvai assemblages to which it was most similar in terms of its classification function. This was to ascertain to what degree the Sterkfontein handaxes resembled those in the defined Acheulian and Developed Oldowan B assemblages. The program was run again with Sterkfontein acting as one of the defined groups to see how well the handaxes could be classified correctly in order to evaluate the internal consistency of handaxe similarity for this assemblage. For both runs the SPSS discriminant analysis program was employed with Mahalonobis D^2 as the distance measure (N i e et. al. 1970).

Principal components analysis (PCA) accounts for the variance within a set of data by providing linear combinations of correlated variables that maximize the variance of the weighted sum (P r e s s 1972: 283). The purpose is to construct a new set of variables, called principal components, the first of which accounts for the largest portion of variance within the data. Of the remaining variance the second principal component accounts for the maximum and the third the next largest and so on. There will be as many components as there were original variables. Geometrically, the variables are expressed as points in a multidimensional Euclidean space, each having an axis orthogonal to the others. A PCA finds a new set of orthogonal axes, the first of which is along the direction of maximum spread of variable points, the second along the direction of greatest remaining spread and so on (D o r a n and H o d s o n 1975: 190). In mathematical terms, a weighted sum is computed for each component which requires the calculation of eigenvectors of a covariance or correlation matrix of the variables. In this case a correlation matrix was used as the variable scores were standardized as outlined in D i x o n (1974: 196). There is an eigenvalue for each eigenvector that expresses its percentage of the total variance. Normally, only those components with an eigenvalue greater than one are used for data analysis, as less than one is actually less than the average variance expressed by any original variable. Variables with the highest scores in the eigenvectors are the most highly intercorrelated and express the most variation, therefore when cases described by the variables are plotted graphically it is possible to assess how well the highly variable variables can be used to differentiate cases within defined sets, in this instance artifact-types within assemblages. This argument will become more clear below when a concrete example is presented.

RESULTS

Table 2 presents the coefficients of variation (CV) of the nine handaxe attributes for the Olduvai and Sterkfontein assemblages. In looking at the mean of the CVs of the nine attributes, FCWF and STSE display the lowest values. TKLF is intermediate and EF-HR and TKUF have the highest mean values. If an average is taken of the mean CVs for the two Developed Oldowan B assemblages a value of .26 is obtained and for the Acheulian a value of .29 results. This is a crude way of measuring variability, but these preliminary indicators suggest that there is less biface variability in the Developed Oldowan B assemblages. Sterkfontein is the least variable of all.

Figure 2 shows the dendrogram of the average-linkage cluster analysis program performed on all of the bifaces of the five assemblages combined. This includes cleavers and picks as well as the handaxes. Eleven clusters were chosen from the dendrogram, X's marking their branching location in *figure 2*. *Table 3* contains a list of the bifaces by site and number of entry into the program, corresponding to the numbers in *figure 2*, that make up each of the clusters. In determining to what degree the bifaces are similar to one another in

TABLE 2. *Coefficients of Variation of handaxe attributes.*

	STSE	EFHR	TKLF	TKUF	FCWF
Max L	.19	.21	.38	.50	.18
Max T	.19	.16	.14	.40	.12
B/L	.16	.15	.25	.21	.12
T/B	.10	.21	.11	.21	.21
NSCAR	.27	.41	.29	.34	.11
SLWE	.17	.34	.36	.45	.17
ICSB	.26	.83	.32	.42	.51
WE/C	.22	.27	.13	.15	.11
BA/BB	.15	.32	.29	.25	.23
$\overline{X}$	.19	.32	.25	.33	.18

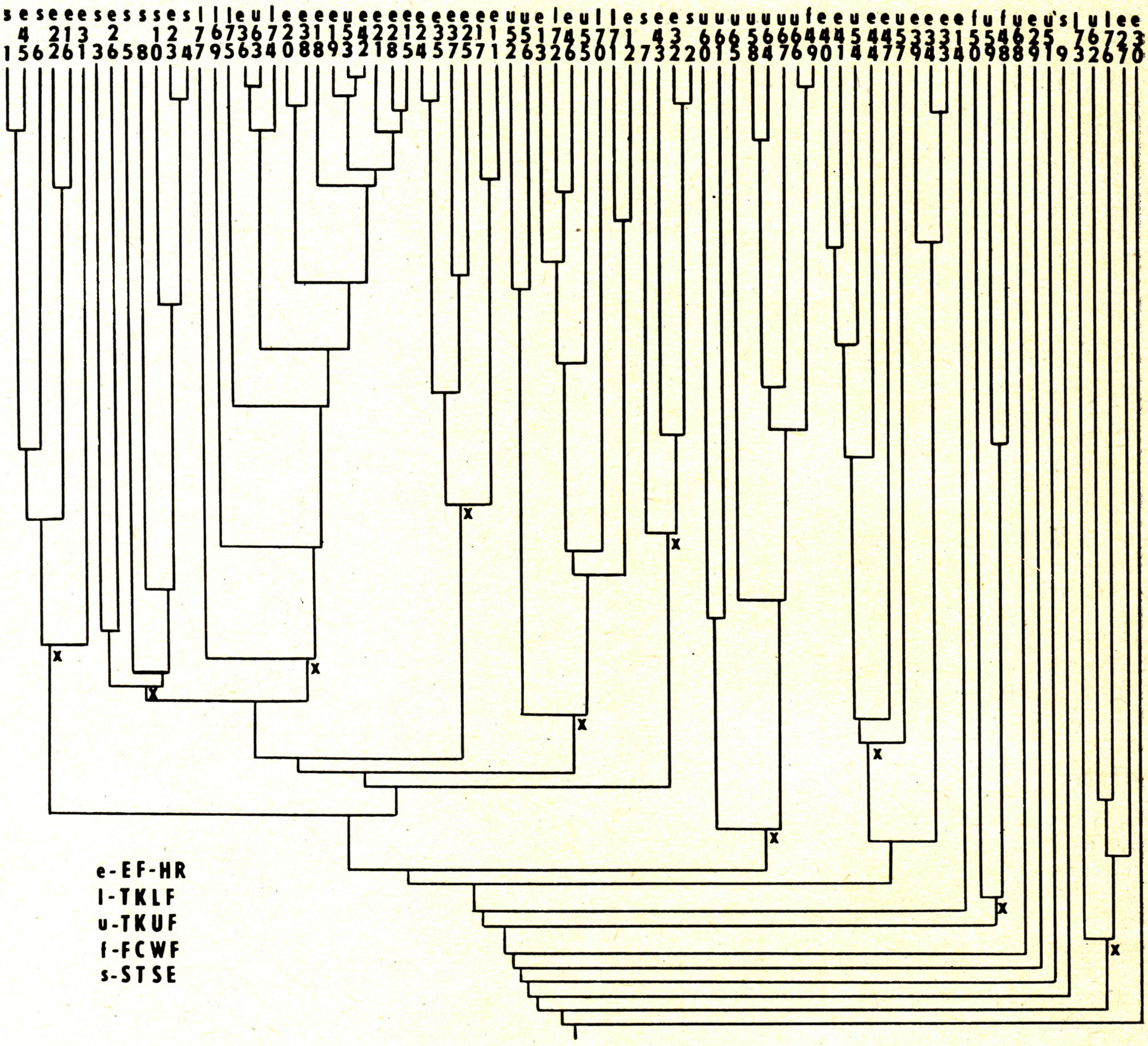


FIG. 2. *Cluster analysis dendrogram of Olduvai and Sterkfontein bifaces.*

TABLE 3. *Handaxes in Clusters.*

1	2	3	4	5	6	7	8	9	10	11
S 1	S 3	L 77	E 24	U 52	S 7	U 60	E 40	E 39	F 50	L 73
E 45	E 26	L 69	E 35	U 56	E 43	U 61	E 41	E 34	U 59	U 62
S 6	S 5	L 75	E 37	E 13	E 32	U 65	U 54	E 33	F 48	L 76
E 22	S 8	E 36	E 25	L 72	S 2	U 58	E 44			E 27
E 16	S 10	U 63	E 17	E 46		U 64	E 47			
E 31	E 23	L 74	E 11	U 55		U 67	U 57			
	S 4	E 20		L 70		U 66				
		E 38		L 71		F 49				
		E 18		E 12						
		E 19								
		U 53								
		E 42								
		E 21								
		E 28								
		E 15								

TABLE 4.

