Anthropologie et Préhistoire, 100, 1989 : 43-56

A further study of the morphological affinities of the Border Cave 1 cranium, with special reference to the origin of modern man

Gerrit-N. VAN VARK, Alan BILSBOROUGH and Jacob DIJKEMA

Abstract

The morphological status of the Early Upper Pleistocene cranium found in the Border Cave in South Africa has recently become the subject of study by several authors. This had led to a controversy, the main question being whether this skull displays morphological affinities to recent Khoisan, to recent Negro, or to none of these populations.

In an extensive study where the skull was compared with recent and non-recent, African as well as non-African skull series, and where (in part new) multivariate statistical methodology was used, we arrived at the following conclusions :

a. the Border Cave 1 cranium does not fit in with any of the populations with which it was compared,
b. it is not definitely more like a recent African population than it is like other recent populations,
c. the evidence obtained suggests that it is less obvious to call it "anatomically modern" as is usually done.

Key words : Multivariate analysis, Hominid evolution.

Résumé

La position morphologique du crâne du Pleistocène supérieur récent trouvé à Border Cave en Afrique du Sud a été étudiée récemment par plusieurs auteurs. Ceci a provoqué une controverse, la question principale étant de savoir si ce crâne présente des affinités morphologiques avec les Khoisans actuels, les Noirs actuels ou s'il ne se rapproche d'aucune de ces populations. Dans une étude approfondie où le crâne est comparé à des séries de crânes récents et anciens, africains et non-africains, et où nous avons appliqué une méthodologie statistique multivariée en partie nouvelle, nous sommes arrivés aux conclusions suivantes :

a. le crâne de Border Cave 1 ne s'intègre dans aucune des populations auxquelles il a été comparé;
b. il n'est pas plus semblable à la population africaine récente qu'aux autres populations récentes;
c. d'après les résultats obtenus, il est moins évident de l'appeler "anatomiquement moderne" comme on le fait habituellement.

Mots clé : Analyse multivariée, évolution des Hominidés.

INTRODUCTION

The morphological affinities of the fragmentary cranium that was excavated at Border Cave, South Africa, almost forty years ago (Border Cave 1) has recently become the subject of a new series of investigations (Ambergen & Schaafsma, 1984, Campbell, 1980, Fatti, 1985, Rightmire, 1979, 1981).

These studies all utilized multivariate statistical methods to compare the Border Cave cranium with various of recent African skulls, but have resulted in controversial conclusions as regards the morphological and phylogenetic status of the population from which the skull originates. Rightmire (1981), reacting to a criticism made by Campbell, *op. cit.*, on his 1979 paper, is of the opinion that "there remains a substantial body of metric evidence to support allocation of the Border Cave 1 cranium to a large Bushman-like population apparently present in South Africa, early in the Upper Pleistocene". However, Fatti, *op. cit.*, concluded that the skull is "fairly typical of most of the Negro populations", whereas he found "the chance of deriving it from either the Bush male or female population to be relatively slim". Ambergen & Schaafsma, *op. cit.*, on the other hand, using interesting new statistical methodology, concluded that the skull "cannot be regarded as a random drawing from any of the (recent African) populations involved".

The importance of these investigations does, however, not primarily lie in the specific affinities of the skull with recent, be it African or non-African, populations but rather in the question whether it can be seen as an "anatomically modern", that is fully *sapiens* specimen. A status which, according to general opinion, has *e.g.* also be attained by all Upper Palaeolithic specimens, as contrasted to specimens assigned to more archaic groups such as Neanderthals. If this were the case then the skull would be, given its claimed antiquity, one of the first, if not the first anatomically modern specimen found so far. There is fair agreement that it may be as old as 100,000 years or even older (see *e.g.* Beaumont *et al.*, 1978 ; Beaumont, 1980 ; Bräuer, 1981, 1984a, 1984b ; Howells, 1986, 1988 and Protsch, 1975) although an age of just over 50,000 years cannot be excluded (Smith, 1985). A screening of the recent literature shows that there is hardly any doubt as to the anatomically modern status of the skull (see e.g. Bräuer, 1984b, Clarke, 1985; Howells, 1986, 1988, Rightmire, 1981 and Stringer, 1985).

In the present study, we first investigate the morphological affinities of the Border Cave 1 skull with recent African as well as non-African skull series so as to clarify its position relative to modern populations. In a second part of this study we more directly deal with the main issue : can the Border Cave 1 specimen be seen as anatomically modern ? To that end, its relative morphological position within a framework of recent and non-recent hominid groups is investigated. In all instances, various multivariate statistical methods are applied, that is more traditional ones as well as recently developed ones such as methods suggested by Ambergen & Schaafsma, *op. cit.*. Two series of sets of measurements of the Border Cave 1 cranium are used : the first series consists of selections of measurements collected by W.W. Howells (1973), the second one of selections of measurements taken by Rightmire (Rightmire, 1979).

MATERIAL

The material we use consists of new measurements of the Border Cave cranium taken by Professor Howells during his visit to South Africa early in 1985, and which were kindly put at our disposal. We concentrate on a selection of eight measurements which could accurately be scored from the cranium. Six other measurements which were scored with one point of the calipers on plaster are also used. For a comparison with Rightmire's results eight of his list of eleven measurements published in his 1979 paper are employed. The set of Howells' and Rigthmire's measurements which are used in the present study are listed in table 1.

In the first part of this study where the Border Cave specimen is compared with skull series of recent *Homo sapiens*, we use as reference material scores on the above sets of variables of 26 male and 26 female samples from recent populations which may reasonably be considered to cover the variation of present-day *Homo sapiens*. These samples, totalling 2 216 specimens, were also measured by Howells, and in part described in his well-known 1973 monograph (Howells, 1973).

In the second part of this study the Border Cave skull is compared with recent and non-recent hominid groups. Due to missing scores in the non-recent groups, selections from the above set of variables are used. The non-recent series consist of skulls from Late Upper Palaeolithic *Homo sapiens* (±16,000-±10,000 B.C., n=14), Early Upper Palaeolithic *Homo sapiens* (±34,000- ±19,000 B.C., n=11), Neanderthal and Neanderthaloid (n=13), Solo, Indonesian *Homo erectus* (n=1), Beijing, Chinese *Homo erectus* (n=3). The greater part of these measurements were taken by Ch. Stringer (British Museum); a smaller part was taken by Howells. Hominid groups and specimens are listed in table 2.

Measures no. according to Howells (1973)	Code and short name of measures according to Howells(1973)	Measurements of Border Cave 1 taken by Howells	Measurements of Border Cave 1 taken by Rightmire
1	GOL Glabello-occipital length	194	–
2	NOL Nasio-occipital length	189	–
3	BNL Basion-nasion length	106	–
4	BBH Basion-bregma height	141	–
16	OBB Orbit breadth, right	–	45
20	MDH Mastoid height	–	26
21	MDB Mastoid width	15	–
24	FMB Bifrontal breadth	111	–
25	NAS Nasio-frontal subtense	16	15
26	EKB Biorbital breadth	–	112
35	WMH Cheek height	–	21
36	SOS Supraorbital projection	–	10
37	GLS Glabella projection	5	–
39	FRC Nasion-bregma chord	116	116
40	FRS Nasion-bregma subtense	33	32
41	FRF Nasion-subtense fraction	51	–
50	SSR Subspinal radius	109	–
51	PRR Prosthion radius	114	–
56	ZMR Zygomaxillare radius	88	–

Table 1 : Measurements of the Border Cave 1 cranium which are used in the present study. The 14 measurements taken by Howells are unpublished so far, and were kindly put at the disposal of the authors. The 8 measurements taken by Rightmire form a selection of the 11 measurements published in Rightmire (1979). The other 3 measurements of that publication were not scored according to Howells' measuring system (Rightmire, personal communication).

