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THE MAGNETIC POLARITY STRATIGRAPHY OF THE SIWALIK GROUP AT HARITALYANGAR (INDIA) AND A NEW LAST APPEARANCE DATUM FOR *RAMAPITHECUS* AND *SIVAPITHECUS* IN ASIA

GARY D. JOHNSON[1], NEIL D. OPDYKE[2], S. K. TANDON[3] and A. C. NANDA[4]

[1]*Department of Earth Sciences, Dartmouth College, Hanover, NH 03755 (U.S.A.)*
[2]*Department of Geology, University of Florida, Gainesville, FL 32611 (U.S.A.)*
[3]*Department of Geology, University of Delhi, Delhi 110 007 (India)*
[4]*Wadia Institute of Himalayan Geology, 15 Municipal Road, Dehra Dun 248 001 (India)*

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ABSTRACT

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The Haritalyangar (India) local fauna contains type specimens of several hominoid primates which are assigned a new last appearance datum age based on a magnetic polarity stratigraphy. This youngest assigned age for *Sivapithecus indicus*, *S. sivalensis* and *Ramapithecus punjabicus* in Asia is about 7.0—7.5 m.y. The age of the holotype specimen of *Gigantopithecus bilaspurensis* is about 6.3 m.y. The Nahan Sandstone Formation is at least in part contemporary with the Nagri Formation (lithofacies) of the Potwar Plateau, Pakistan.

INTRODUCTION

Recent investigations into the vertebrate paleontology of the fresh-water Siwalik Group of India and Pakistan (the Himalayan molasse) have resulted in the establishment of a Neogene and Quaternary biochronology for South Asia which is constructed for the first time on a stratigraphically documented faunal succession (Opdyke et al., 1979; Barry et al., 1982). This biochronology is in turn temporally constrained by a radiometric and paleomagnetic stratigraphy. For the most part, the traditional divisions of the South Asian land mammal faunal zones that preceded this new biochronology and the redefined chronology itself have been derived from the study of Siwalik Group stratotypes and local faunas which are defined from the Potwar Plateau in the northern Punjab, Pakistan. The bio- and chronostratigraphy presently established for the Late Miocene-aged Lower and Middle Siwalik formations (including the Chinji, Nagri and Dhok Pathan faunal zones (*sensu* Pilgrim,

0031-0182/83/$03.00

1910, at their type localities) have been documented from the central Potwar Plateau of Pakistan (Tauxe and Opdyke, 1982; N. M. Johnson et al., 1982; Barry et al., 1982). That for the Pliocene- and Pleistocene-aged Upper Siwalik formations (including the Tatrot and Pinjor faunal zones) have been established from sites along the southeastern edge of the Potwar Plateau and in the hills of the eastern Salt Range of Pakistan (Opdyke et al., 1979; G. D. Johnson et al., 1979) (Fig.1).

Interest in the fossiliferous Siwalik Group as a potential record of primate evolution in Asia resulted in its being the focus of nearly a century of activity in the search for and recovery of fossil hominoid and non-hominoid material. In this extensive record of acquisition, a number of localities are recognized which account for the bulk of the fossil material recovered. In the Pakistani Pubjab, type primate material has been recovered from within the vicinity of the villages of Chinji and Dhok Sethi Nagri along the southern margin of the Potwar Plateau (Pilgrim, 1910, 1915, 1927; Brown et al., 1924; Lewis, 1934, 1936; Gregory et al., 1938; Simons and Pilbeam, 1971; Pilbeam et al., 1977), the villages of Dhok Pathan and Khaur in the central Potwar Plateau (Simons and Pilbeam, 1965; Pilbeam et al., 1977; Pilbeam, 1982), and Hasnot—Bhandar—Tatrot in the eastern Salt Ranges (Pilgrim, 1910; Lewis, 1934; Simons and Pilbeam, 1965) (Fig.2). In India, two localities occur as important sites in the history of recovery of hominoid and

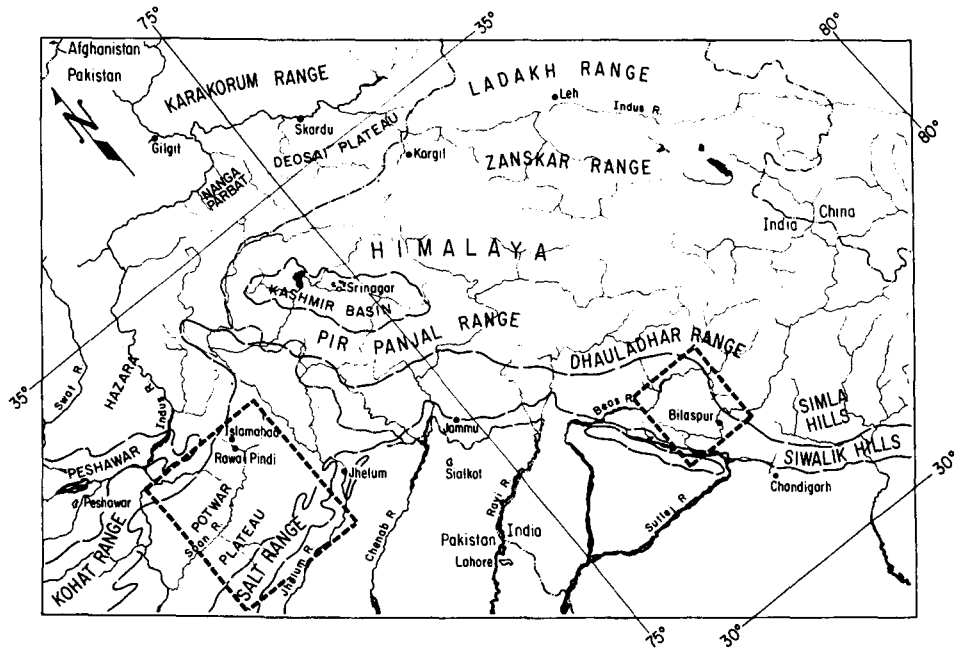


Fig.1. The northwest Himalaya showing the two major areas of Siwalik Group outcrops discussed in text. Haritalyangar is situated in the center of the area outlined at the right. See Figs.2 and 3.