The percentage of handaxes of each assemblage in the clusters and the average cluster percentage value.

Cluster	EF-HR		TKLF		TKUF		FCWF		STSE	
	%	No.	%	No.	%	No.	%	No.	%	No.
1	66.7	4							33.3	2
2	28.6	2							71.4	5
3	60.0	9	26.7	4	13.3	2				
4	100.0	6								
5	33.3	3	33.3	3	33.3	3				
6	50.0	2							50.0	2
7					87.5	7	12.5	1		
8	66.7	4			33.3	2				
9	100.0	3								
10					33.3	1	66.7	2		
11	25.0	1	50.0	2	25.0	1				
	$\bar{X}$ — 66.3		$\bar{X}$ — 34.1		$\bar{X}$ — 54.0		$\bar{X}$ — 48.6		$\bar{X}$ — 58.2	

TABLE 5.

Similarity Index for the handaxes in each assemblage.

Assemblage	Observed Mean %	Expected %	'Similarity Index'
EF-HR	66.3	47.9	18.4
TKLF	34.1	12.3	21.8
TKUF	54.0	22.5	31.5
FCWF	48.6	4.2	**44.4**
STSE	58.2	12.3	**45.9**

TABLE 6.

Discriminant analysis of handaxes with Sterkfontein as a known group.

Actual Group	Predicted Group Membership							
	EF-HR		TKLF		TKUF		STSE	
	No.	%	No.	%	No.	%	No.	%
EF-HR	20	60.6	9	27.3	2	6.1	2	6.1
TKLF	2	22.2	6	66.7	1	11.1	0	0
TKUF	1	5.9	2	11.8	12	70.6	2	**11.8**
STSE	0	0	0	0	2	25.0	6	**75.0**

65.7 % of known cases classified correctly.

TABLE 7.

Discriminant analysis with Sterkfontein as an unknown group.

Actual Group	Predicted Group Membership					
	EF-HR		TKLF		TKUF	
	No.	%	No.	%	No.	%
EF-HR	21	63.6	10	30.3	2	6.1
TKLF	2	22.2	6	66.7	1	11.1
TKUF	3	17.6	2	11.8	12	70.6
Unknown (STSE)	3	37.5	0	0	5	62.5

TABLE 8. *Correlation coefficient matrix of handaxe variables.*

	L	T	B/L	T/B	NSCAR	SLWE	WE/C	ICSB	BA/BB
L									
T	.457								
B/L	–.605	.014							
T/B	–.360	.418	.039						
NSCAR	.421	.250	–.275	–.039					
SLWE	.828	.334	–.544	–.267	.621				
WE/C	.071	–.107	–.286	.101	.504	.579			
ICSB	.110	.075	–.054	.024	.428	.276	.317		
BA/BB	.015	–.063	–.173	.059	.220	.152	.335	.174	

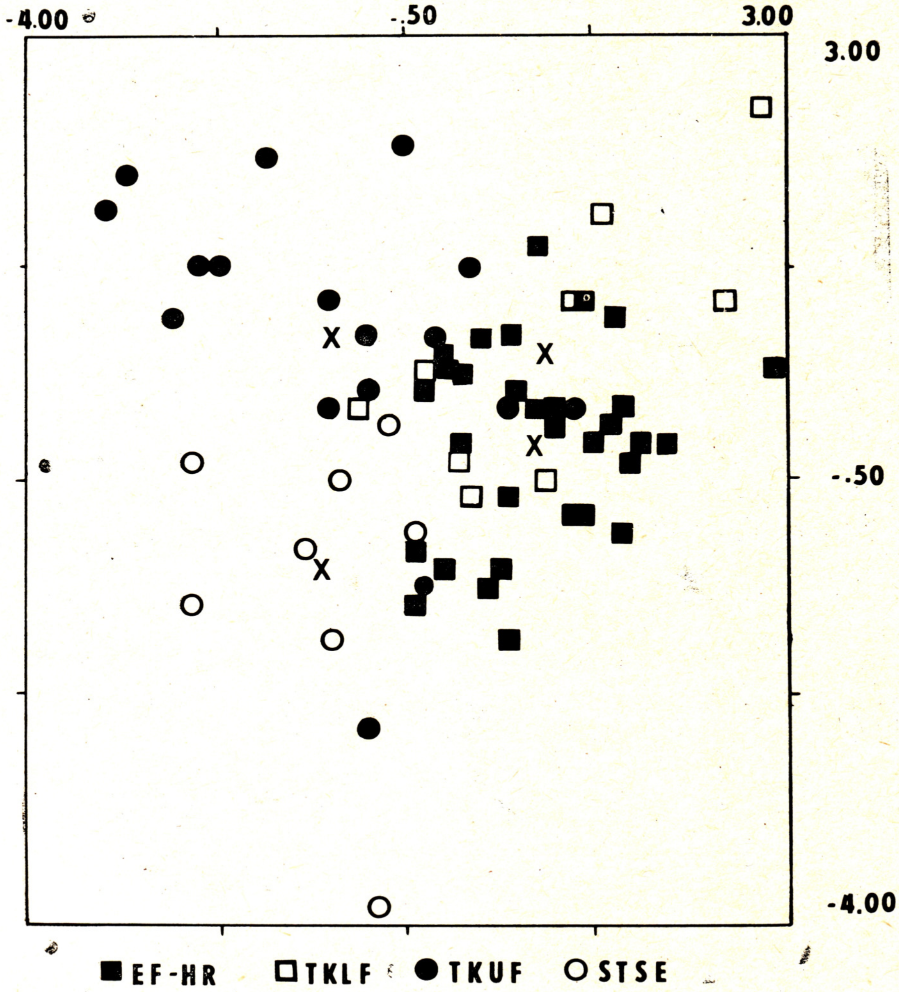


FIG. 3.
Discriminant analysis plot of handaxes with Sterkfontein as a known group.

each assemblage, the number of bifaces from each assemblage in each cluster was divided by the total number of bifaces in that cluster. An average cluster percent value was obtained for each assemblage by multiplying the percentage for each assemblage in each cluster by the number of bifaces for each assemblage in that cluster and then dividing that sum by the total number of bifaces in each assemblage. One can also look at the degree to which Acheulian and Developed Oldowan B bifaces tend to segregate in the clusters as a measure of how well the industries sort out. Thirdly, one can see how Sterkfontein associates in the clusters with the bifaces of the two industries as an indicator of cultural affinity.