Group 1 : "Recent" *Homo sapiens sapiens* n=2216

1.	Northern Europe : Medieval Norse, Oslo	n♂ =55	n♀ =55
2.	Central Europe : Zalavar, Hungary	n♂ =45	n♀ =45
3.	Central Europe : Berg, Carinthia, Austria	n♂ =53	n♀ =53
4.	Egypt : 26th-30th Dynasties	n♂ =53	n♀ =53
5.	East Africa : Teita, Kenya	n♂ =34	n♀ =34
6.	West Africa : Dogon, Mali	n♂ =48	n♀ =48
7.	South Africa : Zulu	n♂ =46	n♀ =46
8.	South Africa : Bushman	n♂ =41	n♀ =41
9.	Australia : Lake Alexandrina Tribes	n♂ =49	n♀ =49
10.	Tasmania : general	n♂ =42	n♀ =42
11.	Melanesia : Tolai, New Britain	n♂ =55	n♀ =55
12.	Polynesia : Mokapu, Oahu, Hawaii	n♂ =49	n♀ =49
13.	Siberia : Buriats	n♂ =54	n♀ =54
14.	Greenland : Inugsuk Eskimo	n♂ =54	n♀ =54
15.	South America : Yauyos, Peru	n♂ =55	n♀ =55
16.	Andaman Islands : general	n♂ =26	n♀ =26
17.	North America : Early Arikara	n♂ =27	n♀ =27
18.	Eastern Asia : Ainu, Hokkaido, Japan	n♂ =38	n♀ =38
19.	Eastern Asia : Hokkaido, N. Japan	n♂ =32	n♀ =32
20.	Eastern Asia : Kyushu, S. Japan	n♂ =41	n♀ =41
21.	Eastern Asia : Han Chinese, Hainan	n♂ =38	n♀ =38
22.	Eastern Asia : Atnyal, Taiwan	n♂ =18	n♀ =18
23.	Marianes : Guam	n♂ =27	n♀ =27
24.	North America : Santa Cruz, Island California	n♂ =38	n♀ =38
25.	Easter Island	n♂ =37	n♀ =37
26.	Chatham Islands : Moriori	n♂ =53	n♀ =53

Group 2 : Late Upper Palaeolithic and Epipalaeolithic *Homo sapiens* n=14

1. Abri Pataud
2. Arene Candide 1
3. Arene Candide 4
4. Arene Candide 6
5. Maritza
6. Ortucchio
7. San Teodoro 2
8. San Teodoro 4
9. Oberkassel♂
10. Oberkassel♀
11. Chancelade
12. Laugerie Basse 2
13. Kostenki 1
14. Markina Gora

Group 3 : Early Upper Palaeolithic *Homo sapiens* n=11

1. Predmost 3
2. Predmost 4
3. Brno 2
4. Mladec 1
5. Mladec 5
6. Dolni Vestonice 3
7. Cro Magnon 1
8. Cro Magnon 2
9. Cro Magnon 3
10. Grimaldi 6
11. Combe Capelle

Group 4 : *Homo sapiens neanderthalensis* and "related" specimens n=13

1. Djebel Irhoud
2. Amud 1
3. Tabun 1
4. Shanidar 1
5. Neanderthal
6. Monte Circeo
7. La Chapelle
8. La Quina
9. Gibraltar
10. Le Moustier
11. La Ferrassie 1
12. Spy 1
13. Krapina E

Group 5 : *Homo erectus* n=4

1. Solo 11
2. Sinanthropus E
3. Sinanthropus 1
4. Sinanthropus 3

Group 6 : *Homo sapiens sapiens* ?

Border Cave 1

Table 2 : Series used in this study. The first 17 "recent" *Homo sapiens* series are described in Howells, 1973. The other 9 series were measured later.

METHODS

The morphological affinities of the Border Cave cranium with recent populations are investigated by various multivariate methods. In order to test the effect of using different estimates for the underlying covariance matrices, all calculations are made on the basis of two different models. The first is based on the assumption that the covariance matrices of the 26 male and 26 female subpopulations as well as that of the subpopulation to which the Border Cave specimen belongs are all equal (model A). In this approach all available sample covariance matrices are pooled. The second model is such that no assumptions whatsoever are made with respect to the respective covariance matrices (model B). Following this second approach, Border Cave is compared with population g on the basis of the corresponding covariance matrix only (g=1,...,52). The reason for using these two different models is that it is difficult to decide which model corresponds best with the actual situation. A difficulty of the latter model is that results are directly influenced by the different sizes of the samples from the recent populations. However, an advantage of this model is that possible differences in population covariance matrices should be approximated by differences in the corresponding sample covariance matrices.

Obviously, the results obtained are also dependent on the choice of the set of variables. Therefore, in all multivariate functions used variables are added in a stepwise fashion, the first function using two variables, the last one p variables, p being the total number of variables employed. Thus, calculation results of series of *p-1* calculations are compared. Also the order of the variables entering the multivariate functions may be important. Therefore, Howells' variables are entered in the corresponding functions in two different orders. In the first series of calculations no mathematical ordering criteria are used, and variables are entered just according to the sequence on Howells' list (Howells, 1973, p. 35). In a second series of calculations ordering criteria from stepwise discriminant analysis (Dixon, 1975) are used. Finally, in order to compare our results with those of Rightmire and Ambergen & Schaafsma, a third series of calculations is carried out, using measurements taken by Rightmire according to Howells' technique (Howells, 1973; for Rightmire's scores see table 1). The procedure is checked by repeating the whole analysis with a male Australian specimen as subject of study.

In the comparison of the Border Cave cranium with the non-recent groups, subsets of the variables also available for the non-recent hominid specimens are used. These variables are also added in a stepwise fashion, leading to further series of calculations. In this part of the investigation only model A is used because most of the sizes of the non-recent samples are too small for obtaining useful results if one were to use model B.

In both parts of this study, four different methods for discussing group membership of single specimens are employed, all of which are implemented in the recently developed computer program POSCON (Van der Sluis *et al.*, 1985), viz. :

a. Estimates are made of posterior probabilities of group membership for Border Cave, using equal prior probabilities. It is a special feature of the POSCON program that standard deviations of these estimates are presented.

b. Since there are no valid reasons for assuming that all prior probabilities are equal and, more importantly, since there is no good reason why Border Cave would stem from one of the populations with which it is compared, we prefer using an approach based on typicality probabilities (see Aitchison & Dunsmore, 1975, Campbell, *op. cit.*, Ambergen & Schaafsma, *op. cit.*).
The typicality probability of a specimen for a certain population becomes smaller the less typical this specimen is for that population. The definition chosen by Ambergen & Schaafsma is as follows : let

$$\Delta^2 = (x-\mu)^T\Sigma^{-1}(x-\mu)$$

be the squared population Mahalanobis distance between the vector of scores x of a specimen and the centroid μ of the population considered. The typicality probability of the specimen with respect to this population is the probability that a randomly chosen individual shows a larger squared Mahalanobis distance. As the squared Mahalanobis distance Y of a randomly chosen individual follows the χ^2 distribution with p degrees of freedom, the typicality probability is equal to

$$P(Y \geq \Delta^2) = P\{\chi^2_p \geq (x-\mu)^T\Sigma^{-1}(x-\mu)\},$$

where x denotes the column vector of scores of the individual, μ is the vector of population means, and Σ denotes the covariance matrix. The elaboration of Ambergen and Schaafsma, implemented in the POSCON program, allows the construction of (rather crude) approximate 95 % confidence intervals for such typicality probabilities. The upper and lower bounds of these intervals are calculated in order to locate the approximate position of Border Cave relative to the populations with which it is compared.

c. The typicality probability of a specimen with respect to a certain population can also be evaluated by applying a modification of Hotelling's two sample test, one sample consisting of the Border Cave specimen, the other sample consisting of individuals from the population with which it is compared. This statistic, following an F distribution with p and another, larger number of degrees of freedom, is in particular useful in those cases where the confidence interval for the typicality probability discussed under (b) contains the point 0.05 with as a consequence that it is not clear from this point of view whether the specimen under consideration is from another population. Probabilities of exceedance for this statistic are calculated so as to obtain more clarity in those instances.

d. Unbiased estimates of squared Mahalanobis distances of Border Cave to all reference populations are calculated. In the comparison of Border Cave with the non-recent groups it is tested whether the Mahalanobis distance of Border Cave to a population g is larger than that to a population h. The present test was developed by A.G.M. Steerneman. A full description is given in van Vark (1984), and van Vark *et al.* (1990). Finally, in order to obtain more clarity as regards the morphological status of Border Cave, unbiased estimates of squared Mahalanobis distances between all groups used in this part of this study are also calculated.