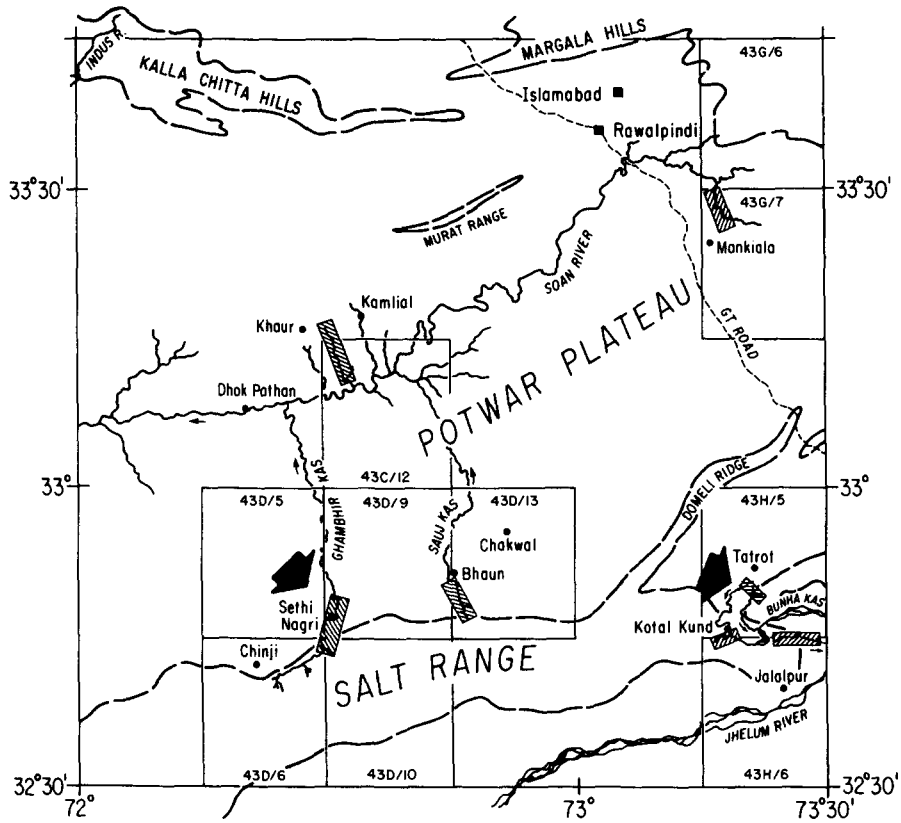


Fig.2. Location map of Potwar Plateau and adjacent areas, northern Pakistan, which contain the stratotypes for many of the Siwalik formations discussed in text. Crosshatched areas have been recently studied and provide a magnetic polarity stratigraphy to which the Haritalyangar data are compared. The locations of the type Chinji/Nagri and the Hasnot—Bhandar—Tatrot areas (Fig.10) are indicated (arrows).

non-hominoid primates: Ramnagar, near Jammu along the southern foothills of the Pir Panjal (Gregory et al., 1938; Simons and Pilbeam, 1965; Dutta et al., 1976) and Haritalyangar, in the Siwalik Ranges, north of Chandigarh (Fig.3) (Pilgrim, 1910, 1915, 1927; Brown et al., 1924; Lewis, 1934, 1936; Gregory et al., 1938; Prasad, 1962, 1964, 1969; Simons and Pilbeam, 1965, 1971; Simons and Chopra, 1969a, b; Tattersall and Simons, 1969; Chopra and Kaul, 1975; Chopra et al., 1979).

An absolute chronology now exists for most of the Pakistani sites (Tauxe, 1979; Barndt et al., 1978; Tauxe and Opdyke, 1982; N. M. Johnson et al., 1982), and correlations have been made of the primate and non-primate fauna and resultant biochronology with other Old World sites (Pilbeam et al., 1979; Barry et al., 1982). The results presented herein establish for the first time the absolute chronology, based upon a magnetic polarity stratigraphy,

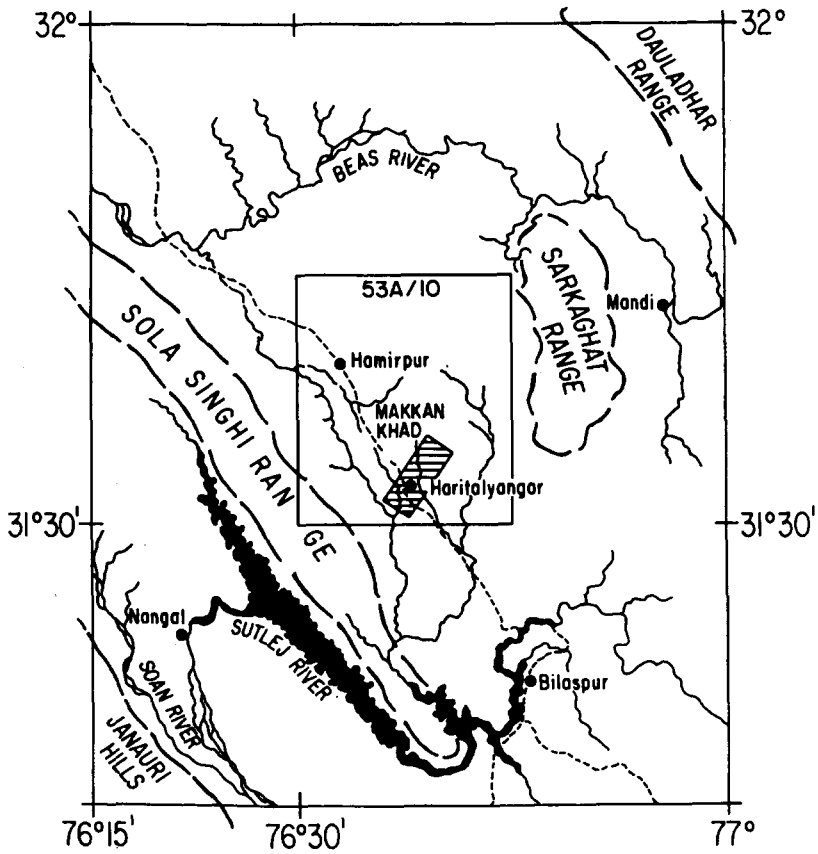


Fig.3. Location map of the Haritalyangar area, Himachal Pradesh, India. See Fig.1 for regional setting.

of the Haritalyangar site in northern India. This site has yielded the holotype of *Gigantopithecus bilaspurensis* (Simons and Chopra, 1969a, b), and other important specimens of *Sivapithecus indicus* (Pilgrim, 1910, 1927; Prasad, 1962; Simons and Pilbeam, 1965, 1971; Pilbeam et al., 1977, 1980; Pilbeam, 1982, *S. sivalensis* (Brown et al., 1924; Pilgrim, 1927; Lewis, 1934, 1936; Pilbeam et al., 1977) and *Ramapithecus punjabicus* (Pilgrim, 1910; Lewis, 1934) (Table I).