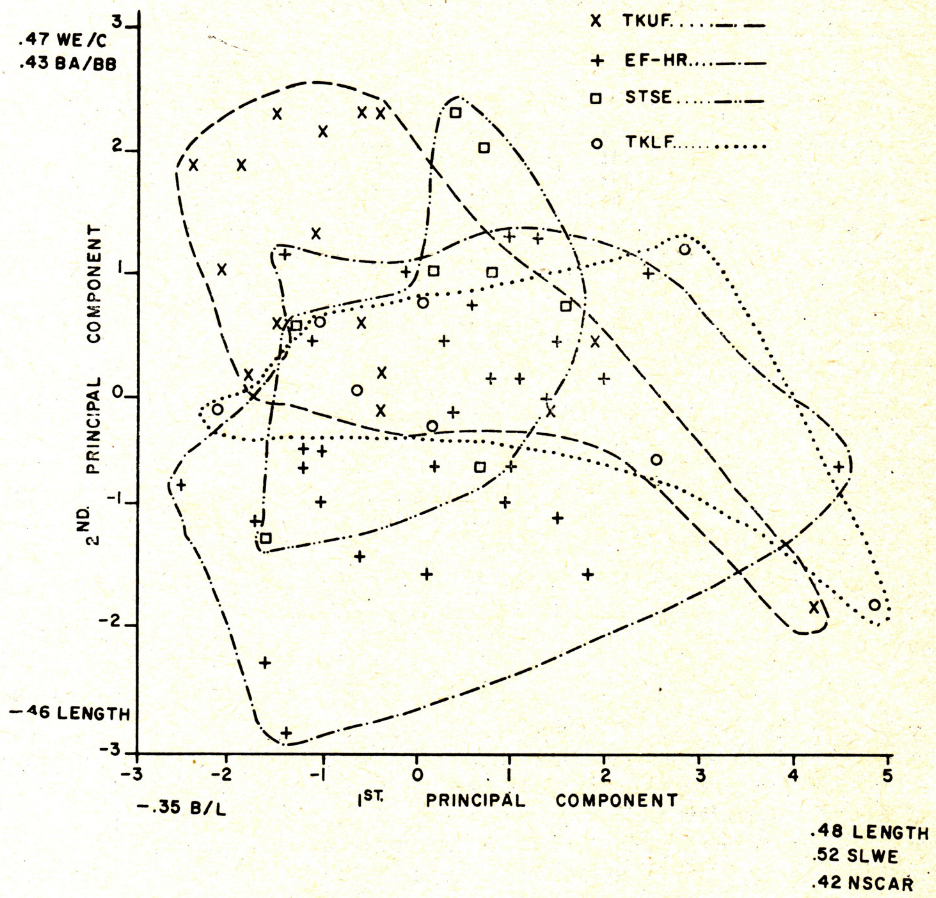
Table 4 displays the percentage value for each assemblage in the clusters and the average cluster percentage value for each assemblage. These scores have to be standardized, however, as assemblages with larger numbers of bifaces would naturally be expected by chance to compose larger percentages of each cluster. To adjust the scores I have subtracted the percentage value that each assemblage makes up of the total number of bifaces, i.e. the expected percent value of bifaces for the assemblages in each cluster. The resultant "similarity indices" present a pattern the opposite of that predicted by M. D. Leakey. FCWF has the highest index at 44.4 followed by TKUF at 31.5. The two Acheulian assemblages have similarity indices of 21.8 for TKLF and 18.4 for EF-HR. Sterkfontein has the highest index of 45.9 *(table 5)*. Hypothesis 4 is therefore not supported.

In assessing how well the Acheulian and Developed Oldowan B bifaces tend to sort out in the clusters the chi-square test has been used. The .001 significance level obtained indicates that bifaces defined as Acheulian are found at a level significantly greater than chance would allow in clusters different than those containing Developed Oldowan B bifaces. This would seem to be good evidence that there is a difference between the bifaces of the two industries.

Sterkfontein bifaces are found in only three of the eleven clusters. In all three of these clusters the only other assemblage represented is EF-HR, which strongly suggests that the Sterkfontein bifaces are more like the Olduvai Acheulian type than the Developed Oldowan B type.

Table 6 displays the results of the discriminant analysis in which Sterkfontein is included as a known group. The pattern of correctly classified handaxes reflects results similar to the cluster analysis. Sterkfontein has the highest incidence of correctly pre-

FIG. 4.
Principal components plot of handaxes from Olduvai and Sterkfontein.



dicted group membership at 75 %, and it had the lowest CV ratio mean and the highest similarity index, consistent findings. TKUF is next at 70.6 % followed by the two Acheulian assemblages, TKLF and EF-HR, at 66.7 % and 60.6 % respectively. This supports the outcome of the cluster analysis and indicates that the Sterkfontein bifaces are the most standardized, followed by the Developed Oldowan B bifaces, and lastly the Acheulian bifaces. These results also do not support the assertion that Acheulian bifaces are more standardized than are Developed Oldowan B bifaces, arguing against the acceptance of hypothesis 4.

Another conclusion is to be drawn by the fact that a minimum of 25 % of the handaxes were misclassified in an assemblage, with a mean for all assemblages of 34.3 %, or more than one third misclassified. This indicates that overall there is a moderate degree of overlap in handaxe morphology and technical features between the assemblages.

The misclassified handaxes do not follow the pattern suggested by the cluster analysis, however. One would have expected the Sterkfontein handaxes to be most often misclassified in EF-HR and vice versa, as they were highly associated in the clusters. Sterkfontein is misclassified only in TKUF and EF-HR is most often misclassified in TKLF, only 2 (6.1 %) of the cases being misclassified in Sterkfontein. The other misclassifications indicate a strong tendency for the Acheulian handaxes to interchange, i.e. EF-HR to go to TKLF and vice versa, supporting the chi-square results indicating a difference between the Acheulian and Developed Oldowan B bifaces. *Figure 3* shows the results plotted. One can see that the principal discrimination is made on discriminant score 1, the horizontal axis. Sterkfontein and TKUF predominate on the negative side and EF-HR and TKLF on the positive side. It is interesting to note, however, that the centroid of Sterkfontein in reduced space is located only marginally closer to TKUF than to EF-HR.

The results of the second discriminant analysis run, with Sterkfontein as an unknown group, is shown in *table 7*. Sterkfontein is most often classified in TKUF and only 37.5 % of the cases are classified in EF-HR. This contrasts with the clustering results. I think that this apparent anomaly can be explained by assuming that individual bifaces of Sterkfontein and EF-HR resemble one another, which is why they cluster together, but that classification probabilities of the Sterkfontein handaxes are in an approximately 2 : 1 ratio more like the centroid value of TKUF than the centroid value of EF-HR. In other words, Sterkfontein handaxes most often have individual analogues in EF-HR, but the multivariate "average" handaxe of TKUF is more similar to most of the Sterkfontein handaxes than is the "average" EF-HR handaxe.

Figure 4 displays the handaxes of EF-HR, TKLF, TKUF, and Sterkfontein (STSE) plotted

TABLE 9. *Eigenvectors and eigenvalues of the principal components of handaxes.*

	1	2	3	4	5	6	7	8	9
L	.437	–.465	–.047	–.023	.167	.072	–.090	.299	–.678
T	.181	–.185	–.730	.040	.215	–.153	–.164	–.537	.113
B/L	–.353	.152	–.147	.542	.219	–.553	–.198	.337	–.174
T/B	–.090	.368	–.626	–.357	–.249	.179	.056	.482	–.089
NSCAR	.423	.190	–.076	.264	–.040	–.240	.807	.004	–.004
SLWE	.523	–.132	.028	.024	–.093	–.208	–.314	.431	.611
WE/C	.331	.466	.147	–.100	–.438	–.340	–.359	–.298	–.341
ICSB	.237	.365	–.045	.585	.107	.641	–.209	–.019	–.004
BA/BB	.166	.433	.142	–.394	.776	–.078	–.031	.030	.016
Eigenvalues									
	3.27	1.56	1.44	.97	.72	.61	.38	.38	.01
Cumulative Proportion of Total Variance									
	.36	.54	.70	.80	.88	.95	.99	1.00	1.00

against the first and second principal components. *Tables 8 and 9* show the correlation coefficient matrix and the calculated eigenvectors and eigenvalues. If the handaxes (or any other artifact-type) were highly standardized within the assemblages and differed in terms of the attribute values for the defined variables between assemblages, then they would form clusters of points located in different areas of the plot. One can see in overall terms that the handaxes are not very standardized and that there is a great deal of overlap in attribute values.