RESULTS

In tables 3, 4, 5, and 6 results are given of unbiased estimates of squared Mahalanobis distances, posterior probabilities with corresponding standard deviations, upper and lower bounds of typicality probabilities, and probabilities of exceedance of Hotelling's F test, all figures which relate to the position of Border Cave with respect to a selection of recent subpopulations.

Outcomes of the present statistics were calculated for all 52 recent subpopulations. For reasons of space we list here only results referring to those subpopulations for which the upper bound of at least one of the typicality probabilities of Border Cave is larger than 0.01. All thus selected subpopulations turned out to be male. An exception is made for Atayal males and females. In model B, the upper bounds of the typicality probabilities referring to these subpopulations were found to be as large as 1.0 in the functions with the maximum number of variables both on using Howells' scores as on using the scores registered by Rightmire. On the other hand, the results of the corresponding F-tests showed that also in these instances Border Cave falls outside the 95 % limits of these sub-populations. Besides, the Mahalanobis distance scores concerned were substantially larger than the corresponding scores referring to the other selected sub-populations. Obviously, the aberrant figures of the typicality probability bounds are mainly due to the relatively small sizes of the Atayal samples (see table 2). Consequently, scores referring to these series were not mentioned in the tables.

The variables used in these calculations are selections of the ones listed in table 1. Tables 3 and 4 refer to calculations made with Howells' scores of the Border Cave cranium, tables 5 and 6 to corresponding calculations made with Rightmire's scores.

In the first series of calculations with Howells' scores, illustrated in tables 3a and 4a, the order of entering the variables in the respective functions corresponds with the one followed in Howells' original list (Howells, 1973), that is MDB, FMB, NAS, GLS, FRC, FRS, FRF, and ZMR, respectively. Thus seven sets of functions were computed, the first set using variables MDB and FMB only, the last set using all these eight variables. In a next series of calculations six other variables were added, viz. GOL, NOL, BNL, BBH, SSR, and PRR, successively. These are variables which could not be scored from the cranium alone : scores were obtained by putting one point of the calipers on plaster. This addition was made because the number of "accurate" measurements was rather small, and we wanted to know whether the addition of still other measurements might affect the general conclusions. The results of the latter series of calculations are illustrated in tables 3b and 4b, respectively. The difference between tables 3 and 4 is that in table 3 model A is used, and in table 4 model B.

With respect to the results of the posterior probabilities and accessory standard deviations we observe that the resulting assignment of Border Cave (if this should be made) is very much dependent on the set of variables employed, as well as on the model assumptions. On using model A, we see that in functions with five to ten variables Border Cave is assigned to Ainu, with eleven variables to Australians, with twelve and thirteen to Tolai and with fourteen variables to Guam. On using model B, there is in the functions with a lesser number of variables a preference for Tasmanians, whereas from the six variable function onward Border Cave is assigned to either Australians or Northern Japanese.

N° and code name of variables added		Zulu♂ n=55	Bushman♂ n=41	Teita♂ n=34	S.Austr.♂ n=52	Tasman♂ n=42	Tolai♂ n=48	Eskimo♂ n=55	Buriat♂ n=54	Ainu♂ n=48	N.Japan♂ n=55	Guam♂ n=30
21-MDB 24-FMB	$\hat{\Delta}^2$	9.395	18.494	10.834	7.391	8.094	7.806	13.145	8.198	9.295	15.902	8.641
	F-prob.	.009	-	.005	.026	.018	.021	.001	.017	.010	-	.014
	P.prob.	.066	-	.032	.180	.127	.146	.010	.120	.069	.002	.096
	St. dev.	.071	-	.038	.168	.128	.142	.011	.121	.075	.003	.105
	up.bound	.021	-	.014	.053	.041	.043	.003	.036	.023	.001	.039
	typ.prob. < low.bound	.003	-	.001	.011	.007	.009	-	.007	.003	-	.004
25-NAS	$\hat{\Delta}^2$	13.372	21.665	18.355	10.719	11.200	10.336	14.065	8.723	11.578	16.519	12.030
	F-prob.	.004	-	-	.014	.011	.017	.003	.034	.009	.001	.008
	P.prob.	.032	-	.002	.124	.097	.150	.023	.336	.080	.006	.064
	St. dev.	.038	-	.003	.132	.108	.154	.027	.260	.090	.008 .077	
	up.bound	.010	-	.001	.031	.027	.036	.007	.069	.022	.002	.023
	typ.prob. < low.bound	.001	-	-	.005	.004	.006	.001	.015	.003	-	.002
37-GLS	$\hat{\Delta}^2$	18.540	25.381	26.259	11.834	12.905	10.385	15.644	11.915	11.621	16.508	12.471
	F-prob.	.002	-	-	.035	.019	.038	.008	.038	.041	.006	.027
	P.prob.	.005	-	-	.150	.067	.170	.025	.166	.186	.016	.103
	St. dev.	.007	-	-	.139	.088	.233	.023	.134	.152	.015	.111
	up.bound	.003	-	-	.043	.030	.072	.009	.041	.048	.006	.043
	typ.prob. < low.bound	-	-	-	.007	.004	.016	.001	.007	.008	-	.004
39-FRC	$\hat{\Delta}^2$	18.632	25.795	27.126	12.092	13.705	11.847	15.620	11.897	11.671	16.558	12.855
	F-prob.	.002	-	-	.035	.019	.038	.008	.038	.041	.006	.027
	P.prob.	.005	-	-	.150	.067	.170	.025	.166	.186	.016	.103
	St. dev.	.007	-	-	.154	.077	.169	.030	.167	.182	.019	.118
	up.bound	.006	-	-	.073	.044	.078	.020	.077	.086	.014	.070
	typ.prob. < low.bound	-	-	-	.014	.006	.017	.003	.016	.017	.002	.008
40-FRS	$\hat{\Delta}^2$	26.386	30.128	34.499	22.926	23.113	24.146	28.617	30.073	19.422	29.757	24.832
	F-prob.	-	-	-	.001	-	-	-	-	.004	-	-
	P.prob.	.019	.002	-	.107	.098	.058	.006	.003	.620	.003	.041
	St. dev.	.027	.004	-	.142	.133	.080	.009	.004	.309	.005	.631
	up.bound	-	-	-	.002	.002	.001	-	-	.010	-	.001
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	.001	-	-
41-FRF	$\hat{\Delta}^2$	26.384	30.202	35.223	22.917	23.172	24.123	29.891	31.317	19.484	29.809	24.817
	F-prob.	-	-	-	.001	.001	.001	-	-	.007	-	.001
	P.prob.	.019	.002	-	.111	.098	.060	.003	.001	.619	.003	.043
	St. dev.	.028	.004	-	.147	.133	.084	.005	.002	.310	.005	.654
	up.bound	.001	-	-	.005	.005	.003	-	-	.019	-	.003
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	.002	-	-
56-ZMR	$\hat{\Delta}^2$	38.801	42.914	39.964	28.602	35.436	30.435	30.046	35.564	26.968	41.156	30.970
	F-prob.	-	-	-	-	-	-	-	-	-	-	-
	P.prob.	.001	-	-	.217	.007	.087	.1051	.006	.493	-	.006
	St. dev.	.002	-	.001	.258	.010	.117	.143	.010	.357	-	.101
	up.bound	-	-	-	.001	-	-	-	-	.002	-	-
	typ.prob. < lw.bound	-	-	-	-	-	-	-	-	-	-	-
1-GOL	$\hat{\Delta}^2$	39.657	42.924	40.724	29.849	35.697	30.451	30.620	35.751	29.131	41.515	30.970
	F-prob.	-	-	-	-	-	-	-	-	-	-	-
	P.prob.	.001	-	-	.216	.011	.160	.147	.011	.309	-	.123
	St. dev.	.002	-	.001	.243	.017	.191	.182	.016	.305	-	.171
	up.bound	-	-	-	.001	-	.001	.001	-	.002	-	.001
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-
2-NOL	$\hat{\Delta}^2$	39.634	42.943	40.898	30.823	37.424	32.375	33.222	37.066	29.448	41.504	31.172
	F-prob.	-	-	-	-	-	-	-	-	.001	-	-
	P.prob.	.002	-	.001	.209	.007	.096	.063	.009	.415	.001	.175
	St. dev.	.003	-	.002	.248	.011	.128	.088	.013	.356	.001	.236
	up.bound	-	-	-	.002	-	.001	.001	-	.003	-	.002
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-
3-BNL	$\hat{\Delta}^2$	40.976	42.994	41.088	30.793	37.435	32.559	35.186	37.593	34.555	44.403	33.830
	F-prob.	-	-	-	.001	-	-	-	-	-	-	-
	P.prob.	.003	.001	.002	.499	.018	.206	.055	.016	.080	-	.109
	St. dev.	.004	.001	.005	.364	.027	.251	.081	.025	.115	-	.164
	up.bound	-	-	-	.004	-	.002	-	-	.001	-	.001
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-
4-BBH	$\hat{\Delta}^2$	40.492	54.147	46.075	35.751	40.276	33.387	36.357	44.380	35.132	45.110	33.795
	F-prob.	-	-	-	-	-	.001	-	-	-	-	.001
	P.prob.	.002	-	-	.042	.012	.380	.086	.001	.158	.001	.309
	St. dev.	.003	-	.001	.063	.019	.365	.122	.002	.211	.001	.361
	up.bound	-	-	-	-	-	.003	.001	-	.001	-	.003
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-
50-SSR	$\hat{\Delta}^2$	44.041	58.189	47.872	37.998	40.791	34.123	39.347	48.361	37.591	46.336	35.144
	F-prob.	-	-	-	-	-	.001	-	-	-	-	.001
	P.prob.	.003	-	-	.070	.017	.448	.035	-	.086	.001	.292
	St. dev.	.005	-	-	.104	.027	.401	.055	-	.128	.001	.368
	up.bound	-	-	-	.001	-	.004	-	-	.001	-	.004
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-
51-PRR	$\hat{\Delta}^2$	50.339	60.114	51.148	41.889	41.804	38.735	39.553	49.346	40.036	49.255	38.140
	F-prob.	-	-	-	-	-	-	-	-	-	-	-
	P.prob.	-	-	-	.053	.055	.256	.139	.001	.133	.001	.345
	St. dev.	.001	-	-	.079	.084	.301	.191	.002	.185	.002	.382
	up.bound	-	-	-	-	-	.001	.001	-	.001	-	.002
	typ.prob. < low.bound	-	-	-	-	-	-	-	-	-	-	-

