THE FOSSIL HOMINID FROM THE NARMADA VALLEY, INDIA: *HOMO ERECTUS* OR *HOMO SAPIENS*?

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HISTORIC BACKGROUND AND RESEARCH

The search for fossil man in India began in the 1830s when bones thought to be human were dredged from the Yamuna river, along with fossilized remains of other mammals, by British military engineers (Princep 1833). The specimens were transported to the museum of the Asiatic Society in Calcutta which became the repository for subsequent finds hailed by their discoverers as vestiges of primordial man in the Indian subcontinent. Impetus for this enthusiastic search may be traced to several events taking place in Europe some 160 years ago.

This was the period of vigorous debates between European geologists over the question of human antiquity raised by Tournal (1830) and other French prehistorians who found human bones in direct association with remains of extinct fauna and stone tools in deposits recognized today to be of Pleistocene age. Wernerian geology was being challenged by uniformitarian concepts articulated by Hutton and Lyell, and followers of both theories looked to India for sources of scientific confirmation. William Buckland (1829), the English geologist and a firm believer in the Neptunist views of Abraham Werner in Germany, had examined nonhuman fossil materials collected by an army physician in Burma in 1826 and sent to the Geological Society of London (Crawfurd 1834). Buckland was confident that this collection would corroborate his thesis of a Universal Deluge once it was established that the fossil species were the same as their living counterparts. India had long nurtured European speculations about the geographical cradle of human origins and the sources of ancient wisdom and civilization. The Himalayas and the Tibetan plateau appeared to be an appropriate place for Providence to set the cradle of our exalted species. Writers as diverse as Sir Walter Raleigh (1614), Immanual Kant (1785) and Buffon (1778) favored this scenario, although Voltaire (1777) argued that civilization first emerged on the banks of the Ganges. The discovery by Sir William Jones in the 1780s that Sanskrit bore a close linguistic affinity to Persian and certain ancient and modern European languages (which belonged to a

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common Indo-European stock) lent further support to the idea that the roots of mankind lay in the mysterious East.

It was against this background of developments in prehistoric archaeology, geology, historical reconstruction and linguistics that British colonial officers and civilians were motivated to contribute to the scientific study of early man in South Asia. Three geographical regions seemed particularly promising.

The first reports that fossil fauna were found in the Himalayan range came from a Captain Webb who told Henry Thomas Colebrook, an orientalist in Calcutta, about natives finding "lightning stones" in areas of reputed electrical storm activity (Murchison 1868). This was some time before 1814, and Colebrook sent Webb's specimens to Buckland who refers to them in his *Reliquiae Diluvianae* published in 1823. The Siwalik hills that border these mountains yielded their first fossils to Proby Thomas Cautley prior to June 1831 when Hugh Falconer (1832), who had visited Cautley in the Dehra valley, sent a letter about these discoveries to the Honorable Secretary of the Asiatic Society. By 1836 it was known that the Siwalik deposits contained fossils of primates, these earliest discoveries including bones and teeth of colobines and an ape canine. Falconer's publication about the ape tooth precedes by two months Edward Lartet's report of the lower jaw of an ape (*Pliopithecus*) found at Sansan in Gers (Murchison 1868). Subsequent research in the Siwaliks produced a rich harvest of fossil primates which include sivapithecines, ramapithecines, and *Gigantopithecus*.

A second region of palaeontological importance is the Narmada valley where a fossil elephant was found in 1833 at Jabalpur by a Capt. Sleeman, and horse teeth were collected by G.G. Spilsbury that same year. In 1834 fossils of a giant buffalo were observed on the banks of the Narmada by Spilsbury, a find that the Honorable Secretary of the Asiatic Society praised since these fossils "have fairly won for him (Spilsbury) all the fame that the most enthusiastic disciple of the Wernerian manner could covet" (Princep 1834). From the Siwaliks and the Narmada valley came such a multitude of fossil specimens that it was necessary for the Asiatic Society to prepare a catalogue in 1836 and to create special shelving in its museum to accommodate the bones of mastodon, hippopotamus, rhinoceros, suids, equids, bovids, deer, antelope, hyaena, elk and crocodiles. To these specimens were added the reputedly human bones found in 1833 by the dredgers of the Yamuna.

A third area of palaeontological promise was in peninsular India in Kurnool District, Andhra Pradesh, where a series of caves had been mapped in a geological survey of 1844 but were not relocated until forty years later when Robert Bruce Foote (1885) recognized them and began serious archaeological excavations in quest of fossil man in India.