MAGNETIC POLARITY STRATIGRAPHY

Procedures

In excess of 2000 m of relatively undeformed sediments of the Siwalik Group are exposed in the Gumbhar—Sarkarghat thrust sheet of the Punjab/ Himachal Pradesh structural re-entrant of the outer Himalayan foothills (G.D.

TABLE I

Hominoidea from the vicinity of Haritalyangar, District Bilaspur, H.P., India

Repository abbreviations as follows: CYP = Chandigarh—Yale Project (Dep. of Anthropology, Panjab University, Chandigarh, India); GSI = Geological Survey of India, Calcutta, India; MCZ = Museum of Comparative Zoology, Harvard, Cambridge, MA; YPM = Yale—Peabody Museum, New Haven, Conn. Speciation *sensu* Simons and Pilbeam (1965, 1971), Simons (1969a, b), Pilbeam (1978) and Pilbeam et al. (1977).

Sivapithecus indicus (Pilgrim) 1910		
GSI	189*	mandibular symphysis, left half w/roots of I_{1-2}, $\overline{C}$, and P_3
	190*	right P_3
	196*	maxilla, right half w/C, p^{3-4}, M^{1-3}
	197	mandibular ramus, left half w/symphysis
	18039	mandibular ramus, left half w/crowns of P_3—M_3
	18040*	mandibular ramus
	18065	right $\underline{P}$
	18066*	$\underline{C}$ (several specimens)
	18069	P_3
	18070	M
YPM	13828*	mandibular ramus, left, fragment
	13837	2 crowns
	16919*	I^1
Sivapithecus sivalensis (Lydekker) 1879?		
GSI	K29/466(617)	maxilla
	18041	M_1 (several specimens)
	18042	M_1
	18064	maxilla fragment
	18067	right $\overline{M}$
YPM	13825	mandibular ramus, right, fragment w/M_{2-3}
Hominoidea indet.		
CYP (PUA)	58369**	left M_3
	76069**	M_3?
	104769	symphysis w/roots of I_{1-2}, $\overline{C}$, and P_{3-4}
	105269**	right P_3
	112869**	right I^1
GSI	D-191	maxilla, left, fragment w/M^{2-3}
Ramapithecus punjabicus (Pilgrim) 1910		
GSI	D-185	maxilla, right, fragment w/P^3, P^4, M^{1-2} and adjacent parts of alveoli of $\underline{C}$ and M^3
	D-199	mandibular ramus, left, w/P_4—M_3
	18068	left M^3
MCZ	6205	maxilla, right, fragment w/M^{1-2}
YPM	13799	maxilla and pre-maxilla, right w/distal portion of I^1 alveolus, root of I^2, $\underline{C}$ alveolus, P^3—M^2
	13806	mandibular ramus, right, fragment w/M_{2-3}
Gigantopithecus bilaspurensis Simons and Chopra 1968		
CYP (PUA)	359/68	mandibular rami w/$\overline{C}$, P_3, M_{1-3} (left) and $\overline{C}$, P_{3-4}, M_{1-3} (right)

*Possibly from same individual (Simons and Pilbeam, 1971).
**Provisional field identifications.

Johnson and Vondra, 1972). A number of transverse streams developed on this terrane result in the excellent exposure of this non-marine sequence. In the vicinity of Haritalyangar (Fig.3) about 1600 m of fossiliferous, fluvial sediments characterized by alternating lateral accretion (channel) sandstones and vertical accretion (floodplain) mudstones occur as gentle, northeast-dipping, cuesta-forming strata. Exposures to the east and southeast of the villages of Haritalyangar constitute the bulk of the fossil-bearing strata and have been prolific sources of primate fossils over the years (Figs.4 and 5).

Within this stratigraphic context 77 magnetic sites were established in outcrops along the Makan Khad (stream) and one of its tributaries, the Aur Khad, west and northwest of Haritalyangar. The stratigraphically lowest magnetic sites occur at the eastern mouth of the canyon where the Makan Khad flows southwest through the Jhangar Dhar (hill) west of the villages. Additional sites were established in the cuesta scarp of Hari Mandar Dhar, east of Haritalyangar, and along fresh road cuts and outcrops between the villages of Dangar and Susnal. The stratigraphically highest sites were sampled from outcrops along the Rohul Khad to within the vicinity of Domira, 3 km northeast of Haritalyangar. From three to five oriented samples were collected at each site according to procedures outlined in N. M. Johnson et al. (1975).

All samples were measured on a commercially available spinner magnetometer (Molyneux, 1971). Related work on Miocene-aged sediments from the Potwar Plateau of Pakistan has shown that partial thermal demagnetization of these sediments is by far the best technique to use to determine the character of the residual depositional remanent magnetization held within these rocks (Tauxe et al., 1980). This may be due to the fact that a considerable proportion of the remanence resides in high blocking temperature minerals, undoubtedly hematite, present in these sediments. Therefore, sixteen representative samples were subjected to partial thermal demagnetization in steps up to 665° C in order to characterize sample magnetic stability. Two examples of such treatment presented as Zijderveld diagrams (Zijderveld, 1967) are shown in Fig.6. In most cases, a characteristic direction of magnetization was isolated which decayed towards the origin. Often a low-temperature component of magnetization was removed at temperatures up to 400° C. As a result of this analysis, all 77 sites were thermally demagnetized at a temperature of 606° C.

Analysis

Table II gives the statistical parameters of all Class A sites (see below) of both normal and reversed polarities. The mean direction of magnetization for all normal and reversed sites have overlapping circles of confidence (Fig.7), indicating both that the sediments from the Haritalyangar locality pass the polarity reversal test and that the directions of magnetization are stable and probably primary. The directions of magnetization are, however, about 20° shallower than the direction of the modern dipole field at this