Table 3 : Comparison of Border Cave with recent *Homo sapiens* skull series. Unbiased estimates of Mahalanobis squared distances, *F*-probabilities, posterior probabilities and standard deviations, and upper and lower bounds of typicality probabilities. Model A. Howells' measurements. Values smaller than 0.000 are denoted by a - sign. For further explanation see text.

N^{O}and code name of variables added		Zulu ♂ n=55	Bushman ♂ n=41	Teita ♂ n=34	S.Austr. ♂ n=52	Tasman ♂ n=42	Tolai ♂ n=48	Eskimo ♂ n=55	Buriat ♂ n=54	Ainu ♂ n=48	N.Japan ♂ n=55	Guam ♂ n=30
21-MDB 24-FMB	$\hat{\Delta}^2$	8.570	8.554	8.314	5.785	5.544	8.485	13.625	6.406	5.953	13.291	7.497
	F-prob.	.017	.018	.021	.060	.067	.017	.002	.045	.056	.002	.031
	P.prob.	.049	.026	.034	.196	.198	.050	.003	.136	.162	.004	.847
	St. dev.	.065	.037	.050	.198	.201	.065	.005	.151	.174	.007	.115
	typ.prob. up.bound	.090	.127	.191	.217	.260	.092	.020	.175	.220	.021	.252
	typ.prob. low.bound	.002	.001	.001	.014	.015	.002	–	.009	.011	–	.002
25-NAS	$\hat{\Delta}^2$	11.204	13.859	14.204	7.821	6.208	12.075	14.488	6.498	10.765	10.240	10.768
	F-prob.	.014	.006	.006	.056	.108	.010	.004	.095	.018	.004	.021
	P.prob.	.032	.003	.002	.154	.346	.021	.005	.308	.036	.006	.039
	St. dev.	.050	.007	.005	.189	.313	.035	.009	.295	.056	.011	.070
	typ.prob. up.bound	.095	.077	.120	.239	.389	.076	.041	.320	.126	.042	.258
	typ.prob. low.bound	.001	–	–	.009	.024	–	–	.023	.001	–	–
37-GLS	$\hat{\Delta}^2$	15.778	16.919	28.675	7.904	6.350	11.923	15.417	9.450	11.061	14.174	13.199
	F-prob.	.006	.005	–	.103	.178	.024	.007	.059	.034	.011	.020
	P.prob.	.005	.001	–	.252	.490	.027	.005	.107	.051	.010	.133
	St. dev.	.010	.002	–	.290	.357	.046	.010	.151	.083	.019	.279
	typ.prob. up.bound	.060	.080	.017	.177	.550	.151	.068	.266	.213	.089	.301
	typ.prob. low.bound	–	–	–	.020	.046	.001	–	.008	.002	–	–
39-FRC	$\hat{\Delta}^2$	15.636	16.677	29.745	7.761	8.114	12.546	15.663	10.117	12.321	13.869	12.623
	F-prob.	.013	.011	–	.175	.158	.037	.013	.082	.041	.024	.044
	P.prob.	.006	.001	–	.498	.244	.027	.005	.101	.032	.014	.024
	St. dev.	.013	.002	–	.370	.296	.046	.010	.148	.056	.026	.049
	typ.prob. up.bound	.114	.153	.034	.535	.557	.217	.117	.352	.265	.166	.488
	typ.prob. low.bound	–	–	–	.043	.031	.002	–	.011	.002	.001	–
40-FRS	$\hat{\Delta}^2$	24.426	18.770	37.973	15.228	20.708	43.049	31.282	25.899	20.063	20.824	25.541
	F-prob.	.001	.011	–	.028	.006	–	–	.001	.007	.005	.003
	P.prob.	.005	.029	–	.878	.016	–	–	.001	.351	.027	–
	St. dev.	.015	.081	–	.224	.046	–	–	.004	.095	.073	.002
	typ.prob. up.bound	.030	.175	.020	.216	.102	–	.006	.022	.100	.005	.165
	typ.prob. low.bound	–	–	–	.001	–	–	–	–	–	–	–
41-FRF	$\hat{\Delta}^2$	24.330	18.312	36.631	15.068	23.532	42.503	31.884	26.206	19.819	20.904	25.449
	F-prob.	.003	.022	–	.049	.005	–	–	.002	.013	.009	.006
	P.prob.	.003	.028	–	.914	.001	–	–	–	.030	.015	–
	St. dev.	.011	.077	–	.169	.005	–	–	.002	.083	.042	.001
	typ.prob. up.bound	.055	.284	.052	.320	.103	.001	.011	.039	.169	.108	.276
	typ.prob. low.bound	–	–	–	.002	–	–	–	–	–	–	–
56-ZMR	$\hat{\Delta}^2$	33.581	33.685	44.210	22.412	33.977	59.610	32.777	35.721	37.223	26.840	35.825
	F-prob.	–	.001	–	.011	–	–	–	–	–	.003	.001
	P.prob.	–	–	–	.968	–	–	.001	–	–	.028	–
	St. dev.	.003	–	–	.106	–	–	.005	–	–	.101	–
	typ.prob. up.bound	.014	.044	.039	.143	.028	–	.018	.010	.012	.057	.159
	typ.prob. lw.bound	–	–	–	–	–	–	–	–	–	–	–
1-GOL	$\hat{\Delta}^2$	33.958	32.569	44.188	29.786	33.198	59.943	37.400	34.928	39.880	28.108	34.060
	F-prob.	.001	.002	–	.003	.001	–	–	–	–	.004	.003
	P.prob.	.024	.005	–	.442	.009	–	.002	.007	–	.487	–
	St. dev.	.093	.024	–	.986	.037	–	.011	.092	.001	.983	.002
	typ.prob. up.bound	.025	.090	.078	.063	.057	–	.013	.022	.013	.073	.308
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–
2-NOL	$\hat{\Delta}^2$	35.462	31.676	44.214	32.653	38.288	59.096	37.940	34.222	39.141	28.214	32.218
	F-prob.	.001	.004	.001	.002	.001	–	–	.001	–	.006	.008
	P.prob.	.019	.010	–	.136	–	–	.002	.016	–	.755	.001
	St. dev.	.082	.046	–	.497	.001	–	.008	.066	.003	.651	.007
	typ.prob. up.bound	.032	.160	.142	.063	.043	–	.021	.042	.028	.112	.508
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–
3-BNL	$\hat{\Delta}^2$	40.839	30.561	52.586	32.105	40.688	57.939	37.019	35.876	45.598	33.624	37.799
	F-prob.	–	.009	–	.004	.001	–	.001	.002	–	.003	.005
	P.prob.	.001	.053	–	.663	–	–	.009	.014	–	.069	–
	St. dev.	.007	.217	–	.859	–	–	.040	.062	–	.268	–
	typ.prob. up.bound	.020	.265	.120	.106	.050	–	.043	.052	.016	.071	.522
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–
4-BBH	$\hat{\Delta}^2$	42.929	47.667	56.678	34.816	40.377	56.984	36.275	38.100	45.751	32.802	36.184
	F-prob.	–	–	–	.004	.002	–	.003	.002	–	.006	.010
	P.prob.	.001	–	–	.379	–	–	.056	.010	–	.406	–
	St. dev.	.005	–	–	.997	.002	–	.221	.044	–	.984	–
	typ.prob. up.bound	.024	.054	.159	.107	.086	.001	.076	.057	.028	.121	.729
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–
50-SSR	$\hat{\Delta}^2$	43.762	51.201	56.119	34.375	39.906	59.570	39.541	38.163	45.503	32.040	35.303
	F-prob.	.001	–	.001	.007	.003	–	.002	.003	.001	.010	.017
	P.prob.	–	–	–	.422	–	–	.004	.006	–	.498	–
	St. dev.	.002	–	–	1.101	.001	–	.019	.030	–	1.102	–
	typ.prob. up.bound	.034	.060	.289	.164	.139	.002	.071	.087	.049	.190	.877
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–
51-PRR	$\hat{\Delta}^2$	48.479	50.291	55.982	33.446	41.402	60.274	41.733	37.174	48.555	33.318	37.111
	F-prob.	–	.001	.002	.012	.004	–	.002	.006	.001	.012	.019
	P.prob.	–	–	–	.700	–	–	.001	.018	–	.239	–
	St. dev.	–	–	–	.921	–	–	.005	.080	–	.043	–
	typ.prob. up.bound	.026	.089	.463	.251	.172	.003	.078	.144	.075	.220	.946
	typ.prob. low.bound	–	–	–	–	–	–	–	–	–	–	–