Although fossil hominids were *not* found in South Asia in the last century - or if they were found they were not preserved - the presence of prehistoric man in the subcontinent was irrefutably demonstrated in 1863 when Foote (1866) recognized and collected the first Palaeolithic tool from this part of the world. The discovery site was at Pallavaram in Tamil Nadu, and the nearby locality of Attirampakkam proved to be a rich factory site abounding in Acheulian handaxes, cleavers and other tools similar in style to those associated with a Middle Pleistocene antiquity in Europe. An officer of the Geological Survey of India, Foote exhibited his lithic collections to British colleagues in 1868 at the Geological Society of London where his claim that India was inhabited by prehistoric man was accepted. It was Thomas Henry Huxley who proposed that the caves of Kurnool District be explored as a likely place for human fossil remains, but in this excavation endeavor Foote was not successful. Nor did any well documented discovery of Pleistocene man in India emerge until the 1970s and 1980s, although human skeletal remains were found in Holocene sites associated with Mesolithic, Neolithic, Chalcolithic, Harappan and Iron Age cultures in South Asia (Kennedy 1980; Kennedy and Caldwell 1984).

The earliest lower Palaeolithic tools from India come from Umrethi in Saurashtra and are dated to 170±30 kyr (Rajaguru and Lale 1986). Stone materials collected since 1983 from Riwat in the Soan Valley and Dina in the Pabbi Hills of northern Pakistan are identified as artifacts and assigned a date of 2.0 myr on the basis of palaeomagnetic and fission-track dating (Dennell *et al.* 1988; Hemingway 1989). These dates, if verified, fall close to the range of 1.6-1.8 myr for *in situ* artifacts from Koobi Fora and Olduvai Bed I in East Africa. But the bones of the manufacturers of these cobble tools in Pakistan have not been found.

Today there exists a respectable fossil hominid record from Pleistocene deposits in South Asia which includes the cave site of Darra-I-Kur in northeastern Afghanistan (30,000+1900-1200 BP, Gx 112; Dupree 1972) and the Sri Lankan sites of Beli lena Kitulgala (12,260±870 BP, PRL 861; Kennedy *et al.* 1986b, 1987) and Batadomba lena (15,830±1260 BP; PRL 858; Kennedy *et al.* 1986b, 1987). At the latter site a radiocarbon date of 28,510+2150-1710 BP (PRL 857; Kennedy and Deraniyagala 1989) has been obtained at the lower level of the cave deposit which contains human skeletal remains and the earliest geometric microlithic tools recovered thus far from Asia. A terminal Pleistocene date of 10,500±110 BP (TF 1104; Kennedy 1984; Kennedy *et al.* 1986a) assigned to fossilized human skeletons from Sarai Nahar Rai, Uttar Pradesh, requires confirmation. The human skeletal remains from the 28,510 year old deposit at Batadomba lena cave are the earliest known anatomically modern *Homo sapiens* recovered thus far from South Asia.

However, the search for middle Pleistocene hominids contemporary with *Homo erectus* fossils from China and Southeast Asia and their collaterals in Europe and Africa continued to elude palaeoanthropologists who explored the regions of the Siwalik hills, the Narmada valley and peninsular India. Expeditions to the Narmada valley mounted by Helmut De Terra, T.T. Paterson, Teilhard de Chardin, Theodore D. McCown, A.P. Khatri and many other foreign and Indian scholars failed to recover hominid fossil remains, although all of these investigators encountered an abundance of Acheulian tools and fossil middle Pleistocene megafauna.

DISCOVERY OF THE NARMADA CALVARIA

This long quest was rewarded on 5 December 1982 with the discovery of a fossil hominid calvaria near Hathnora village in the middle course of the Narmada by Arun Sonakia, Senior Geologist of the Geological Survey of India Central Region. He found the specimen resting in situ on the surface of an alluvial terrace on the north bank of the river while surveying this region 40 km northeast of Hoshangabad town in Madhya Pradesh. Announcements of this discovery were released to news media on 21-22 July 1983, a notice appearing that same month in the newsletter of the Geological Survey of India Central Region (Anonymous 1983). It was reported that the skull was found in association with middle Pleistocene fossils of *Stegodon, Bos, Cervus* and *Equus* along with stone implements of flint, quartzite and chert shaped as choppers, scrapers and handaxes. In the following year, N.G.K. Murthy, Director of the Geological Survey of India for the Southern Region, presented a paper to the Birla Archaeological and Cultural Research Institute in Hyderabad (Anonymous 1984). Also in 1984 appeared the more complete report by Sonakia (1984) in the *Records of the Geological Survey of India* in which the calvaria was assigned to the taxon *Homo erectus narmadensis*. This decision was based upon Sonakia's measurements of the specimen according to procedures practised by Dudley Buxton in 1925 and Franz Weidenreich in 1943 since their works were available to him. A morphological analysis was undertaken by T.L. Patil, Professor and Head of the Department of Anatomy, Government Medical College, Nagpur.