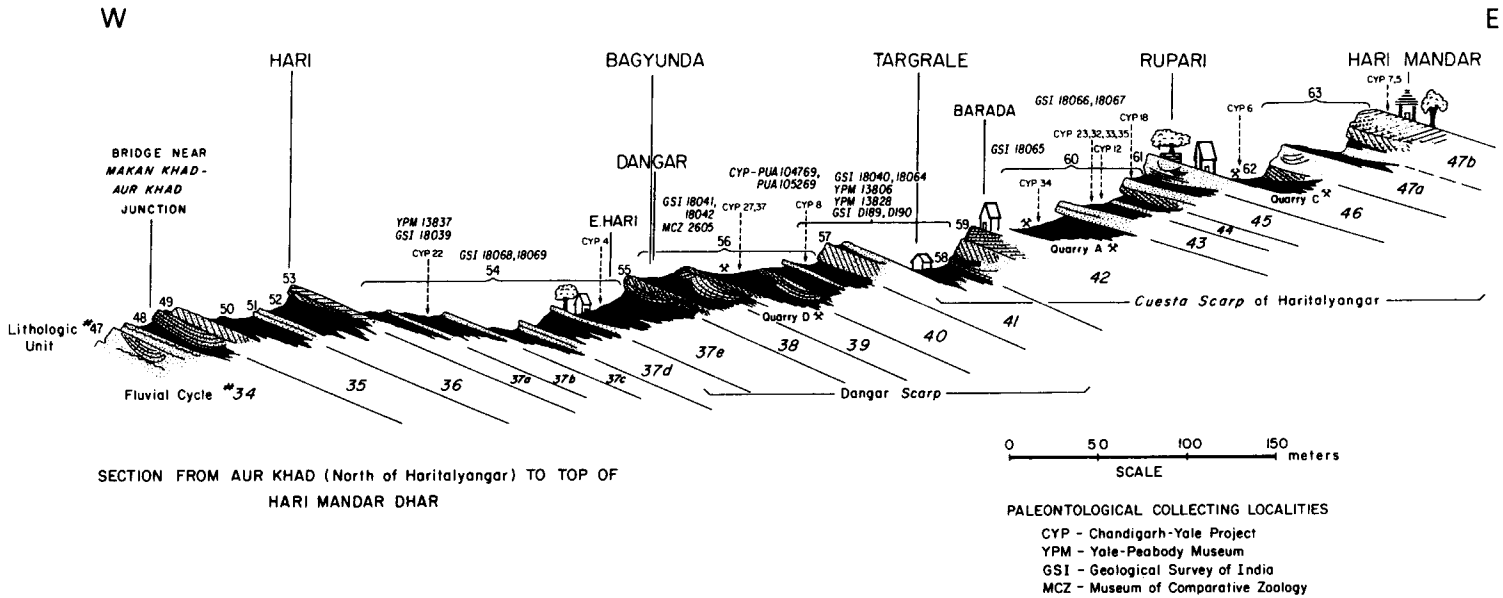
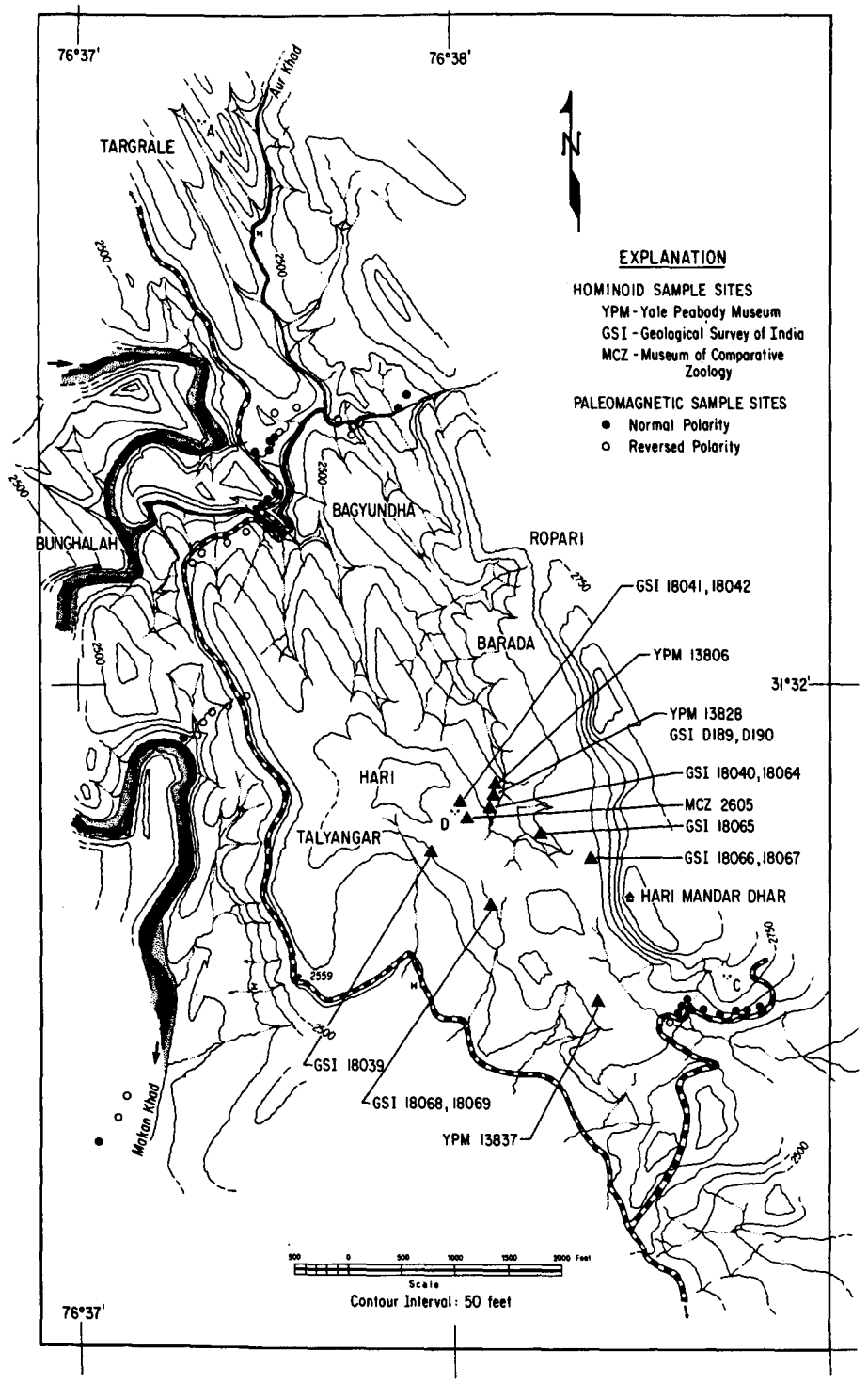


Fig.4. Schematic profile of the alternating sequence of lateral accretion (channel), sandstones (patterned) and vertical accretion (floodplain), mudstones (black) developing a cuesta-forming topography east of the villages of Haritalyangar. Paleontological collecting localities and the probable stratigraphic occurrence level of certain hominoid primate specimens (italics) are indicated. Refer to Fig.8 for stratigraphic position of various lithologic units. See Table I for description of fossil specimens.