Table 4 : Comparison of Border Cave with recent *Homo sapiens* skull series. Unbiased estimates of Mahalanobis squared distances, F-probabilities, posterior probabilities and standard deviations, and upper and lower bounds of typicality probabilities. Model B. Howells' measurements. Values smaller than 0.000 are denoted by a – sign. For further explanation see text.

N°and code name of variables added		Zulu♂ n=55	S.Austr.♂ n=52	Bushman♂ n=41	Tasman♂ n=45	Buriat♂ n=54	N.Japan♂ n=55	Guam♂ n=30
Model A								
36-SOS 26-EKB	$\hat{\Delta}^2$	12.093	10.834	18.849	8.441	8.804	12.641	17.982
	F-prob.	.004	.006	–	.019	.015	.004	–
	P.prob.	.074	.109	.001	.379	.355	.029	.002
	St. dev.	.123	.164	.003	.378	.363	.057	.006
	up.bound	.041	.053	.008	.127	.085	.071	.037
	typ.prob. < low.bound	–	–	–	.001	.001	–	–
25-NAS	$\hat{\Delta}^2$	15.914	14.836	26.469	16.469	11.761	19.892	17.044
	F-prob.	.001	.002	–	.001	.009	–	–
	P.prob.	.066	.113	–	.050	.529	.009	.037
	St. dev.	.083	.135	–	.064	.297	.012	.052
	up.bound	.003	.005	–	.003	.020	–	.003
	typ.prob. < low.bound	–	–	–	–	.003	–	–
35-WMH	$\hat{\Delta}^2$	18.092	22.549	27.159	23.845	21.260	28.076	24.089
	F-prob.	.001	–	–	–	–	–	–
	P.prob.	.503	.054	.005	.028	.103	.003	.025
	St. dev.	.329	.071	.007	.395	.129	.005	.037
	up.bound	.003	–	–	–	.001	–	–
	typ.prob. < low.bound	–	–	–	–	–	–	–
39-FRC	$\hat{\Delta}^2$	28.038	26.031	31.952	26.748	29.600	32.080	28.765
	F-prob.	–	–	–	–	–	–	–
	P.prob.	.124	338	.017	.236	.056	.016	.086
	St. dev.	.156	.309	.025	.259	.075	.025	.124
	typ.prob. < up.bound	–	–	–	–	–	–	–
	low.bound	–	–	–	–	–	–	–
40-FRS	$\hat{\Delta}^2$	28.083	26.137	32.678	26.884	45.280	34.367	34.192
	F-prob.	–	–	–	–	–	–	–
	P.prob.	.164	.436	.016	.300	–	.007	.007
	St. dev.	.209	.363	.025	.323	–	.011	.013
	up.bound	–	–	–	–	–	–	–
	typ.prob. < low.bound	–	–	–	–	–	–	–
16-OBB	$\hat{\Delta}^2$	31.568	26.639	34.541	29.086	45.379	36.275	34.541
	F-prob.	–	–	–	–	–	–	–
	P.prob.	.055	.647	.012	.190	–	.005	.012
	St. dev.	.083	.337	.020	.255	–	.009	.021
	up.bound	–	.001	–	–	–	–	–
	typ.prob. < low.bound	–	–	–	–	–	–	–
20-MDH	$\hat{\Delta}^2$	34.137	30.251	35.097	29.779	47.201	40.850	38.610
	F-prob.	–	–	–	–	–	–	–
	P.prob.	.051	.361	.032	.458	–	.001	.005
	St. dev.	.077	.372	.050	.395	–	.003	.009
	up.bound	–	–	–	.001	–	–	–
	typ.prob. <							
Model B								
36-SOS 26-EKB	$\hat{\Delta}^2$	15.674	14.633	25.809	15.711	11.784	19.870	16.715
	F-prob.	–	–	–	–	.003	–	–
	P.prob.	.065	.110	–	.064	.458	.008	.039
	St. dev.	.080	.127	–	.079	.296	.011	.052
	up.bound	.001	.002	–	.001	.007	–	.001
	typ.prob. < low.bound	–	–	–	–	.001	–	–
25-NAS	$\hat{\Delta}^2$	11.870	10.877	18.362	27.015	8.885	12.632	18.243
	F-prob.	.012	.017	.001	–	.037	.011	.002
	P.prob.	.096	.186	.001	.152	.492	.284	.003
	St. dev.	.158	.264	.004	.230	.387	.056	.008
	up.bound	.102	.120	.026	.003	.177	.162	.094
	typ.prob. < low.bound	–	.001	–	–	.005	–	–
35-WMH	$\hat{\Delta}^2$	11.776	15.108	18.407	18.954	16.418	24.819	20.040
	F-prob.	.027	.008	.003	.002	.005	–	.003
	P.prob.	.725	.153	.010	.010	.065	–	.008
	St. dev.	.391	.299	.027	.027	.138	–	.025
	up.bound	.194	.085	.059	.049	.053	.036	.151
	typ.prob. < low.bound	.001	–	–	–	–	–	–
39-FRC	$\hat{\Delta}^2$	17.908	16.902	18.460	21.923	24.712	24.156	24.772
	F-prob.	.007	.009	.006	.002	–	.002	.002
	P.prob.	.221	.665	.082	.016	.006	.002	.003
	St. dev.	.473	.559	.208	.047	.020	.007	.011
	up.bound	.096	.105	.110	.053	.014	.085	.156
	typ.prob. < low.bound	–	–	–	–	–	–	–
40-FRS	$\hat{\Delta}^2$	19.815	16.490	21.412	24.090	37.464	23.247	38.625
	F-prob.	.008	.020	.005	.002	–	.005	–
	P.prob.	.091	.888	.011	.005	–	.002	–
	St. dev.	.248	.271	.035	.017	–	.007	–
	up.bound	.115	.187	.113	.065	.001	.175	.061
	typ.prob. < low.bound	–	–	–	–	–	–	–
16-OBB	$\hat{\Delta}^2$	19.917	18.459	21.656	26.201	36.764	28.319	36.645
	F-prob.	.013	.019	.009	.003	–	.003	.001
	P.prob.	.165	.806	.023	.002	–	–	–
	St. dev.	.429	.458	.074	.010	–	–	–
	up.bound	.180	.204	.176	.080	.004	.155	.156
	typ.prob. < low.bound	–	–	–	–	–	–	–
20-MDH	$\hat{\Delta}^2$	24.533	23.787	21.629	25.653	40.565	33.619	39.779
	F-prob.	.007	.008	.016	.006	–	.002	.001
	P.prob.	.135	.510	.309	.041	–	–	–
	St. dev.	.386	.800	.700	.135	–	–	–
	up.bound	.133	.129	.264	.142	.003	.142	.222
	typ.prob. < low.bound	–	–	–	–	–	–	–