On 6-10 April 1984, Sonakia (1985a) displayed a cast of the specimen to palaeoanthropologists attending the international Ancestors symposium held at the American Museum of Natural History, New York, a brief description appearing the following year in *Ancestors: the Hard Evidence* edited by Delson (1985). In the summer of that same year, Sonakia joined Marie-Antoinette de Lumley at the Institute de Pala‰ontologie Humaine in Paris for a more rigorous study of the original specimen. The appearance in 1985 of the results of the study written in French and published in *L'Anthropologie* (M.-A. de Lumley and Sonakia 1985) coincided with an article in English in the *American Anthropologist* (Kennedy 1985; Sonakia 1985b). Since then a number of published studies of the Narmada fossils have appeared, but with the emphasis upon stratigraphic and archaeological contexts (Basu 1984; H. de Lumley and Sonakia 1985; Agrawal *et al.* 1988; Badam *et al.* 1986; Badam 1989; Salahuddin *et al.* n.d.).

Palaeoanthropologists who had observed the cast of Narmada Man at the *Ancestors* conference or were familiar with the few published sources that stated its classification as *Homo erectus* were already asking if this could be its proper taxon (Wolpoff *et al.* 1988). It was to clarify this problem as well as to conduct a thorough morphometric comparative and statistical analysis of the specimen that I accepted a long-standing invitation from the Geological Survey of India to examine the calvaria at its present repository in Nagpur during the period of 19-22 June 1988.

ANTIQUITY

Dating of the deposit in which the calvaria was embedded is given as middle Pleistocene by Henri de Lumley and Sonakia (1985) on the basis of finding fossils of *Stegodon genesa* and an archaic form of *Elephus hysudricus* with the specimen. They assign the handaxes and cleavers in the deposit to the late Acheulian. However, Badam assigns the tools to a

MEASUREMENT/INDEX*	VALUE	CODES IN TABLE 2
Glabella-Opistocranion length (1)	203	A
Glabella-Inion length	194	B
Maximum transverse breadth (8)	(164)	C
Bi-parietal breadth	(145)	D
Basion-Bregma height (17)	(138)	E
Auricular-Bregma height (20)	115	F
Cranial length-breadth index (maximum transverse)	80.78	
Cranial length-breadth index (bi-parietal)	71.42	
Basion-Bregma height-length index	67.98	
Basion-Bregma height-breadth index (maximum transverse)	84.14	
Basion-Bregma height-breadth index (bi-parietal)	95.17	
Auricular-Bregma height-length index	56.65	
Auricular-Bregma height-breadth index (maximum transverse)	70.12	
Auricular-Bregma height-breadth index (bi-parietal)	79.31	
Bregmatic index	44.84	
Nasion-Bregma chord (29)	118	G
Nasion-Bregma arc (26)	132	H
Nasion-Bregma chord-arc index	89.39	
Bregma-Lambda chord (30)	112	I
Bregma-Lambda arc (27)	125	J
Bregma-Lambda chord-arc index	89.60	
Lambda-Opisthion chord (31)	85	K
Lambda-Opisthion arc (28)	90	L
Lambda-Opisthion chord-arc index	94.44	L
Lambda-Stenobasion chord	(120)	M
Bi-asterionic breadth (12)	(144)	N
Occipital height - Bi-asterionic breadth index	88.33	
Bi-coronale breadth (10)	(120)	O
Bi-frontotemporale breadth (9)	(106)	P
Bi-orbital breadth (44)	(120)	
Frontal divergence index	88.33	
Bi-frontotemporale - Bi-orbital index	83.33	
Orbital breadth (51)	(43)	
Orbital height (52)	(38)	
Orbital height-breadth index	88.37	
Orbital depth	48	
Temporal line-Sagittal border distance	58	
Temporal bone length	87	
Cranial capacity	1155-1421 CM^3	W

*Measurements are in millimeter units. Martin and Saller code numbers are in parentheses following the name of each measurement. Values in parentheses are estimated measurements.