76°37'
76°38'
Aur Khad
TARGRALE
2500
2559
BUNGHALAH
BAGYUNDHA
ROPARI
2750
BARADA
31°32'
HARI
TALYANGAR
D
C
HARI MANDAR DHAR
Makan Khad
GSI 18041, 18042
YPM 13806
YPM 13828
GSI D189, D190
GSI 18040, 18064
MCZ 2605
GSI 18065
GSI 18066, 18067
GSI 18039
GSI 18068, 18069
YPM 13837
N
EXPLANATION
HOMINOID SAMPLE SITES
YPM - Yale Peabody Museum
GSI - Geological Survey of India
MCZ - Museum of Comparative Zoology
PALEOMAGNETIC SAMPLE SITES
Normal Polarity
Reversed Polarity
500 0 500 1000 1500 2000 Feet
Scale
Contour Interval: 50 feet
76°37'

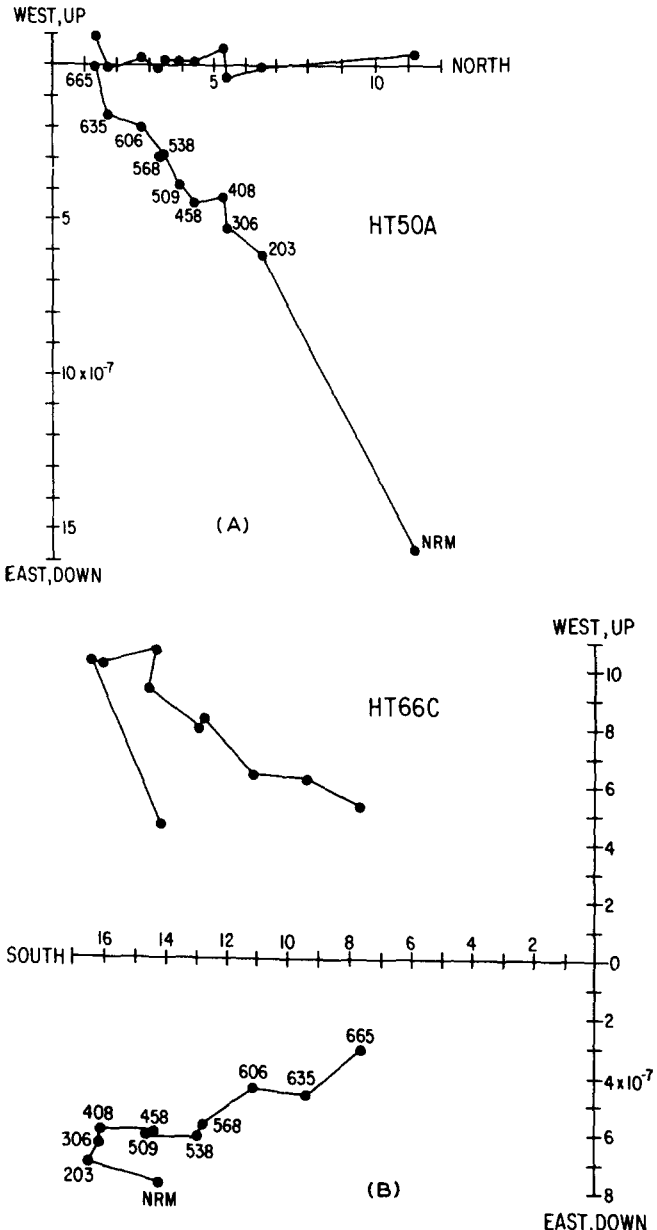


Fig.6. Representative Zijderveld diagrams of thermally demagnetized samples from Haritalyangar. See Fig.8 for stratigraphic position of samples.

Fig.5. Location map of paleomagnetic sample sites in the vicinity of Haritalyangar. Approximate location where certain hominoid primate specimens were most likely recovered. Based on published and original field notes and maps. Topography by G. Johnson, C. Vondra and T. Bown. Fossil hominoid sample sites interpreted by G. Johnson, T. Bown and G. Meyer.

TABLE II

Mean of Class A sites

	N	Dec	Inc	α_{95}	κ	R
Normal	30	7.58	33.26	5.21	26.38	28.9
Reversed	21	187.44	−25.68	6.43	25.44	20.21

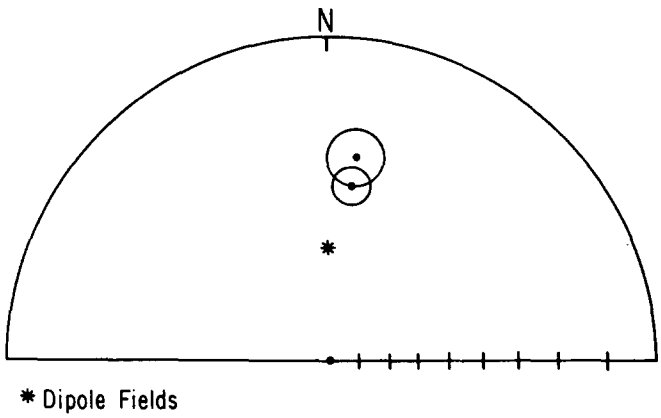
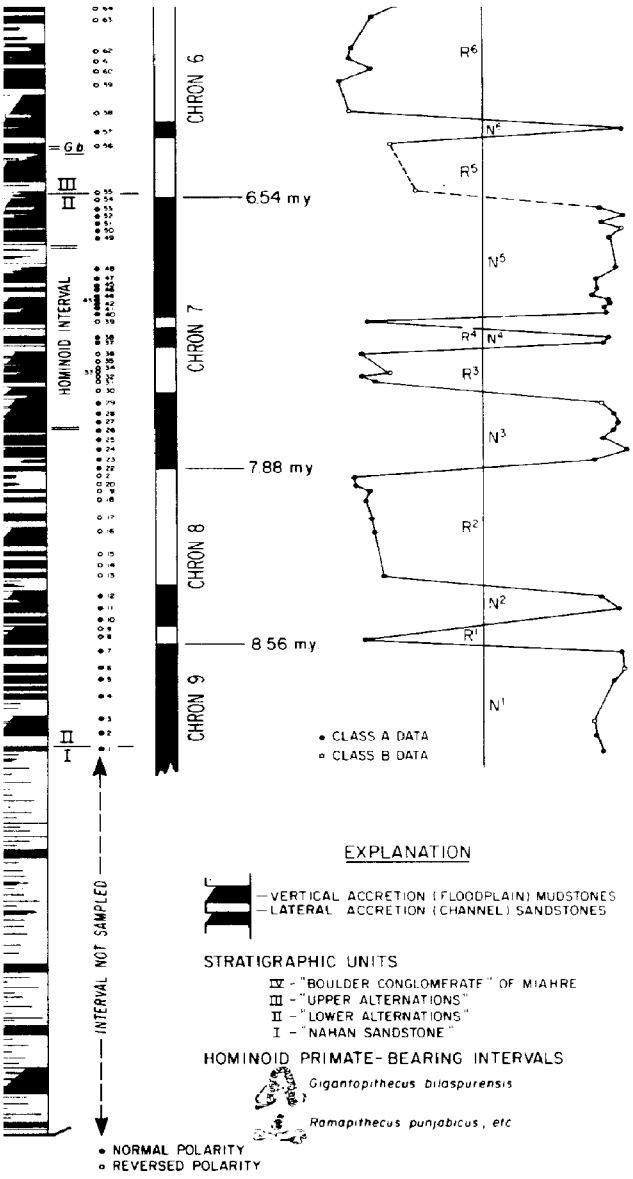