Table 5 and 6 : Comparison of Border Cave with recent *Homo sapiens* skull series. Unbiased estimates of Mahalanobis squared distances, *F*-probabilities, posterior probabilities and standard deviations, and upper and lower bounds of typicality probabilities. Model A and B. Rightmire's measurements. Values smaller than 0.000 are denoted by a – sign. For further explanation see text.

N° and code name of variables added		Recent *H. sapiens* n=2216	Late Upp. Pal. n=11	Early Upp. Pal. n=7	Neanderthal n=8	*H. erectus* n=2
	$\hat{\Delta}^2$	9.766	4.232	7.414	3.129	3.571
21 - MDB	F-prob.	.007	.132	.034	.222	.217
24 - FMB {	P.prob.	.014	.227	.046	.395	.3166
	St. dev.	.019	.288	.078	.406	.448
typ. prob.<	up. bound	.010	.414	.190	.733	1.000
	low. bound	.005	.035	.003	.059	.010
	$\hat{\Delta}^2$	12.158	5.549	7.634	11.396	7.344
25 - NAS	F-prob.	.006	.148	.070	.015	.116
{	P.prob.	.019	.540	.190	.029	.220
	St. dev.	.028	.465	.293	.054	.444
typ. prob.<	up. bound	.009	.438	.326	.084	1.000
	low. bound	.004	.038	.008	.001	.001
	$\hat{\Delta}^2$	12.066	5.575	7.473	17.436	7.013
37 - GLS	F-prob.	.017	.244	.133	.003	.198
{	P.prob.	.020	.521	.202	.001	.254
	St. dev.	.030	.490	.312	.002	.495
typ. prob.<	up. bound	.023	.606	.506	.021	1.000
	low. bound	.012	.076	.020	-	.005
	$\hat{\Delta}^2$	12.061	5.770	7.373	18.610	8.520
39 - FRC	F-prob.	.034	.335	.215	.004	.196
{	P.prob.	.024	.572	.256	-	.144
	St. dev.	.035	.456	.369	.002	.346
typ. prob.<	up. bound	.045	.722	.665	.028	1.000
	low. bound	.025	.122	.041	-	.004
	$\hat{\Delta}^2$	20.971	9.481	10.646	34.769	25.409
40 - FRS	F-prob.	.001	.163	.122	-	.004
{	P.prob.	.002	.640	.357	-	-
	St. dev.	.003	.517	.516	-	-
typ. prob.<	up. bound	.003	.452	.461	—	.090
	low. bound	.001	.039	.015	-	-
	$\hat{\Delta}^2$	21.005	9.645	10.672	37.465	28.592
41 - FRF	F-prob.	.003	.223	.177	—	.003
{	P.prob.	.002	.624	.373	-	-
	St. dev.	.003	.529	.528	-	-
typ. prob.<	up. bound	.006	.555	.578	-	.067
	low. bound	.002	.062	.028	-	-
	$\hat{\Delta}^2$	21.017	10.090	13.803	41.511	30.208
1 - GOL	F-prob.	.007	.270	.109	-	.003
{	P.prob.	.003	.861	.134	-	-
	St. dev.	.006	.278	.276	-	-
typ. prob.<	up. bound	.011	.623	.422	-	.073
	low. bound	.004	.082	.012	-	-
	$\hat{\Delta}^2$	22.143	10.915	14.897	43.107	29.797
2 - NOL	F-prob.	.008	.292	.117	-	.006
{	P.prob.	.003	.877	.119	-	-
	St. dev.	.005	.258	.256	-	-
typ. prob.<	up. bound	.013	.650	.439	-	.123
	low. bound	.005	.092	.013	-	-

Table 7 : Comparison of Border Cave with recent and non-recent hominid skull series on the basis of nine of Howells' measurements. Unbiased estimates of Mahalanobis squared distances, *F*-probabilities, posterior probabilities and standard deviations, and upper and lower bounds of typicality probabilities. Values smaller than 0.000 are denoted by a - sign. Model A. For further explanation see text.

N° and code name of variables added		Recent *H. sapiens* n=2216	Late Upp. Pal. n=14	Early Upp. Pal. n=11	Neanderthal n=13	*H. erectus* n=4
	$\hat{\Delta}^2$	15.439	7.665	7.096	10.476	4.807
26 – EKB	F-prob.	—	.027	.034	.007	.119
25 – NAS	{ P.prob.	.003	.147	.196	.036	.616
	St. dev.	.004	.230	.289	.062	.432
typ. prob.<	up. bound	—	.106	.118	.030	.824
	low. bound	—	.004	.007	—	.009
	$\hat{\Delta}^2$	15.435	9.137	7.033	11.490	4.861
39 – FRC	F-prob.	.001	.034	.079	.012	.213
	{ P.prob.	.003	.078	.225	.024	.668
	St. dev.	.005	.136	.339	.044	.421
typ. prob.<	up. bound	.002	.130	.240	.049	.947
	low. bound	—	.005	.019	.001	.024
	$\hat{\Delta}^2$	20.684	12.003	10.176	23.965	24.627
40 – FRS	F-prob.	—	.022	.044	—	—
	{ P.prob.	.003	.284	.710	—	—
	St. dev.	.005	.420	.422	.001	.001
typ. prob.<	up. bound	—	.092	.149	—	.005
	low. bound	—	.003	.008	—	—
	$\hat{\Delta}^2$	25.061	12.494	11.720	27.383	27.345
36 – SOS	F-prob.	—	.036	.046	—	—
	{ P.prob.	—	.403	.594	—	—
	St. dev.	.001	.507	.507	—	—
typ. prob.<	up. bound	—	.136	.154	—	.004
	low. bound	—	.005	.008	—	—

Table 8 : Comparison of Border Cave with recent and non-recent hominid skull series on the basis of five of Rightmire's measurements. Unbiased estimates of Mahalanobis squared distances, *F*-probabilities, posterior probabilities and standard deviations, and upper and lower bounds of typicality probabilities. Values smaller than 0.000 are denoted by a – sign. Model A. For further explanation see text.

A second series of calculations was made with the order of entering based on stepwise discriminant analysis (the smallest *F* ratio for pairs of groups was maximized). For this order of entering (GLS, ZMR, FMB, FRF, MDB, FRC, NAS, FRS) the results were such that the Border Cave skull was, with the exception of last function, where it yielded to Ainu, from the third variable (FMB) onward assigned to the Australians, on using model A, and exclusively to Australians, on using model B. Consequently, one might say that, as far as the posterior probability results are concerned, there is a certain preference for Australians, be it that the accessory standard deviations tend to be large. It is also clear that there is no preference for Africans.