TABLE 1: MEASUREMENTS AND INDICES OF THE NARMADA CALVARIUM

late Acheulian tradition with an antiquity no greater than 150,000 years BP, while he assigns the boulder conglomerate deposit in which the tools and calvaria were found to an early late Pleistocene age (Badam 1979). The most recent investigation of the region by a team from the Physical Research Laboratory at Ahmedabad places the antiquity within middle to late middle Pleistocene dates on the basis of artifact typology and stratigraphic dating of the deposit (Agrawal *et al.* 1988). Thus we have a time frame of ca. 250,000 to 150,000 years B.P. for the Narmada calvaria.

MORPHOMETRIC ANALYSIS

The morphometric analysis (Table 1) was based upon a specimen represented by three-quarters of a calvaria with portions still covered with a compact basal conglomerate of hard gravel. The complete right half of the cranium is preserved, but the left side is incomplete. Most basalar portions are preserved and the face is limited to a segment of right orbit. Neither mandible nor teeth were present. All bone tissue is highly mineralized.

On the basis of degrees of ectocranial suture closure, the specimen appears to be an adult in the late third decade or early fourth decade of life, as determined by degrees of ectocranial suture closure and comparison with closure sequences of modern *Homo sapiens* skulls. In the initial report of the specimen issued by the GSI, the sex was given as male, but subsequent examination revises this estimate as female. There is no coincidence of opisthocranion with inion in the maximum cranial length measurement taken on the Narmada calvaria, although coincidence is a feature of most *Homo erectus* skulls from Asia and Africa. Other non-*erectus* features include absence of coincidence of vertex and bregma in auricular height calculation, elevation of the cranial vault with metrical values well above the ranges for *Homo erectus* but within the values of archaic *Homo sapiens*, and an estimated cranial capacity of 1155 to 1421 cm^3, which is high for *Homo erectus*. Indeed, Narmada exceeds cranial height values calculated for Ngandong 7 and 12, Kabwe, Dali, Arago 21-47 and Petralona. Occipital curvature is weaker and less angular than in Asian and African forms of *Homo erectus*, and degree of sagittal curvature is greater. The lateral aspect of the Narmada calvaria reveals a moderately prominent supraorbital torus and a less receding profile than is found in *Homo erectus*. The preserved right orbit is round and large with a low degree of robusticity of the malar region. The high orbital height-breadth index brings it into the category of hypsiconchy which is rare in *Homo erectus* but frequent among modern Asians. This orbital shape variable contrasts with the more rectangular chamaeconchic pattern of many *Homo erectus* crania. When viewed in Norma verticalis, it is apparent that postorbital constriction is not as extreme in Narmada as in many *Homo erectus* specimens. In this feature it resembles Steinheim.

However, some morphological features often associated with *Homo erectus* are present in the Narmada calvaria. The most lateral points of the Narmada vault fall on the supramastoid crest of the temporal bone. There is a close approximation of the temporal lines on the parietal bones which is created by reconstructing the left side of the vault as a mirror image of the preserved right side. Dolichocrany, although a feature shared by most Pleistocene hominids, is present. In addition, one observes a large torus angularis, a pentagonal form of the vault due to steep angulation formed by the vertex-temporal line with the temporal-euryon line, and a small mastoid process.

The Narmada calvaria possesses some unique features seldom found or absent in *Homo erectus*, Neanderthals and archaic *Homo sapiens*. These include the combination of high vault height with maximum breadth diameter falling between the euryonic points on the temporal bones. A low median frontal ridge is continuous with a prominently elevated sagittal ridge where the sagittal suture lies in a depression between the borders of a furrow. The external auditory meatus is also large.

STATISTICAL ANALYSIS

To what degree do these morphological and mensural variables support the initial identification of the Narmada specimen as *Homo erectus*? Might Narmada be more closely associated with archaic *Homo sapiens* and Neanderthals? Or is Narmada a unique hominid with features that defy assignment to these large, but generally recognized, categories? Given its geographical isolation from other middle Pleistocene hominids in Asia, its assignment to a distinctive species or subspecies merits consideration.

The customary practice for finding answers to these questions is to compare the morphometric variables of the specimen in question with trait lists held to be diagnostic of established fossil series. Using a sorting criteria listing for *Homo erectus* that was compiled by Rightmire in 1988, it was possible to identify only 43% *Homo erectus* traits in the Narmada specimen. Lower percentages of shared characteristics were observed when other lists were consulted. The combination of morphological and mensural characters in the pattern revealed by univariate analysis is not encountered in other hominid calvaria recovered thus far, hence an assessment of the biological affinities of Narmada requires further examination. The multivariate statistical procedure of Bayesian analysis constitutes the second phase of analysis.