For the first principal component, pieces with high values for maximum length, sum of the length of the working edge (SLWE) and number of flake scars (NSCAR) will be located to the right, and those pieces with a high B/L ratio will be located to the left side. For the second principal component, length is important to the low end of the vertical axis and the working edge/circumference ratio (WE/C) and BA/BB are the most important towards the top. There are two very large handaxes on tabular quartz, one from TKLF and one from TKUF, and these are the two plotted in the lowest right hand corner. The cluster of short, stubby handaxes from TKUF are those located in the upper left hand corner. Although there is much overlap, one can see that the handaxes of EF-HR tend to be longer and have a lower B/L ratio than those from TKUF, features already noted.

The first principal component (36 %) is concerned with size and size correlated variables and conversely with B/L. The second principal component (18 %) depends on degree of pointedness (BA/BB) and the percent of retouched edge around the circumference (WE/C), the first of which is also correlated with size. The third principal component (16 %) is conditioned by attributes associated with thickness (T) and relative thickness (T/B).

Principal components analysis is a good way of summarizing the variability, but it should be pointed out that there are some weaknesses of a mathematical nature. Press (1972: 284) states that unless samples are very large there are problems in interpreting principal components calculated from correlation rather than covariation matrices because the objective of finding linear functions of the original variables with maximum variance is not achieved. Because the units of measurement of the variables were not the same, however, and rarely are in archaeology, it is necessary to perform a standardization which results in working with with a correlation matrix. One must therefore interpret the PCA results with some caution.

The PCA plot suggests a conclusion in accordance with the results of the other multivariate techniques: EF-HR and TKUF are the assemblages which are the most dissimilar in handaxe morphology, but is is still not possible to differentiate assemblages based on differences in handaxe size and shape. The BMD O1M program (Dixon 1974) was used.

The CV and multivariate analyses result in the following conclusions:

1. The Acheulian handaxes display at least as much attribute variability as the Developed Oldowan B handaxes, and probably more.

2. There is a significant difference between the Acheulian and Developed Oldowan B handaxes.

3. Individual bifaces of Sterkfontein are most like those of EF-HR, an Acheulian assemblage, but in reference to the centroids of the assemblages the handaxes are classified most often with TKUF, a Developed Oldowan B assemblage. This reflects the ambiguous pattern obtained with the univariate analysis, where Sterkfontein displayed tendencies for a few attributes to resemble certain patterns of one or the other of the two industries, but exhibited no consistent pattern of association with either.

4. Sterkfontein handaxes are more standardized than the handaxes of the Olduvai assemblages.

The final two hypotheses concern the frequency of large flakes (> 10 cm) in the assemblages of the two industries. M. D. Leakey (in press) has stated that Acheulian bifaces are made significantly more often on large flakes than Developed Oldowan B bifaces because the makers of the Developed Oldowan did not have the technical capability to produce large flakes. *Table 10* shows the frequency of large flakes as the primary form for bifaces in the four Olduvai assemblages. A 2X2 contingency table was made to test large flakes against non-large flakes for the Acheulian and Developed Oldowan B bifaces. The chi-square test showed that the difference was at the .001 level, indicating that there are significantly more bifaces on large flakes in the Acheulian assemblages, verifying hypothesis 5.

To ascertain whether this difference was because the makers of the Developed Oldowan B could not produce large flakes we shall refer again to *table 10* and also to *table 11,* which shows the frequencies for large and non-large unretouched whole flakes. The chi-square test shows that there is a difference between the Acheulian and Developed Oldowan B at the .01 level, indicating that more large flakes in general are present in the Acheulian assemblages. Large flakes were produced in the Developed Oldowan B assemblages, however, thus the makers were technically capable of producing them.

Could the raw material employed have anything to do with the size of the flakes produced? Contingency tables were made up for the raw materials and number of flakes larger and smaller than 10 cm. *Tables 12 and 13* display the results. It is clear that in the case of both bifaces and the whole flakes that large flakes form a significantly smaller proportion of the quartz specimens than they do of the lava.

Do the Acheulian and Developed Oldowan B assemblages differ in the use of these raw materials in flake manufacture? Chi-square tests were then performed camparing the two industries in the proportions of these two raw materials for the bifaces and flakes, and both showed the Developed Oldowan B assemblages to have significantly higher proportions of quartz flakes *(tables 14 and 15).*

Alternative hypotheses that might explain these results are, 1. it is technically more difficult to produce large flakes on quartz than lava, hence fewer large quartz flake bifaces, 2. there was a cultural preference for producing more quartz flakes and bifaces by the Developed Oldowan B makers, 3. activities were being performed in which quartz

TABLE 10.
Contingency table of large and non-large flakes for handaxes.

	Large Flakes	Non-large Flakes	
Acheulian	28	18	
Developed Oldowan B	2	19	$X^2 = 15.4$ $df = 1$ Significant at .001

TABLE 11.
Contingency table of large and non-large whole flakes.

	Large Flakes	Non-large Flakes	
Acheulian	14	193	
Developed Oldowan B	5	249	$X^2 = 6.7$ $df = 1$ Significant at .01

TABLE 12.
The raw material of large and non-large flakes of bifaces.

	Quartz	Lava		
Large	7	23	$X^2 = 6.0$	Significant at .02
Non-large	5	2	$df = 1$	

TABLE 13.
The raw material of large and non-large whole flakes.

	Quartz	Lava		
Large	8	11	$X^2 = 5.3$	Significant at .05
Non-large	282	135	$df = 1$	

TABLE 14.

The raw material of bifaces for the industries.

	Quartz	Lava		
Acheulian	14	28	$X^2 = 4.0$	Significant at .05
Developed Oldowan B	13	9	$df = 1$	

TABLE 15.

The raw material of whole flakes for the industries.

	Quartz	Lava		
Acheulian	102	88	$X^2 = 27.1$	Significant at .001
Developed Oldowan B	188	55	$df = 1$	

was preferred over lava, or 4. quartz was a more readily available raw material than lava. I think that hypothesis 2 is unlikely because lava was also used in the Developed Oldowan B assemblages: 37.5 % of the bifaces and 22.6 % of the flakes. It is not possible to exclude this as an explanation, but postulating that raw material preference distinguished two cultural groups for hundreds of thousands of years lacks conviction. Hypotheses 3 and 4 would not be incompatible with hypothesis 1, and I feel that whether due to functional needs or raw material availability, the higher frequency of quartz use in the Developed Oldowan B assemblages led to the reduced average size of the bifaces made on flakes. I would conclude, therefore, that differential raw material use and not culture tradition explains the biface differences. This is a very important finding, as the Acheulian is distinguished from the Developed Oldowan B by biface differences. If the differences are due to raw material use then one can conclude that the industrial divisions only reflect differential raw material use.

Sterkfontein had 22.2 % of the bifaces made on large flakes and 7.2 % of the unretouched flakes were more than 10 cm in length. The former proportion falls intermediate between the Olduvai Acheulian and Developed Oldowan B proportions and the latter is very similar to the Acheulian values. All of the Sterkfontein bifaces were made from quartzite, lava is not present at the site. The fine-grained quartzite present at Sterkfontein, however, has flaking properties much more like lava than like quartz. Quartzite made up 56.4 % of the whole flakes and quartz formed 41 %. It is possible that the difference in raw material at Sterkfontein from that at Olduvai can account in part for the differences seen between this assemblage and those of Olduvai.

CONCLUSIONS

The answers to question 1 posed at the beginning of this paper are all negative. The Developed Oldowan B is not properly defined and the evidence that exists to support a redefinition has been assessed as being inadequate for that purpose. Of the six criteria proposed by M. D. Leakey for differentiating the Acheulian from the Developed Oldowan B, only two were substantiated: Acheulian bifaces are larger and are more often made on large flakes than are the Developed Oldowan B bifaces. Analysis has indicated both of these factors can be attributed to differential raw material use in the two industries, though what explains the differential raw material use has still to be ascertained. If raw material and primary form can account for a significant proportion of the variation in biface morphology and technical features between assemblages, what then is the justification for retaining two separate industries?