However, all results mentioned become rather irrelevant when one considers Hotelling's *F* test statistic. Here we see that on using model A Border Cave exceeds the 5 % level of exceedance in all instances whereas on using model B the same holds true from the sixth variable onward. In other words, as far as the information contained in Howells' set of variables is concerned, Border Cave is significantly different from all recent subpopulations. These results are corroborated by the typicality probability results as far as model A is used. Here we see that from the six variable function onward all typicality probability upper bounds are lower than 0.05. On using model B, however, quite a number of these bounds are larger. Doubtlessly, the small sample sizes play an important role here.

Finally, when we look at the unbiased estimates of the squared Mahalanobis distances we see that, quite in line with the *F*-test results, the distance of Border Cave to all groups is remarkably large. On using model A and 14 variables (table 3b), lowest estimated squared Mahalanobis distances of Border Cave are found to Guam (38.14), Tolai (38.74), Eskimo (39.95), Ainu (40.04), Tasmania (41.81), and Australia (41.89), respectively. Squared distances to recent African groups like Zulu (50.34) and Bushman (60.11) are larger still.

That these figures are large indeed will become evident on mentioning that the unbiased estimates of the mutual squared Mahalanobis distances between the recent reference groups ranged from 2.6 (Norse males – Egyptian males) to 56.6 (Andaman females – Easter Island males). The peculiar position of Border Cave relative to recent *Homo sapiens* specimens is furthermore illustrated by a comparison of the average of the unbiased estimates of the mutual squared distances between all 2 216 recent single specimens, on the one hand, and the average of the distances of Border Cave to all 2 216 single recent specimens, on the other (*cf.* van Vark, 1984, p. 339). On using the same sets of 14 variables, these figures are 27.5 and 46.2 respectively. For model B a comparison of squared Mahalanobis distances does not make sense because different metrics are involved.

In the calculations with Rightmire's scores (*cf.* Rightmire, 1979), the variables entered were SOS, EKB, NAS, WMH, FRC, FRS, OBB, MDH, successively. On using the present figures, Border Cave turned out to be significantly different from all recent subpopulations in all instances. The typicality probability upper bounds were all lower than 0.05 on using model A from three variables onwards whereas upper bounds larger than 0.05 were found up to all eight variables on using model B. The calculated figures for the respective posterior probabilities made clear that Border Cave showed a preference for Australians in the functions that used a larger number of variables. An exception was found only on using eight variables and model B where it yielded to Tasmanians. Finally, the calculation of the unbiased estimates of the squared Mahalanobis distances concerned made clear that, on employment of the set of eight variables, Border Cave was closest to the Tasmanians, Australians, Zulus, and Bushmen, respectively on using model A. As mentioned earlier, for model B such a comparison of estimated squared Mahalanobis distances does not make sense because different metrics are involved. The results are listed in tables 5 and 6, respectively. Obviously, the calculations with Rightmire's scores indicate that Border Cave is quite different from all 52 recent subpopulations.

In the light of earlier results, mentioned in the introduction, these findings are certainly remarkable. Checking of our procedure by redoing the calculations with a randomly chosen Australian specimen, gave as a result that, with the exception of some functions with a lower number of variables, this skull was assigned to and typical for its own group (from which it was omitted before starting the calculations), and excluded from all other groups.

Although these calculations show that Border Cave is very different from all recent series listed in table 2, they do not make clear what its morphological status is when evaluated within a framework of recent and non-recent hominid skulls. Is it, like Upper Palaeolithic skulls are generally considered to be and its outer appearance suggests, "anatomically modern", in the sense of fully *sapiens* ?

To cast some light on this question, Border Cave was also compared with the series of non-recent hominid skulls. Results of the same statistics as in the comparison of Border Cave with recent subpopulations were calculated. In this part of our study only model A was used since the small sample sizes of the non-recent groups did not allow the calculation of acceptable estimates of separate group covariance matrices.

In a first series of calculations Howells' scores of Border Cave were used. Nine variables were selected so that specimens from all non-recent hominid groups could be included together with a large sample of all available recent skulls (see table 7). All statistics used point to a relatively close affinity of Border Cave to the Upper Palaeolithic groups. A detail is that closest affinity of Border Cave is to the Late Upper Palaeolithic group rather than to the Early Upper Palaeolithic group but this difference is not statistically significant at the 5 % level.

Relatively close affinity of Border Cave with the Upper Palaeolithic groups was also found in a next series of calculations where Rightmire's scores were used and five variables were selected. Contrary to the results obtained with Howells' scores, however, the closest affinity found here was to the Early Upper Palaeolithic group. An important additional result but one which was only found on using Rightmire's scores was that according to the F-statistic Border Cave is, at the 5 % level, significantly different from all groups, including the Upper Palaeolithic ones (see table 8).

On testing with the aid of the Steerneman test the differences between the distances of Border Cave to other groups at the 5 % level, we found, both on using Howells' as on using Rightmire's scores, that Border Cave was closer to the Upper Palaeolithic groups than to each of the other three groups. All other distances did not differ significantly at that level so that we could not on the basis of the Steerneman test differentiate between *e.g.* the distances of Border Cave to the Late and Early Upper Palaeolithic groups.

Finally, the distance calculations illustrated in table 8 were extended by calculating the unbiased estimates of the squared Mahalanobis distances between all six groups of that table (see table 9). The most relevant column of the latter table is doubtlessly the first one where we see how much more different Border Cave is from recent *Homo sapiens* than are the Upper Palaeolithic *Homo sapiens* groups. This result is in keeping with the claimed great antiquity of the Border Cave specimen (the difference between the respective figures 25.0 and 5.3 is significant at $\alpha = 0.05$). A comparison of these figures alone makes it less obvious to call Border Cave anatomically modern. This becomes less obvious still if other figures of this table, specifically those of the last row, are considered simultaneously.

	1	2	3	4	5
1. Recent *Homo sapiens* n=2216					
2. Late Upper Palaeolithic *Homo sapiens* n=14	2.5				
3. Early Upper Palaeolithic *Homo sapiens* n=11	5.3	2.0			
4. Neanderthal n=12	29.3	20.1	24.5		
5. Asiatic *Homo erectus* n=4	27.1	19.1	21.5	2.1	
6. Border Cave n=1	25.1	12.5	11.7	27.4	27.3

Table 9 : Unbiased estimates of squared Mahalanobis distances calculated from scores on five cranial variables.

DISCUSSION

As Fatti, *op. cit.*, remarks, the reasons for the discrepancies between his results and those of Rightmire (1981), and Ambergen & Schaafsma, *op. cit.*, are most probably that these studies use different measurements of the skull, as well as different reference populations. A third reason will certainly be that the techniques employed in these studies are also different.

The results of the present study where various sets and subsets of variables were tried out on the basis of two different model assumptions and where, as a further new aspect, a number of other, mostly non-African reference populations were introduced, just form a clear confirmation of this. These results make clear that the discrepancies mentioned can all be explained in terms of the use of different variables, different methods, and different reference populations.

At the same time, these results demonstrate that there are no clear indications that the population from which the Border Cave cranium stems is ancestral to any of the populations now living in southern Africa. Relatively close affinities with non-African rather than with African populations were found.

An explanation for the differences between model A and model B might be that a certain sample may have a relatively large covariance matrix which gave rise to relatively high posterior and typicality probabilities and relatively low Mahalanobis distances. Obviously, sample size plays an important role in the calculated values for *e.g.* the posterior and typicality probabilities so that due to different sample sizes of the recent groups these values are not directly comparable. On trying to evaluate the present values one should also keep in mind that due to Border Cave's observed large distinctiveness, implying that its position is in the tails of the respective distributions, it may easily shift from one recent group to another if only slight numerical changes occur.