Statistical techniques are used to summarize data and to modify opinion in the light of data. Bayesian statistical techniques differ from classical techniques in several ways: they require an explicit statement of the probability of a hypothesis prior to the incorporation of new data; they provide a direct measurement of the evidence for or against a hypothesis supplied by new data without regard to the intentions of the data collector; and they do not consider as relevant data that might have been observed, but were not. This third characteristic, relying only on the data actually observed rather than assuming observations to be samples from some mathematically describable distribution, is particularly important for studies of fossil material. Assumptions of classical statistics concerning sample size, random selection of samples, and experiment design are often violated in paleontological studies. In the present analysis, adequate comparative materials are not available to allow the straightforward application of traditional statistical techniques.

Comparative data comprise 29 fossil hominid crania from 3 continents organized into four groups: *Homo erectus* (N=9), early (archaic) *Homo sapiens* (N=10), Neanderthal (N=7) and modern *Homo sapiens* (N=2 late Pleistocene specimens + means of 17 modern *Homo sapiens* populations; Table 2). Certain specimens in the series merit particular attention with respect to their placement in the four groups. Arago 21-47 and postcranial bones associated with the cranial portions (Arago 44, 48, 51 and 53) suggest *Homo erectus* affinities (Howells 1971; Day 1982, 1986; Sigmon 1982), whatever

Experi-ment	Skulls included	Measurement variables used	# of skulls (S)	# of variables (N)	Information bits addressed (N x S)	NAR-E			NAR-N			NAR-A			Prior Prob			Post Prob		
						D	L	P	D	L	P	D	L	P	E	N	A	E	N	A
1	1-7, 9-27	A, C, D	26	3	78	27.4	.40	.30	14.1	.44	.33	17.9	.49	.37	.60	.05	.35	.55	.05	.40
2	1, 2, 9, 10, 12, 15-17, 23, 24, 26	A, B, F, G, H, I, J, K	11	8	88	37.1	.46	.19	16.3	1.00	.44	18.6	.86	.38	.60	.05	.35	.42	.08	.49
3	1-21, 23-27	W**	26	1	26	238.1*	.59	.34	266.8*	.58	.34	43.3*	.55	.32	.60	.05	.35	.61	.05	.34
4	1, 2, 5 7-17, 21, 23, 24, 26	N, O, P	18	3	54	31.2	.33	.30	21.8	.38	.35	22.3	.37	.34	.60	.05	.35	.57	.05	.38
5	1, 2, 7, 12, 16, 23, 24 26	A, B, C, D, E F, G, H, K, M, N, O, P	8	13	104	54.7	.37	.30	33.2	.46	.37	36.7	.40	.33	.60	.05	.35	.57	.06	.37
1-5 inclusive			26	16	244										.60	.05	.35	.32	.10	.58

*Numerical coding for skulls included in the study: Narmada (1); Arago 21-47 (2); KNM-ER 3733 (3); KNM-ER 3883 (4); Olduvai H9 (5); Sale (6); Sangiran 17 (7); Zhoukoudien 10 (8); Zhoukoudien 11 (9); Zhoukoudien 12 (10); Amud 1 (11); La Chapelle-aux-Saints (12); La Ferrassie 1 (13); Monte Circeo 1 (14); Saccopastore 1 (15); Shanidar 1 (16); Skhul 5 (17); Dali (18); Ehringsdorf (19); Fontéchevade (20); Kabwe (21); Ngandong 7 (22); Ngandong 11 (23); Petralona (24); Sambungmachen 1 (25); Steinheim (26); Swanscombe (27).

**NOTE: This variable, measured in cm^3 is not directly comparable to the other variables, all of which are measured in mm.

TABLE 2: BAYESIAN ANALYSES OF HOMINID SPECIMENS*

relationship the Tautavel specimens may have to *Homo sapiens* (Stringer 1984). The Sambungmachan calvaria has marked similarities to Ngandong, Orchiston and Siesser (1982) assigning specimens from both sites to *Homo sapiens soloensis*. Day (1986) concurs with this designation. Although nearly all of the Javanese fossils are assigned to the genus *Pithecanthropus* by Jacob (1982), he observes close similarities between Sambungmachan and Ngandong. The Skhul 5 specimen possesses a number of anatomical features encountered in modern *Homo sapiens* but the relationship of the Skhul population to the earlier inhabitants of the Mount Carmel caves remains obscure. While the Tabun skeletal materials have been called Neanderthal, it is necessary to stress that some of their morphological features are present in the Skhul skulls, namely in Nos. 2, 4, 7 and 9. This suggests that the Tabun-Skhul populations reveal an evolutionary trend away from *Homo sapiens neanderthalensis* to anatomically modern *Homo sapiens sapiens*. Skhul 5 is not fully modern in all of its morphometric variables, hence its taxonomic position continues to be a source of dispute (Wolpoff 1980; Trinkaus 1983).