Fig.7. Class A site means at 606°C of magnetic vector inclination and declination for Haritalyangar samples. Position of present dipole field is indicated. Circles represent 95% confidence limits. See Table II.

locality. This has been noted before in equivalent Miocene-aged rocks of the Potwar Plateau in Pakistan (Tauxe et al., 1980; Tauxe and Opdyke, 1982), 200 km to the west. Here the phenomenon has been attributed to the combined effects of bedding error due to compaction of specular hematite and to the continued northward motion of the Indian lithospheric plate. This explanation is also favored by the present authors.

The mean declinations of the normal and reversed sites are almost exactly opposed (Fig.7) and show a rotation of about 7.5° in a clockwise direction. Siwalik Group rocks of like age from the Potwar Plateau show similar or greater amounts of rotation but in a counter-clockwise sense (Opdyke et al., 1982). The rotation observed at Haritalyangar probably took place during the thrusting of the Gumbhar—Sarkghat thrust sheet to the southwest during the Plio-Pleistocene and represents the complementary motion to that of the Potwar Plateau about the Nanga Parbat—Haramosh or northwest Himalayan syntaxis.

A virtual geomagnetic pole (VGP) latitude was calculated for each sample site. The results were classified as statistically significant if $k \geqslant 10$ and were



representation of the lithologic character, magnetic polarity stratigraphy on of the virtual geomagnetic pole (VGP) latitude for Class A and B sites angar section. Our interpretation of the geomagnetic chron boundaries .9 and discussion in text) is included for clarity. See Fig.4 for schematic he "hominoid interval" outcropping east of the villages of Haritalyangar. s from G. D. Johnson and Vondra (1972) and Gill (1951).

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designated Class A data (Tauxe and Opdyke, 1982). In those cases where only two samples survived pre-treatment and the two samples yielded concordant data, they were designated class B. Randomly magnetized sites were given a Class C designation. This analysis allowed the establishment of a magnetic polarity stratigraphy (MPS) for the 77 sites.

After demagnetization, 56 sites yielded Class A data. Eight sites yielded Class B data, and 13 sites yielded Class C. The resultant MPS, compiled from Class A and B data, indicates that approximately 50% of the section is reversely magnetized (magnetozones R^1—R^7) (Fig.8), with the remainder representing normal polarity intervals (magnetozones N^1—N^8). Several magnetozones are represented by only one sample site (magnetozones R^1, R^4, and N^6).

CORRELATION OF THE HARITALYANGAR MAGNETIC POLARITY STRATIGRAPHY TO THE MAGNETIC POLARITY TIME SCALE

The interpretation of the MPS of the Haritalyangar sequence is equivocal when compared to the magnetic polarity time scale (MPTS) for the late Neogene and Quaternary. The MPS established for sites in Pakistan which yield a fauna similar to that of Haritalyangar exhibits a long-duration normal polarity magnetozone within the polarity record. Additionally, most of the Pakistani localities contain at least one volcanic ash, usually associated with this long normal polarity interval (N. M. Johnson et al., 1982; G. D. Johnson et al., 1982). Fission-track dating of the ash at the Nagri stratotype yielded an age of 9.46 m.y. ± 0.59 (G. D. Johnson et al., 1982), identifying the long normal polarity interval as Chron 9 of the MPTS.

Although no dateable volcanic ashes have been found at Haritalyangar, if the presence of *Ramapithecus* and related fauna (e.g., *Hipparion* spp. throughout the entire stratigraphic section, the rhizomyids *Kanisamys sivalensis*, *Brachyrizomys nagrii* and *B. pilgrimi*, and other larger fauna: *Tetraconodon magnus*?, *Dorcatherium majus*? and *Deinotherium* sp.) (Colbert, 1935; Pascoe, 1964; Prasad, 1970; Flynn, 1982) is indicative, the time spanned by the Haritalyangar sequence must be younger than the first appearance datum of *Hipparion* s.l. in the subcontinent and may *encompass* 8 m.y., the age of the last appearance datum of *Ramapithecus* in nearby Pakistan (Tauxe, 1979). Additionally, using the random sampling model of Johnson and McGee (1983) for calculating time estimates from paleomagnetic data, the predicted age span of the Haritalyangar stratigraphic section should be 2.5 m.y. ± 0.6 (Table III). Based on these constraints, we have made the correlation of the Haritalyangar MPS with the MPTS as shown in Fig.9. No other correlation involving Late Miocene chronologies appears reasonable. Within this context, a striking similarity between the Haritalyangar MPS and the immediate post-Chron 9 portion of the MPTS exists.

Magnetozones N^3—N^5 of the Haritalyangar MPS (Fig.9) essentially replicate

TABLE III

Estimate of the Haritalyangar stratigraphic time span using the random sampling model of N. M. Johnson and McGee (1983)

Given

N = number of sampling sites = 64
R = number of magnetic reversals (transitions) = 14
$\bar{\tau}$ = mean polarity interval for the Neogene = 120,000 yr.

Derived

p = manifest sampling probability = $R/(N-1)$ = 0.222
$\overline{S_r}$ = mean sample spacing* = $\Delta t/\bar{\tau}N$ = 0.325 ± 23.5%
Δt = $0.325\bar{\tau}N$ = 2.5 ± 0.6 m.y.