I would suggest, in the light of the foregoing analyses, that the assemblages studied are samples drawn from a highly variable stone artifact population of a flexible early hominid industrial complex. This industrial complex is not divisible into major industrial phyla such as may be implied by opposition terms such as Developed Oldowan B and Acheulian. I would therefore accept the hypothesis that states that, "the Acheulian Industrial Complex, beginning about 1.5 m.y. BP, was marked by a high degree of variability in biface morphology and percent frequency of stone artifact types".

Under these circumstances I can see no reason for not dropping the category Developed Oldowan B as a classificatory entity. Sterkfontein is therefore considered to be distinctive specific occurrence of stone artifact patterning that can be included in the early stages of the Acheulian Industrial Complex as defined at the 6th Panafrican Congress of Prehistory and Quarternary Studies (Hugot 1972).

These conclusions contrast with the results of a study conducted by Bower (1977). In this study choppers and scrapers of Oldowan, Developed Oldowan A and B, and Early Acheulian were analyzed using a set of attributes in order to assess the taxonomic interpretation of the East and South African Oldowan and Early Acheulian materials. Based on a comparison of mean values of measurements and ratios and of frequency distributions, Bower (1977) concluded that the Sterkfontein and Swartkrans assemblages were better viewed as variants of the Oldowan Industrial Complex, which he called the Krugersdorp Oldowan. The historical and taxonomic significance of the presence of bifaces was not discussed and, in fact, no explanation of the rationale behind the taxonomy proposed was presented. The Early Acheulian is even placed in the Oldowan Industrial Complex.

One can infer that Bower's taxonomic assessment was based on results that indicated continuities in chopper and scraper design norms (Bower 1977: 124), which suggested to him that all of the industries belonged to the same general tradition. Since scrapers and choppers of assemblages from industries later than the Early Acheulian were not studied, it is possible that African forms of these artifact-types display design continuities from the Oldowan to the Late Stone Age. Are all of the industries from the ESA to the LSA then to be included in the Oldowan Industrial Complex? Choppers and scrapers alone are not very appropriate criteria with which to assess Early Stone Age industrial taxonomy, because none of the industries were defined or distinguished in the first place by these types. Choppers, and to some extent scrapers, seem to persist in more or less the same shape and size from the earliest industries right through the Stone Age archaeological record, except for blade or microlithic based industries in the LSA.

I think that the appearance of bifaces should be accorded taxonomic significance and, following historical precedance, assemblages containing them during the appropriate time period should be considered as part of the Acheulian Industrial Complex, though there is still some uncertainty as to when this period began and ended (Isaac 1972; Clark 1975, 1976).

Clark (1976: 33) apparently holds a similar view and believes that the Developed Oldowan B and the Early Acheulian, along with the Karari Industry, are all cultural phases or facies of the Acheulian Industrial Complex. He thinks a likely explanation for these phases or facies is that they are related to different sets of activities, "the large cutting tools being used for a purpose other than were the small flake tools or the choppers and spheroids. This explanation is strengthened by the clear evidence of selection in the use of raw materials. The large cutting tools of the Acheulian are more often than not made from tough hard rocks such as quartzite or various kinds of lavas. The small flake tools, on the other hand, are generally made from fine-grained rocks- quartz or chert, for example . . .", (Clark 1976: 34). The hypotheses suggested above as explanations of biface raw material differences are similar to Clark's opinions for explaining assemblage composition variability. This general idea has been expressed earlier as an explanation for the facies seen in the Upper Acheulian (Clark 1959; Kleindienst 1961) and Isaac (1969) has discussed its relevance to interpretations of earlier Stone Age assemblage variability.

If phases or facies of the earlier portion of the Acheulian Industrial Complex are to be defined based on relative frequencies of artifact-types, then I think that a new terminological system should be created to label the categories. The term "Developed Oldowan B" has strong connotations indicating that it is an industry distinct from the Acheulian for culture-tradition reasons, as discussed in its definition (Leakey 1967, 1971, in press). The new terminology should ideally be agreed upon at an international conferrence by a consensus of opinion, but I would suggest terms such as the Early Acheulian of Olduvai facies, Karari facies, etc. The type assemblages that served as definitions of the facies from these localities could then be used as reference points from which to assign any assemblage a taxonomic industrial label in the future.

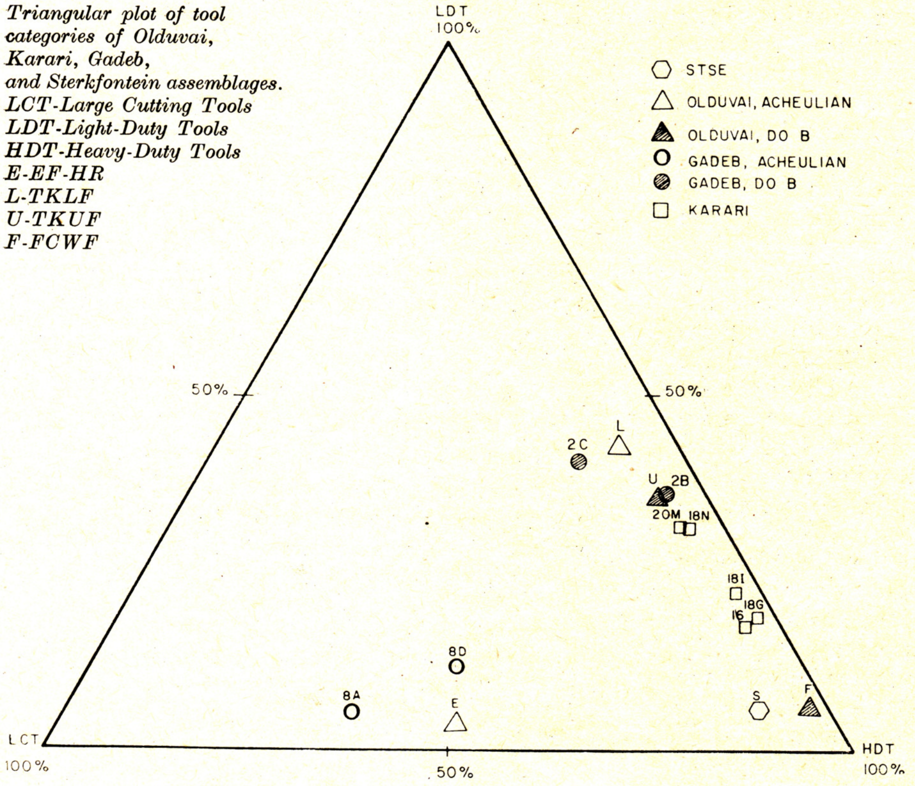
KARARI AND GADEB

The Karari Industry sites have been securely dated to between 1.5 and 1.2 m.y. BP (Isaac and Harris 1978: 77) and therefore fall within the time range of the Early Acheulian and the Developed Oldowan B. The definition of the Karari Industry is as follows (Harris 1978):

> *The Karari Industry is a set of early Pleistocene artifact assemblages that share broad, generalized features with other sets of occurrences but which also shows distinctive patterns of differences from them. Generalized features held in common include the preponderance of opportunistic flaking technology in which highly organized, fixed patterns of core preparation are rare or lacking. Choppers, polyhedra, and discoids are important components of the Karari Industry as in many other generalized industries. The Karari Industry, however, is distinguishable from all other near contemporaneous industries by the tendency of core scrapers. The percentage incidence of these is variable. A few assemblages, that clearly formed part of the Karari Industry, show a low or negligible incidence of the key forms, but in the majority where the sample is large enough, they are present in proportions well outside the range observed in other contemporaneous industries. In the Karari Industry even the scrapers that are not specifically core scrapers are distinct from those of most Oldowan assemblages in their tendency to be more massive. If an associated set of excavated artifacts is needed as a type sample of the newly defined industry the archaeological material from the FxJj 18 Site Complex is suitable.*

This definition has been modified from the original one first presented in Harris and Isaac (1976: 105). It was first thought that handaxes and cleavers found in surface occurrences were part of the Karari Industry, but Harris (1978) now believes that these types come from deposits stratigraphically above those containing Karari artifacts and that the Karari Industry is chronologically contemporary with the Developed Oldowan A at Olduvai Gorge. He further concludes that the Karari Industry forms part of the Oldowan Industrial Complex rather than the Acheulian Industrial Complex. If, in fact, bifaces are not found in any Karari Industry assemblages and if no Karari assemblages are younger than approximately 1.5 m.y. BP then Harris's conclusions seem valid. It is not known with any certainty how young the youngest Karari sites are, however, and the small number of tools in each assemblage, ranging from one to 169 with an average of 48, leaves open the question of whether bifaces might be part of the Karari Industry tool repertoire.