Additional fossil crania could have been included in the comparative series, e.g., Hexian and Maba from China, but selection was based upon completeness of specimens and comprehensiveness of published morphometric data concerning them, particularly in cases where the original fossils were not examined at first hand by the senior author.

Given that there is no anthropological consensus for assigning some of the specimens in our comparative series to specific taxa, it may be argued that *a priori* assumptions about groupings and taxa are unjustified. However, the function of the current analysis is not a re-evaluation of hominid taxonomy but, rather, a testing of the hypothesis that Narmada belongs to *Homo erectus*, as was announced in the first published descriptions of the calvaria. Therefore, it is appropriate to compare Narmada's morphometric features with those of already described fossil specimens which a majority of present investigators have sorted into the groupings of *Homo erectus*, Neanderthals, and early and modern *Homo sapiens*. There is general acceptance of these categories by palaeoanthropologists, although assignment of certain specimens to any single taxon, evolutionary grade or transitional form is subject to differences of interpretation.

Our analysis has been two stage. First, morphologic evaluation of the Narmada specimen was undertaken to determine its placement with respect to the *Homo erectus*, Neanderthal, and archaic *Homo sapiens* populations. This analysis was assisted by comparison of metric variables of 49 mensural characters and indices of the Narmada skull with published materials providing craniometric data of the other fossil hominid specimens (Table 1). Following this analysis and the conclusion that the Narmada specimen fits well within the variation seen for the comparative materials, a Bayesian analysis was undertaken to determine the relative probabilities of placement within each of the three groups under consideration.

It is important to emphasize that Bayesian techniques are not simply an alternate set of tests to supplement the t-tests, F-tests, etc., of classical statistics. The Bayesian tradition, one of long standing within the statistical community, emphasizes the interplay of data and hypotheses, of prior and posterior probabilities. Shortcomings of classical techniques, particularly those associated with experimenter's intent and experimental design, are discussed by Edwards *et al.* (1963), Berger (1985), and Berger and Berry (1988). The most serious stumbling block to the application of classical multivariate analysis in this particular study is the absence of metrical data within the comparative data matrix. It was because we did not want to exclude either specimens or variables from analysis, and because we did not wish to replace missing values with averages, that we chose to use a non-classical analysis for placement.

Because of the manner in which data are used directly and not summarized by reference to mathematical distributions, Bayesian techniques are not currently available to investigators in user-friendly computer packages. No program will handle multivariate, discriminate function analysis of a matrix with blank cells, as might be required in the present investigation. Larkin and Chiment (n.d.) are preparing a program to meet this need and are investigating the application of Bayesian analysis to more general questions in taxonomy and systematics. At present it is possible to retain much of the Bayesian approach and effect a relatively sophisticated investigation of the available data matrix using a series of mathematically simple steps. It should be noted that steps 1 through 3 below are not especially Bayesian in their nature.

(1) For each variable, the mean and range are determined for the *Homo erectus*, Neanderthal, and archaic *Homo sapiens* subgroups.

2) One- and two-dimensional plots of selected variables are made. The position of the Narmada specimen within clusters is noted. For this data set, none of the variables, taken one or two at a time, was able to separate unambiguously the three subgroups or assign the Narmada specimen to any one group. This graphic analysis, however, confirmed our earlier conclusion, based on morphologic comparisons, that the Narmada specimen fits well in the cluster of *Homo erectus*, Neanderthal, and archaic *Homo sapiens*.

(3) Variables and means are then used to calculate an N-dimensional Euclidean distance between each specimen and the centroid for each subgroup: $D=(\breve{o}(\bar{x}-x)^2)^{1/2}$. Each specimen determines a point in N-space with N equal to the number of variables used in a particular "experiment." Additional points in N-space, the centroids, are determined by the mean values of the variables for each of the three subgroups. The Euclidean distance, D, between each specimen and each of the three centroids is calculated. In order for a particular specimen to be used in the calculation of D, that specimen must have known values for all N variables compared. All fossil specimens, however, are used in the calculation of their appropriate centroid value and are included indirectly in each "experiment." In this paper we have performed five such experiments on the data matrix of craniometric values of these fossil specimens. Each experiment compares a somewhat different subset of variables and specimens. Because of missing values for some specimens, it is not possible for a single statistic to capture all of the information in the matrix.