*From Johnson and McGee (1983, eq. 5) 1σ sampling fluctuation = $[p(1-p)(N-1)]^{0.5}$ = 3.3% sampling fluctuation = $(\sigma/R) \times 100$ = 23.5%.

the polarity character of Chron 7 of the MPTS. Given these apparent correlations, R^5—R^6 can be identified as Chron 6, R^1—R^2 represents Chron 8 and N^1 appears to be the upper portion of Chron 9. N^7—N^8 represent Chron 5. The top of the Haritalyangar section appears to end within upper portion of Chron 5 (Fig.9). A correlation coefficient of 0.998 can be demonstrated between the Haritalyangar MPS and this indicated portion of the post-Chron 9 MPTS. Additionally, the data suggest a rather constant rate of sedimentation at the Haritalyangar site over the stratigraphic interval sampled (30 cm per 1000 yr).

HISTORICAL FAUNAL CORRELATION

Numerous arguments exist concerning the Haritalyangar non-primate fauna and their correlation with other Old World and even New World sites. Although the entire stratigraphic interval at Haritalyangar is demonstrably fossiliferous, major collecting bias exists in nineteenth and twentieth century collections in favor of accessible outcrops within a short distance of the villages and the old Bilaspur—Hamirpur cart road. Repeatedly, locality descriptions from many sources indicate fossil specimens coming from the cuesta scarps of Dangar and Haritalyangar and from within the vicinity of Hari Temple, the Hindu shrine at the crest of Hari Mandar Dhar, 0.8 km southeast of Haritalyangar (Pilgrim, 1910, 1927; Lewis, 1934; Colbert, 1935; Gregory et al., 1938; Prasad, 1962, 1964, 1970; Prasad, pers. commun., 1969; Pascoe, 1964; Simons and Chopra, 1969a, b; Tattersall and Simons, 1969; G.D. Johnson and Vondra, 1972; Chopra and Kaul, 1975; G.D. Johnson, 1977; Vasishat et al., 1978; Chopra et al., 1979; Chopra and Vasishat, 1979).

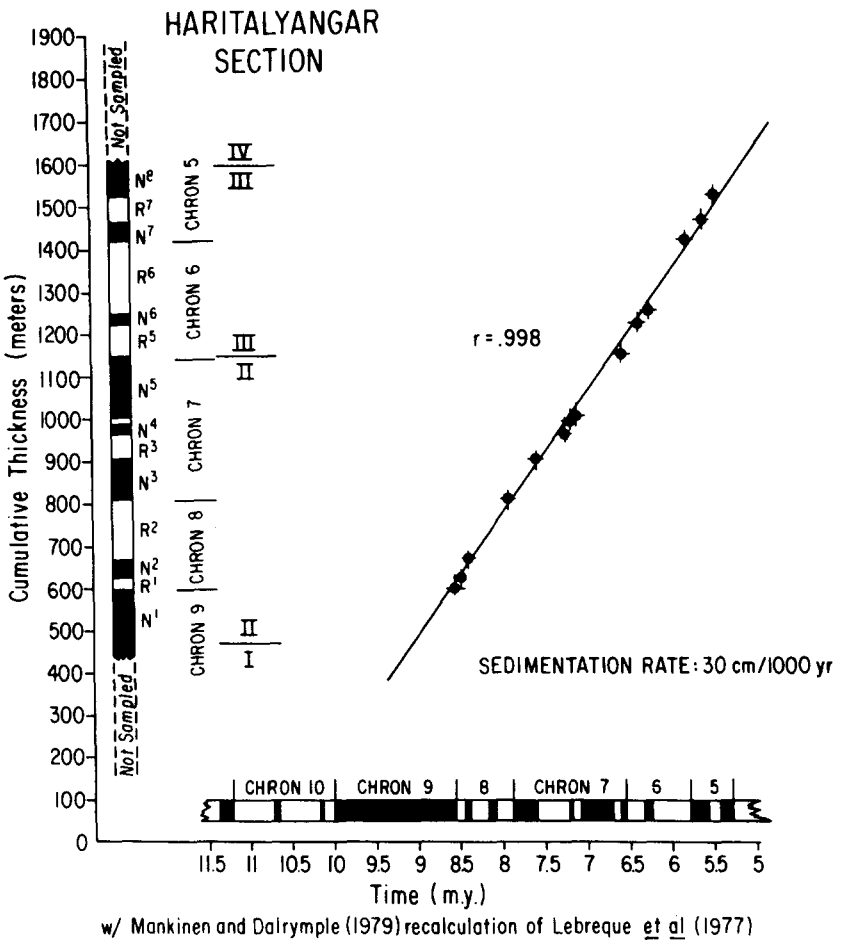

Fig.9. Correlation of the Haritalyangar magnetic polarity stratigraphy (MPS) with the magnetic polarity time scale (MPTS) of Labrecque et al. (1977). See Fig.8 for interpretation of the lithostratigraphic units (*I, II, III, IV*) associated with the MPS.

Analysis of original and published field notes and maps of several collecting expeditions to the Haritalyangar region [American Museum of Natural History (Brown et al., 1924; Colbert, 1935; Gregory et al., 1938), Yale Peabody Museum/Panjab University (G. D. Johnson et al., 1969) and Geological Survey of India (Pascoe, 1964; Prasad, 1969, 1970)] confirms a rather limited stratigraphic context to the primate and some of the non-primate taxa taken from the area and makes possible tentative assignments of probable stratigraphic position for a number of the fossil specimens (Figs.4 and 5).

This interval, represented by stratigraphic units Nos. 49—70 (Fig.8) contains the fauna traditionally used to make the correlation of the Haritalyangar strata with the Siwalik stratotype of the Potwar Plateau to the west. Of

particular significance is the extremely narrow interval from which the hominoid primates *Sivapithecus indicus* and *S. sivalensis* and *Ramapithecus punjabicus* have apparently been collected: Stratigraphic units Nos. 54—63 (Figs.4 and 8), a thickness of some 200 m. Also of importance is the horizon that is presumed (Simons and Ettel, 1970) to have yielded the holotype of *Gigantopithecus bilaspurensis* (Simons and Chopra, 1969a, b). Collectively, these strata, the upper portion of the "Lower Alternations" of Gill (G. D. Johnson and Vondra, 1972; Gill, 1951) and the lower portion of his "Upper Alternations", are those which have been generally identified as upper Nagri and lower Dhok Pathan equivalent.