FIG. 5.
Triangular plot of tool categories of Olduvai, Karari, Gadeb, and Sterkfontein assemblages.
LCT-Large Cutting Tools
LDT-Light-Duty Tools
HDT-Heavy-Duty Tools
E-EF-HR
L-TKLF
U-TKUF
F-FCWF



Another point to consider is the fact that Acheulian assemblages without bifaces are not unknown (de Lumley 1969b; Clark 1970: 96–100; Isaac 1977: 106). For these reasons, I feel that the Karari material deserves attention as comparative material in a study of lithic industries related to the Early Acheulian.

Data used in the following discussion was drawn from the Ph. D. thesis of J. W. K. Harris (1978) and from data kindly furnished by J. D. Clark and H. Kurashina, for which I am very grateful. The assemblages studied by Clark and Kurashina (1979, in press) were excavated around Gadeb in the Awash river basin of Ethiopia. The age of these sites dates to between 1.5 and 0.7 m.y. BP (Williams et al. 1979) and both Developed Oldowan B and Acheulian assemblages have been defined (Clark and Kurashina 1979), hence the relevance of this site complex for comparative purposes here.

Figure 5 shows all of the assemblages considered in this paper plotted by relative frequency of tool classes, divided up into Large Cutting Tools (bifaces and protobifaces), Heavy-Duty Tools (choppers, polyhedrons, discoids, spheroids, subspheroids, heavy-duty scrapers, and modified cobbles, nodules, and blocks), and Light-Duty Tools (scrapers, burins, awls, outils écaillés, and laterally trimmed flakes).

The Acheulian assemblages of EF-HR, Gadeb 8A, and Gadeb 8D stand out clearly because of their high frequency of Large Cutting Tools. The Acheulian assemblage of TKLF is more like the Developed Oldowan B assemblages of TKUF, Gadeb 2B, and Gadeb 2C in having a relatively low percentage of Large Cutting Tools and close to equal proportions of Heavy-Duty and Light-Duty Tools. The Sterkfontein and FCWF assemblages are similar in displaying very high frequencies of Heavy-Duty Tools and low frequencies of the other classes. The Karari assemblages selected for study here form a relatively homogeneous grouping displaying very low frequencies of Large Cutting Tools, moderate frequencies of Light-Duty Tools, and high proportions of Heavy-Duty Tools. The Karari assemblages, along with FCWF, occupy the same area of the triangular plot as do Olduvai Oldowan assemblages and they are distinct from later Acheulian assemblages (see Isaac 1977, *figure 37*).

Table 16 summarizes mean values for attributes of artifact-types from the Olduvai, Sterkfontein, Karari, and Gadeb assemblages. Only five of the Karari assemblages reported in Harris (1978) involve numbers of tools sufficient for inclusion in the statistical comparisons made. Gadeb 8A and 8D are defined as Acheulian and Gadeb 2B and 2C are defined as Developed Oldowan B (Clark and Kurashina 1979).

The conclusions that can be drawn from *table 16* are the following:

1. The Acheulian choppers at Olduvai and Gadeb 8A are the longest.

2. Karari choppers have more working edge flake scars (NWES) than all assemblages except TKLF.

3. The Karari protobifaces are relatively short when compared to Sterkfontein. In length range they are more similar to those seen at Olduvai in the Developed Oldowan A (FLK N overall mean is

73.6 mm and the HWK East overall mean is 79.3 mm).

4. The Olduvai polyhedrons are generally larger than in the other assemblages. Except for F×Jj 16, the Karari polyhedrons are very small.

5. Karari discoids are very small, the means being smaller on the average than even the LD scrapers there.

6. Karari HD scrapers are more elongate than those at Sterkfontein and they have on the average many more working edge flake scars than at Sterkfontein and Olduvai.

7. The Gadeb Acheulian LD scrapers are longer on the average than those in the other assemblages, though this is due in part to the fact that HD scrapers are included. The Karari LD scrapers are longer, display more retouching, and have a higher WE/C ratio than those at Sterkfontein and Olduvai.

8. No bifaces, spheroids, or subspheroids were found in excavated occurrences at Karari.

Although the Sterkfontein and Olduvai assemblages are probably not separated in time by any great period from the Karari assemblages, there are some important differences between them. The main difference to be noted is the significantly greater degree of flaking of the pieces in the Karari Industry, as indicated by the higher means of working edge related flake scars of the choppers, HD scrapers, and LD scrapers. It would be interesting to know if this pattern holds true for the polyhedrons and discoids as well. The higher WE/C ratios of the Karari assemblages is a reflection of this higher degree of flaking. Along with typological considerations, the Karari Industry does appear to be a distinct entity. As Harris and Issac (1976:107) state, it is not known whether this distinctiveness is due to cultural factors, effects of raw material and/or primary form, activity differences, or a combination of factors or factors not considered. It would be useful to conduct a much more detailed study of primary form in relation to artifact-type, size, and technical features such as scar counts. The Karari Industry might prove to be a plausible example of an instance of early hominid cultural differentiation if other explanatory factors can be eliminated. In other words, the Karari artifacts may indicate that their makers had a set of social rules of tool manufacture that were significantly different than the rules prevalent among hominid groups at Olduvai Gorge and elsewhere during the same period. This difference in social rules of tool manufacture, assuming alternative explanatory factors of the differences seen with other stone industries could be ruled out, might be a reflection of the existence of distinct ethnic entities.

Not enough data was available to examine how different the handaxes of the Gadeb Acheulian and Developed Oldowan B were. Except for maximum length, in wich 8A and 8D were longer on the average than 2B and 2C, there were no consistent differences between the two industries in the other attribute value means. It was not possible for me to test the effects of raw material or primary form on handaxe size. The reason for the large difference in T/B ratio means between Gadeb 8A, 8D, and 2B compared to Sterkfontein likewise could not be examined.

CONCLUSIONS

A univariate and multivariate analysis of size and shape-defining attributes of selected artifact-types of assemblages from the Early Stone Age of Africa has shown there to be few consistent differences between assemblages defined as Developed Oldowan B and Early Acheulian. There are no regular patterns of difference in percent frequency of artifact-types between assemblages assigned to the two industries by Leakey (in press) at Olduvai Gorge. There are significant differences in the bifaces of assemblages assigned to the two industries at Olduvai, but it has been shown that these differences can be explained in large part by the differential use of raw material. Grounds are not sufficient for maintaining the Developed Oldowan B as an industry distinct from the Early Acheulian.

If percent prequency of artifact-types alone are used as defining criteria, it is possible to distinguish facies of the Early Acheulian as suggested by Clark (1976). One facies would be the Early Acheulian proper containing relatively high proportions of bifaces. Another facies would be represented by former Developed Oldowan B assemblages of Leakey's (1971) first classification, characterized by low percentages of bifaces and high frequencies of subspheroids/spheroids and light-duty flake tools. Early Acheulian facies could be reflections of activity differences (Clark, 1976 : 34).

At present it seems best to view the Karari Industry as a late phase of the Oldowan Industrial Complex, as proposed by Harris (1978). If the dating of Karari assemblages can be further resolved, however, and if they are found to be contemporaneous with Early Acheulian assemblages at Olduvai and elsewhere, or if bifaces are found *in situ* in future excavations in Karari assemblages, then it would become another facies of the Early Acheulian.