However, what is clear is that the Border Cave skull is different from all recent series, and therefore der Cave looks anatomically modern have a point : cannot be seen as a random drawing of the populations with which it was compared, thus making a discussion of the question whether it is more Zulu-like, or more Bush-like irrelevant. Rather, Border Cave seems to be indefinite as regards contemporary population diversity. Consequently, such cranial diversity may have originated at a later date and/or in a different place. This viewpoint is supported by results from the second part of this study where Border Cave is compared with recent as well as non-recent groups, all belonging to the genus *Homo*. From these results we take it that the skull is perhaps (statistical proof is lacking) only slightly more distinct from Asiatic *Homo erectus* than it is from recent *Homo sapiens*. This is the more interesting since, besides, it seems to be far from intermediate between these two groups. This would imply that it does not necessarily represent an evolutionary stage somewhere in between these groups. One possible but necessarily speculative explanation, given the poor condition of the specimen, is that the Border Cave skull represents a phylogenetic branch that might have evolved in a direction somewhat different from that leading to recent *Homo sapiens* populations. In a way this brings us back to the period before the statistical studies referred to in the introduction were carried out where *e.g.* de Villiers (1973) and Beaumont *et al.*, *op. cit.*, considered links between Border Cave and modern Africans to be fairly remote. One may say that, consequently, an important controversy seems to be solved.

On the other hand, our results create a new controversy which may even be said to bring us in conflict with mainstream anthropological literature. Most, if not all workers familiar with the cranium arrive at the conclusion that Border Cave is anatomically modern in the sense mentioned in the introduction. According to Rightmire (personal communication), who has examined the specimen, there are no features in which it departs substantially from the modern form. Those who are of the opinion that Borthat there is a conflict between results obtained by visual and by mathematical comparison is not altogether new. In an earlier mathematical analysis (van Vark, 1984, 1987) the first author found the skulls of Petralona, Broken Hill, and Steinheim to be far more distant from recent *Homo sapiens* than skulls of Asiatic *Homo erectus*. In a second not yet published mathematical analysis he found the mutual distance between Asiatic and African (OH9) *Homo erectus* skulls to be about as large as the distances of both *Homo erectus* groups to recent *Homo sapiens*. Although the taxon *Homo erectus* is under intense debate this result is rather unexpected. What makes these results the more striking is that the mutual distances of other hominid skulls which were calculated in the same runs correspond with current opinions taken from their visual comparison.

That results of a visual and a mathematical analysis correspond only in part is not quite illogical. Essentially, both visual and mathematical comparison of the morphology are multivariate statistical approaches. The difference is that they make use of different data and also of a different technique, whereby it is important to realize that the mathematical approach takes into account the correlations between the measurements in a far more sophisticated way. Consequently, the latter approach may reveal structures which are not or at least not easily revealed by mere visual inspection. On the other hand the visual approach may use morphological details which might not be expressed in sets of variables in a mathematical analysis. This makes certain differences in results understandable, and at the same time points to the fact that they both have their own specific value. At this moment, one has little insight in how and why these differences arise. For the time being, we just conclude that the Border Cave cranium is on the basis of our results, though it may look modern, quite different from recent *Homo sapiens*.

Acknowledgements

The authors wish to thank Drs. A.W. Ambergen (Univ. of Maastricht), W.W. Howells (Harvard Univ.), G.P. Rightmire (SUNY at Binghamton), and W. Schaafsma (Univ. of Groningen) for their comments on an earlier draft of this paper, and Mr. D. Kuizenga and Mrs G.T. Hoogenberg for secretarial and technical assistance.

References

AITCHINSON, J. & DUNSMORE, I.R., 1975. *Statistical Prediction Analysis*. Cambridge, Mass., Cambridge University Press.

AMBERGEN, A.W. & SCHAAFSMA, W., 1984. Interval estimates for posterior probabilities, applications to Border Cave. *In* : G.N. van Vark, W.W. Howells (eds). *Multivariate statistical methods in physical anthropology*. Dordrecht, D. Reidel Publishing Cy.:115-134.

BEAUMONT, P.B., 1980. On the age of Border Cave hominids 1-5. *Palaeontologica africana*, **23**:21-33.

BEAUMONT, P.B., DE VILLIERS, H. & VOGEL, J.C., 1978. Modern man in sub-Saharan Africa prior to 49,000 years B.P.: a review and evaluation with particular reference to Border Cave. *South African Journal of Science*, **74**:409-419.

BRÄUER, G., 1981. New evidence on the transitional period between Neanderthal and modern man. *Journal of human Evolution*, **10**:467-474.

BRÄUER, G., 1984a. Präsapiens-Hypothese oder Afro-europäische sapiens Hypothese ? *Zeitschrift für Morphologie und Anthropologie*, **75/1**:1-25.

BRÄUER, G., 1984b. A craniological approach to the origin of anatomically modern Homo sapiens in Africa and implications for the appearance of modern Europeans. *In* : F.H. Smith, F. Spencer (eds). *Origins of modern humans : a world survey of the fossil evidence*. New York, Alan Liss:327-410.

CAMPBELL, N.A., 1980. On the study of the Border Cave remains : statistical comments. *Current Anthropology*, **21/4**:532-535.

CLARKE, R.J., 1985. Australopithecus and Early Homo in southern Africa. *In* : E. Delson (ed.). *Ancestors : the hard evidence*. New York, Alan Liss:171-177.

DE VILLIERS, H., 1973. Human skeletal remains from Border Cave, Ingwavuma District, Kwa Zulu, South Africa. *Annals of the Transvaal Museum*, **28**:229-256.

DIXON, W.J., (ed.), 1975. *BMDP biomedical computerprograms*. Berkeley, Cal., University of California Press.

FATTI, L.P., 1985. *Discriminant analysis in prehistoric anthropology*. Technical report TWISK 386. National Research Institute for Mathematical Sciences CSIR, Pretoria.

HOWELLS, W.W., 1973. Cranial variation in man. A study by multivariate analysis of patterns of difference among recent human populations. *Papers of the Peabody Museum of Archaeology and Ethnology*, Harvard University, **67**.

HOWELLS, W.W., 1986. Origine de la diversité actuelle. *In* : Ferembach D., Ch. Susanne, M.-C. Chamla (eds). *L'homme. Son évolution, sa diversité*. Paris, C.N.R.S.:491-499.

HOWELLS, W.W., 1988. The meaning of the Neanderthals in human evolution. *In* : *L'évolution dans sa réalité et ses diverses modalités*. Colloque Fondation Singer-Polignac, novembre 1985, Paris, Masson:221-239.

PROTSCH, R., 1975. The absolute dating of Upper Pleistocene Subsaharan fossil hominids and their place in human evolution. *Journal of human Evolution*, **4**:297-322.

RIGHTMIRE, G.P., 1979. Implications of Border Cave skeletal remains for Late Pleistocene human evolution. *Current Anthropology*, **20/1**:23-35.

RIGHTMIRE, G.P., 1981. More on the study of the Border Cave remains. *Current Anthropology*, **22/2**:199-200.

SMITH, F.H., 1985. Continuity and change in the origin of modern Homo sapiens. *Zeitschrift für Morphologie und Anthropologie*, **75/2**:197-222.

STRINGER, C.B., 1985. Middle Pleistocene hominid variability and the origin of Late Pleistocene humans. *In* : E. Delson (ed.), *Ancestors : the hard evidence*. New York, Alan Liss:289-295.

VAN DER SLUIS, D.M., SCHAAFSMA, W. & AMBERGEN, A.W., 1985. *POSCON user manual*. University of Groningen.

VAN VARK, G.N., 1984. On the determination of hominid affinities. *In* : G.N. van Vark, W.W. Howells (eds). *Multivariate statistical methods in physical anthropology*. Dordrecht, D. Reidel Publishing Cy:323-349.

VAN VARK, G.N., 1987. An anthropometric approach to the study of evolution. *Acta morphologica neerlando-scandinavica*, **25**:107-116.

VAN VARK, G.N., BILSBOROUGH, A. & SCHAAFSMA, W., 1990. Affinity, hominid evolution and creationism. New computer methods weaken the Creationists' position. Submitted for publication.

Authors' addresses : G.N. VAN VARK & J. DIJKEMA
University of Groningen
Dpt of Anatomy and Embryology
Oostersingel 69
9713 EZ GRONINGEN (Pays-Bas)

A. Bilsborough
University of Durham
Dpt of Anthropology
43 Old Elvet
DURHAM DH1 3HN (G.B.)