(4) A histogram of D values is prepared for each experiment, noting those values that represent a distance from a specimen to the mean of its assigned taxon ("within group distances") and those values that represent distances to the means of the other two subgroups ("outside subgroup distances"). This histogram is taken as the reference distribution. It is important to realize that distances greater than those actually observed in this investigation, while mathematically possible, do not influence the following calculation of hypothesis likelihood. This is not true of such extreme, but unobserved, values in classical statistics (Berger and Wolpert 1984).

(5) The distances Dnar-e, Dnar-n, and Dnar-a, from the Narmada specimen to each of the three subgroup centroids (*erectus*, Neanderthal, archaic *sapiens*), are determined and these distances are plotted on the reference histogram. The results of Experiment Number 5 are shown as Figure 1. The ratio of the "within subgroup distances" less than the Narmada distance to the total number of distances ("within subgroup distances"+"outside subgroup distances") less than the Narmada distance is the likelihood that the observed distance is a "within subgroup distance", i.e., that the Narmada specimen belongs to that particular subgroup. The three likelihoods thus obtained, the likelihood of Narmada's inclusion in the *Homo erectus*, Neanderthal, or archaic *Homo sapiens* subgroups, are normalized linearly and the data presented as probabilities of inclusion, P, summing to one. It should be noted that the reference distribution of D values may be used to generate a number of different comparative measures. The particular statistic used here, which compares areas to the left of particular values, will not be stable under all distributions. Its value in this analysis is that it requires relatively few specimens in each of the subgroups being compared.

The ratio of "within subgroup distances" less than the test distance to total number of distances less than the test distance used in this analysis was chosen following an analysis of D values from each comparative specimen to the centroids for *Homo erectus*, Neanderthal, and archaic *Homo sapiens*. In this preliminary analysis 22 of 26 specimens were correctly assigned to their presumed taxon by lowest value of D. The four other specimens were misassigned as follows: Arago 21-47, a *Homo erectus*, misassigned to archaic *Homo sapiens*; Saccopastore 1, a Neanderthal, mis-assigned to archaic *Homo sapiens*; Fontéchevade 2, an archaic *Homo sapiens*, misassigned to Neanderthal; and Steinheim, an archaic *Homo sapiens*, mis-assigned to *Homo erectus*. It should be noted that all four specimens, mis-assigned based on least value for D, had the appropriate taxon assignment for the intermediate D measurement. That is, for none of the specimens in our data matrix is the largest of the three possible D values associated with the presumedly correct taxon. In this initial analysis, however, the Narmada specimen is found to be most distant from *Homo erectus* (D=67.88), and closest to the archaic *Homo sapiens* (D=48.29) based on a comparison of all variables in Table 1, excepting cranial capacity.

(6) The final step of the analysis involves the modification of the prior assessment of hypothesis probability by the probability factor generated by the data. Our prior

probabilities were suggested by the description of the Narmada specimen by Sonakia (1984) and his colleagues (M.-A. de Lumley and Sonakia 1985) who were led to assign the specimen to the *Homo erectus* taxon. Regardless of prior probability, however, the posterior or final probability will be the product of the prior probability selected by the investigator and the probability factor generated by the analysis. In Bayesian analysis the final conclusion is in the hands of the reader, depending on both the data presented and the reader's initial opinion. Table 2 lists the results of five separate, but not completely independent, "experiments" designed to explore the length and breadth of the data set. A summary of 5 runs shows that with 26 crania, 16 variables and 244 information bits, a prior probability of 60% for Narmada being *Homo erectus* erodes to 31% in the list of posterior probabilities. Shifts with respect to Neanderthal affinities are from 5% to 10%, but most impressive is the posterior probability of 59% for Narmada-archaic *Homo sapiens* affinities. Experiments 1, 3 and 4 were designed to maximize the number of skulls included in the comparison and, therefore, explore a limited number of measurement variables. Experiments 2 and 5 sought to include many measurement variables, but could include only those skulls that had extensive metrical data. The product of the number of skulls included and the number of variables is a gauge of the bits of information addressed by the experiment.