The Sterkfontein assemblage is an occurrence of the Early Acheulian displaying distinct features of variability, but clearly falling within the range of variability of other African Early Acheulian assemblages.

The above discussion has shown that there is currently some confusion about what constitutes proper criteria for the definition of stone industries, facies, and phases. Should it be relative frequencies of artifact-types, features of size and shape of particular artifact-types, or a combination of the two? There seem to be certain implications of anthropological meaning applied to industrial taxa defined depending on which criteria are used. Many people today view industrial taxa defined by relative frequency of artifact-types as representing 'tool kits', activity variants, and different ecological adaptations (Binford and Binford, 1966; Bin-

TABLE 16.

Attribute values for selected artifact-types from Olduvai, Karari, Gadeb, and Sterkfontein.

	Choppers	Protobifaces	Handaxes	Polyhedrons	Discoids	Heavy-Duty Scrapers	Light-Duty Scrapers
LENGTH							
Olduvai							
EF-HR							
N	14	0	33	5	8	3	3
Mean	91.3		140.3	85.6	73.5	75.0	43.0
TKLF							
N	6	0	9	1	0	6	24
Mean	92.5		150.4	110.0		75.5	40.5
TKUF							
N	31	0	17	3	9	13	78
Mean	80.3		101.3	90.3	61.6	99.8	40.1
FCWF							
N	49	0	3	4	4	11	9
Mean	80.9		56.7	79.3	57.3	69.2	42.7
Karari							
FxJj 16							
N	12	2	0	7	—	8	—
Mean	81.3	80.5		83.0		86.0	
FxJj 18GSLH							
N	32	4	0	32	26	33	29
Mean	68.8	66.3		55.0	47.0	62.0	57.0
FxJj 18NS							
N 18	6	2	0	11	8	8	17
Mean	66.5	89.5		56.0	50.4	63.0	53.0
FxJj 18IH							
N	—	3	0	24	29	24	19
Mean		58.3		46.0	46.0	50.5	56.0
FxJj 20M							
N	—	2	0	—	8	—	13
Mean		51.5			44.0		55.0
Gadeb[1])							
8A							
N	90	0	179	42	—	—	25
Mean	91.5		121.1	81.3			69.2
8D	26	0	26	6	—	—	8
Mean	78.3		152.8	51.2			85.5
2B							
N	16	1	1	16	—	—	20
Mean	64.6	116	114	66.3			52.1
2C							
N	18	0	5	12	—	—	27
Mean	81.2		108.4	70.6			43.2
Sterkfontein							
N	66	8	8	38	12	14	9
Mean	73.6	97.1	119.6	78.2	73.3	76.1	44.9
B/L[2])							
Olduvai							
EF-HR							
Mean	.82	—	.61	.91	.87	.85	.78
TKLF							
Mean	.80	—	.65	.91	—	.74	.94
TKUF							
Mean	.84	—	.67	.90	.92	.80	.84
FCWF							
Mean	.78	—	.86	.86	.95	.75	.97
Karari							
FxJj 16							
Mean	.89	.65	—	.90	—	.75	—
FxJj 18GSLH							
Mean	.85	.70	—	.81	.91	.77	.71
FxJj 18NS							
Mean	.86	.79	—	.74	.89	.71	.77
FxJj 18IH							
Mean	—	.70	—	.85	.87	.76	.78
FxJj 20M							
Mean	—	.80	—	—	.91	—	.87
Gadeb							
8A							
Mean	.81	—	.70	.90	—	—	.81
8D							
Mean	.77	—	.55	.93	—	—	.70
2B							
Mean	.80	.53	.75	.86	—	—	.75
2C							
Mean	.81	—	.64	.87	—	—	.88
Sterkfontein							
Mean	.84	.73	.62	.88	.88	.89	.91

[1]) Discoids were classed as cores and all scrapers were grouped together at Gadeb.

[2]) The Ns are the same as given under Length for the other attributes.

Table 16. (cont'd.

	Choppers	Protobifaces	Handaxes	Polyhedrons	Discoids	Heavy-Duty Scrapers	Light-Duty Scrapers
T/B							
Olduvai							
EF-HR Mean	.74	–	.61	.91	.87	.85	–
TKLF Mean	.80	–	.54	.73	–	.59	–
TKUF Mean	.81	–	.63	.80	.71	.63	–
FCWF Mean	.77	–	.62	.78	.62	.85	–
Karari							
FxJj 16 Mean	.84	.64	–	.89	–	.88	–
FxJj 18GSLH Mean	.82	.66	–	.87	.68	.74	.56
FxJj 18NS Mean	.68	.65	–	.83	.71	.80	.50
FxJj 18IH Mean	–	.90	–	.86	.70	.82	.48
FxJj 20M Mean	–	.60	–	–	.56	–	.54
Gadeb							
8A Mean	.71	–	.38	.87	–	–	.46
8D Mean	.65	–	.50	.80	–	–	.44
2B Mean	.69	.51	.55	.88	–	–	.49
2C Mean	.79	–	.70	.85	–	–	.40
Sterkfontein Mean	.75	.71	.70	.88	.73	.67	.44
NWES							
Olduvai							
EF-HR Mean	7.2	–	14.2	11.0	11.9	4.0	3.3
TKLF Mean	8.1	–	16.7	6.0	–	2.0	2.3
TKUF Mean	6.0	–	14.5	9.3	9.1	4.1	3.5
FCWF Mean	5.7	–	10.7	7.5	7.8	3.3	2.9
Karari							
FxJj 16 Mean	8.1	11.5	–	–	–	13.5	–
FxJj 18GSLH Mean	–	–	–	–	–	10.5	8.3
FxJj 18NS Mean	8.5	13	–	–	–	10.5	4.9
FxJj 18IH Mean	–	11	–	–	–	12.4	6.1
FxJj 20M Mean	–	13	–	–	–	–	7.5
Sterkfontein Mean	5.3	15.9	20.1	6.2	10.2	4.7	3.6
WE/C							
Olduvai							
EF-HR Mean	.40	–	.70	–	.97	–	.44
TKLF Mean	.48	–	.77	–	–	–	.25
TKUF Mean	.36	–	.75	–	.86	–	.39
FCWF Mean	.35	–	.73	–	.82	–	.28
Karari							
FxJj 16 Mean	.40	–	–	–	–	.87	–
FxJj 18GSLH Mean	–	–	–	–	–	.81	.60
FxJj 18NS Mean	–	–	–	–	.96	.89	.44
FxJj 18IH Mean	–	–	–	–	1.00	.97	.55
FxJj 20M Mean	–	–	–	–	.98	–	.56
Sterkfontein Mean	.33	.79	.78	–	.85	–	.28

ford, 1972; Clark, 1976; Clark and Kurashina in press). Industrial taxa defined on the basis of artifact form ('style') mean for others cultural or ethnic differences (Collins, 1969; Krieger, 1944; Leakey, 1971). If the criteria used are mixed we get a situation represented by the Developed Oldowan B at present, in which one can stress relative artifact-type frequency and derive activity facies (Clark, 1976) or one can stress artifact form and define cultural phyla (Leakey, in press). When an industry is defined great care should be taken to present explicitly the rationale and criteria for the definition and explain what meaning is implied by the industrial taxon.

ACKNOWLEDGEMENTS

I would like to thank Prof. Glynn Isaac for useful comments and discussion on the ideas expressed in this paper and for support given during the research phase when the data was gathered. I would also like to thank Prof. P. V. Tobias and Mr. A. R. Hughes for their assistance and Dr. R. J. Mason for his cooperation in the study of the Sterkfontein artifacts. I am grateful to M. D. Leakey for her permission to allow me to study the Olduvai collections and to Prof. J. Desmond Clark and Dr. H. Kurashina for providing me with comparative data from Gadeb. Ruth Deuel and H. Kurashina furnished needed and useful advice concerning computer operations.

APPENDIX

Attributes used in univariate and multivariate analysis.
Raw Material- eg. quartz, quartzite, lava, etc.
Primary Form-eg. cobble, angular block, flake, etc.
Maximum Length (Max L).
Maximum Thickness (Max T).
Sum of the Length of the Working Edges (SLWE)- A working edge is defined as that portion of a piece which has been modified by retouch.
Number of Retouch Scars (NWES)- choppers: only those flake removals forming the working edge.
bifaces: the total number of recognizable scars used to shape the piece.
scrapers: only retouch scars along the working edge.
WE/C — the ratio of the sum of the length of the working edges divided by the circumference.
B/L — the maximum breadth divided by the maximum length of a piece.
T/B — the maximum thickness divided by the maximum breadth of a piece.
ICSB — the index of cross-section biconvexity, applied only to bifaces; a ratio of the differences in the distances between the apex of each face of a biface above or below the plane containing both cutting edges. (see Isaac, 1977).
BA/BB — the ratio of the breadth of bifaces at $^4/_5$ length divided by the breadth at $^1/_5$ length.
Platform Angle — the angle formed between the flake striking platform and the flake release surface.
Number of Platform Facets — the number of preparation scars of the striking platform of a flake.
Number or Dorsal Scars — the number of flake scars on the dorsal face of a flake.

REFERENCES

BINFORD, L. R. (1972): Contemporary model building: paradigms and the current state of Palaeolithic research. *In Models in Archaeology (ed.) D. L. Clarke, pp. 109 to 166. London: Methuen.*

BINFORD, L. R. and BINFORD, S. R. (1966): A preliminary analysis of functional variability in the Mousterian of Levallois facies. *American Anthropologist 68: 238—295.*

BORDES, F. (1961): Typologie du Paléolithique Ancien et Moyen. *Bordeaux: Delmas.*

BOWER, J. R. F. (1977): Attributes of Oldowan and Lower Acheulian tools: 'tradition' and design in the early Lower Palaeolithic. *South African Archaeological Bulletin 32: 113—126.*

CLARK, J. D. (1959): The Prehistory of Southern Africa. *Hammondsworth: Penguin.*

CLARK, J. D. (1970): The Prehistory of Africa. *New York: Praeger.*

CLARK, J. D. (1975): A comparison of the Late Acheulian industries of Africa and the Middle East. *In After the Australopithecines. (eds.) K. W. Butzer and G. Ll. Isaac, pp. 605—660. The Hague: Mouton.*

CLARK, J. D. (1976): African origins of man the toolmaker. *In Human Origins. (eds.) G. Ll. Isaac and E. R. McCown, pp. 1—53. Menlo Park: W. A. Benjamin.*

CLARK, J. D. and KURASHINA, H. (1979): Hominid occupation of the east-central highlands of Ethiopia in the Plio-Pleistocene. *Nature 282: 33—39.*

CLARK, J. D. and KURASHINA, H. (in press). New Plio-Pleistocene archaeological occurrences from the plain of Gadeb, upper Webi Shebele basin, Ethiopia, and a statistical comparison of the Gadeb sites with other Early Stone Age assemblages. *Proc. IXth U.I.S.S.P., Nice.*

COLLINS, D (1969): Culture traditions and environment of early man. *Current Anthropology 10 (4): 267—316.*

DIXON, W. J. (1974): Biomedical Computer Programs. *Berkeley: University of California Press.*

DIXON, W. J. (1975): Biomedical Computer Programs. *Berkeley: University of California Press.*

DORAN, J. E. and HODSON, F. R. (1975): Mathematics and Computers in Archaeology. *Edinburgh: Edinburgh University Press.*

HARRIS, J. W. K. (1978): The Karari Industry. Its Place in East African Prehistory. *Unpublished Ph. D. thesis, Univ. of California, Berkeley.*

HARRIS, J. W. K. and Isaac, G. (1976): The Karari Industry: Early Pleistocene archaeological evidence from the terrain east of Lake Turkana, Kenya. *Nature 262: 102—107.*

HAY R. L. (1976): Olduvai Gorge, Vol. 4. *Berkeley: University of California Press.*

HUGOT, H. J. (Ed.) (1972): 6e Congrès Panafricain de Préhistoire, Dakar, 1967. *Paris: Chambéry.*

ISAAC, G. Ll. (1969): Studies of early culture in Africa. *World Archaeology 1 (1): 1—28.*

ISAAC, G. Ll. (1972): Chronology and tempo of cultural change during the Pleistocene. In Calibration of Hominoid Evolution. (eds.) W. W. Bishop and J. A. Miller, pp. 381—430. *Edinburgh: Scottish Academic Press.*

ISAAC, G. Ll. (1977): Olorgesailie. *Chicago: Chicago University Press.*

ISAAC, G. Ll. and CURTIS, G. H. (1974): Age of Early Acheulian industries from the Peninj Group, Tanzania. *Nature 249: 624—627.*

ISAAC, G. Ll. and HARRIS, J. W. W. (1978): Archaeology. In Koobi Fora Research Project. Vol. I. (eds) M. G. and R. E. F. Leakey. *Oxford: Clarendon Press.*

KLEINDIENST, M. (1961): Variability within the Late Acheulian assemblages in eastern Africa. *South African Archaeological Bulletin 16: 35—52.*

KRIEGER, A. D. (1944): The typological concept. *American Antiquity 9: 271—288.*

LEAKEY, M. D. (1967): Preliminary survey of the cultural material from Beds I and II, Olduvai Gorge, Tanzania.

in Background to Evolution in Africa. (eds) W. W. Bishop and J. D. Clark, pp. 417—446. *Chicago: University of Chicago Press.*

LEAKEY, M. D. (1970): Stone artifacts from Swartkrans. *Nature 225: 1222—1225.*

LEAKEY, M. D. (1971): Olduvai Gorge, Vol. 3. *Cambridge: The University Press.*

LEAKEY, M. D. (in press): The early stone industries of Olduvai Gorge. *IXth U.I.S.S.P., Nice.*

LUMLEY, H. DE (1969a): Les civilisations préhistoriques en France. In Etudes Françaises sur le Quaternaire, VIIIth INQUA Congress, *Paris.*

LUMLEY, H. DE (1969b): Une cabane acheuléene dans la Grotte du Lazaret (Nice). *Mémoire de la Soc. préhist. française 7: 1—235.*

MASON, R. J. (1962): The Prehistory of the Transvaal. *Johannesburg: University of the Witwatersrand Press.*

MASON, R. J. (in press): The earliest artifact assemblages in South Africa. *IXth U.I.S.S.P., Nice.*

MOVIUS, H. L. (1948): The Lower Palaeolithic cultures of Southern and Eastern Asia. *Trans. of the American Philosophical Society 38: 324—420.*

NIE, N. H., BENT, D. H. and HULL, C. H. (1970): SPSS: Statistical Package for Social Sciences. *New York: McGraw-Hill.*

PRESS, S. (1972): Applied Multivariate Statistics. *New York: Holt, Rinehart and Winston.*

STILES, D. N. (1977): Acheulian and Developed Oldowan: the meaning of variability in the Early Stone Age. *Mila 6 (1): 1—48.*

STILES, D. N. (1979): Palaeolithic culture and culture change: experiment in theory and method. *Current Anthropology 20 (1): 1—22.*

STILES, D. N. and PARTRIDGE, T. C. (1979): Results of recent archaeological and palaeoenvironmental studies at the Sterkfontein Extension Site. *South African Journal of Science 75: 346—352.*

WILLIAMS, M. A. J., WILLIAMS, F. M., GASSE, F., CURTIS, G. H. and ADAMSON, D. A. (1979): Plio-Pleistocene environments at Gadeb prehistoric site, Ethiopia. *Nature 282: 29—33.*

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