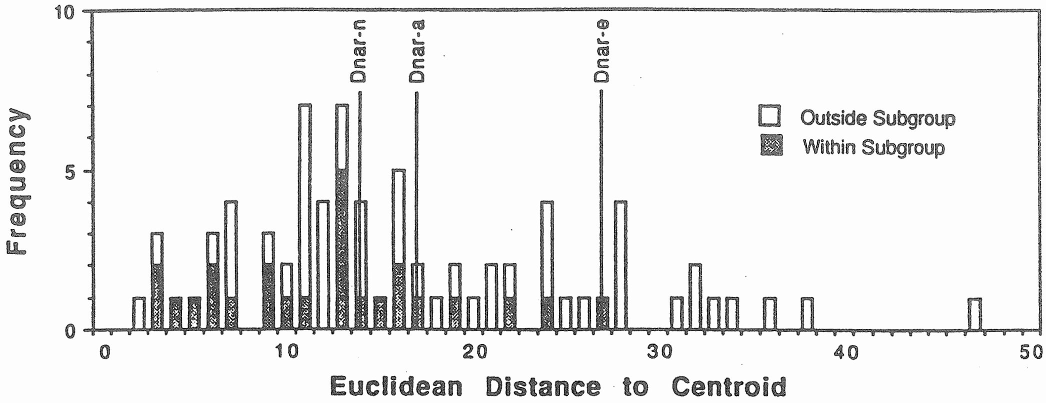

FIGURE 1: AN EXAMPLE OF EXPERIMENT NUMBER 5

Several aspects of this analysis require comment. Small values of Dnar-x do not necessarily correlate with large values of P. In experiment 1, for example, Dnar-n is less than Dnar-a, but Pa is greater than Pn. This is due to the distribution of "within subgroup" distances in the reference distribution. Some of these values exceed the Dnar-n value and are not included in the calculation of the likelihood or probability values for Neanderthal.

In experiment 3 there is no obvious correlation of D to P. Again this is due to the distribution of "within subgroup" distances. They occur throughout the range of "outside subgroup" distances. For this series of skulls at least, cranial capacity has no discriminatory power for assignment to subgroup. The utility of this comparison is further limited by the use of median values for all skulls where only estimates of cranial capacity are available. The very high D values for this experiment are due to the measurement of cranial capacity in cm^3. These values should not be contrasted with D values calculated on other variables or sets of variables measured in mm. Indeed, because experiments in this study are mostly of different dimensionality (N), the D values obtained in different "experiments" are not directly comparable. It should be noted that the distance values of individual specimens to centroids do not always assign the smallest value to the "within subgroup" measure. Taken alone, without a reference distribution, the N-dimensional distance may not be a very reliable tool for assignment of specimen to taxon.

We conclude that all experiments erode the initial confidence (prior probability) in assignment of Narmada to the taxon of *Homo erectus*. Experiments 1-5, as a whole, overturn the high prior probability of assignment to *Homo erectus*, making assignment to archaic *Homo sapiens* the most likely. This analysis supports conclusions reached independently from morphometric analysis that Narmada's closest biological affinities lie within the grouping of anatomically archaic *Homo sapiens*.

CONCLUSIONS

The employment of the Bayes factor in this multivariate analysis erodes the initial confidence in assignment of Narmada to the *Homo erectus* taxon. Rather, the greatest frequency of shared variables is found in middle Pleistocene fossil specimens variously labeled as archaic/early *Homo sapiens* or pre-Neanderthals and ante-Neanderthals. Narmada falls well outside the group of classical Neanderthals of Europe and western Asia.

The Narmada calvaria is the only preserved and authenticated discovery of a middle Pleistocene hominid recovered from the Indian subcontinent, and its geographical mid-point situation between the regions of richer fossil hominid sites in Eurasia and Africa guarantees it a unique place in human palaeontology. However, its advent occurs in the present world of palaeoanthropological controversy, some investigators acknowledging *Homo erectus* as a valid taxon while to others it is a grade, a population, a palaeospecies, or even an assembly of fossil specimens some investigator decides belong together. This suggests that the taxonomic status of Narmada Man will be debated for some time in the future.

Those who are convinced that Narmada Man is an Indian *Homo erectus* will find support among others who accept the validity of this taxon for widely distributed hominid populations of the middle Pleistocene, some calling it an "evolved" form under an assumption that *Homo erectus* is ancestral to all modern humans. However, the present study assigns Narmada Man calvaria to *Homo sapiens*. This is a hominid which exhibits a broad range of morphometric traits that occur in highest frequencies in specimens including Arago 21-47, Petralona and Bilzingsleben, but are reflected, too, in possible Neanderthal antecedents such as Steinheim, Swanscombe, Ehringsdorf and Fontéchevade. Results of Bayesian analysis support the univariate morphometric analysis that Narmada Man shares an impressive suite of anatomical features with middle and late Pleistocene *Homo sapiens* from Eurasia and Africa. It is not appropriate to assign Narmada to a new taxon beyond the trinomial designation of *Homo sapiens narmadensis.*

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