INTERPRETATION

The establishment of a magnetic polarity stratigraphy for the Haritalyangar sequence allows for age limits to be placed on the important hominoid primate-bearing intervals discussed above. Stratigraphic units Nos. 54-63 occur within a local magnetozone interpreted by us as Chron 7, specifically Chron 7.20—7.85*. The *Sivapithecus indicus* and *S. sivalensis* and *Ramapithecus punjabicus* of this interval (Table I) thus have a chronostratigraphic age of 6.8—7.7 m.y. Most specimens have been recovered from the cuesta scarp at Dangar (Figs.3—5) and related superposed strata along a northwesterly strike continuation to just east of Haritalyangar at Hari Mandar scarp. This is represented by stratigraphic units Nos. 56—60, whose interpolated age is about 7.0—7.5 m.y. (Fig.8). This represents the youngest known age reported for these hominoid primates in the Siwalik Group of India and Pakistan, in effect the last appearance datum within the South Asian land mammal biochronology. The holotype of *Gigantopithecus bilaspurensis* was apparently derived from stratigraphic unit No. 68. This occurs within our Chron 6 of the MPTS. The horizon occurs specifically at Chron 6.75 with an approximate chronostratigraphic age of 6.3 m.y.

The results of this analysis show that the Haritalyangar local fauna is of a latest Miocene age. It is younger than the *type* Nagri faunal zone (N. M. Johnson et al., 1982) to which many taxa were tentatively assigned and is younger than the *type* Dhok Pathan of the central Potwar Plateau (Barndt et al., 1978; Tauxe, 1979; N. M. Johnson et al., 1982; Tauxe and Opdyke, 1982). The hominoid primate-bearing stratigraphic interval correlates with

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*We have made reference to stratigraphic position within magnetic polarity chrons as follows: Convention within the MPTS is to assign higher numbers in naming progressively older polarity chrons. For example, Chron 7 is older than Chron 6. We have chosen to represent position within a polarity chron of a local MPS as a decimal fraction of the stratigraphic interval represented by the entire chron. In this method for example, a site identified as Chron 6.90 is stratigraphically lower, and therefore older than one identified as Chron 6.75. Chron 6.75 in this context represents a stratigraphic level 75% of the stratigraphic thickness of the local Chron 6 *below* the Chron 6/Chron 5 boundary or 25% of the stratigraphic thickness of the local chron 6 *above* the Chron 7/Chron 6 boundary.

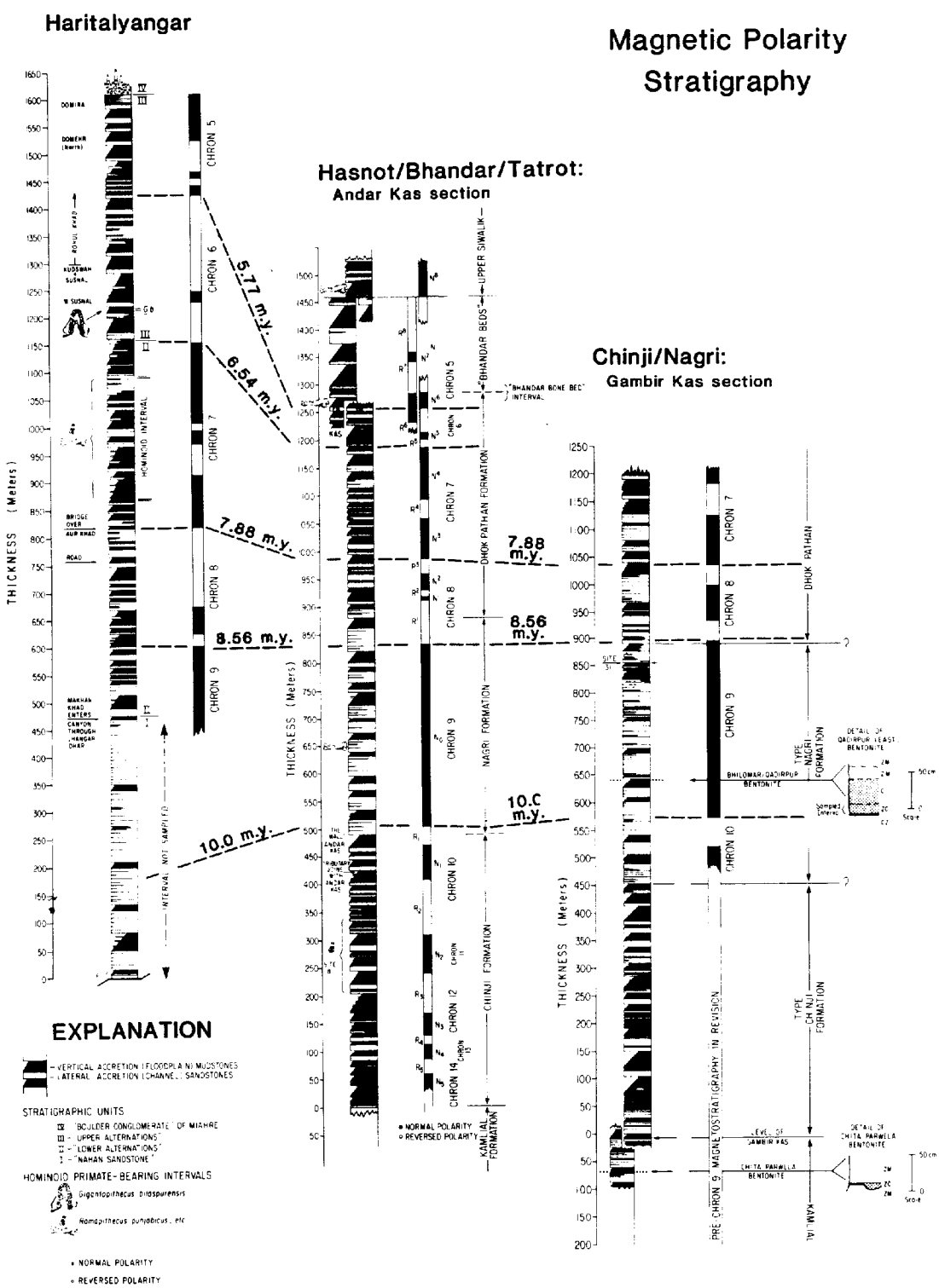

Fig. 10. Correlation of the Haritalyangar magnetic polarity stratigraphy (MPS) with that for the Nagri—Chinji stratotype and the Hasnot—Bhandar—Tatrot areas of the Potwar Plateau and eastern Salt Ranges, northern Pakistan (Figs. 1 and 2). This correlation is made on the isochron defined by the geomagnetic Chron 9/Chron 8 boundary and that defined by the Chron 7/Chron 6 boundary (dashed lines). The differences in enclosed sedimentary thickness among these three localities reflect differing sedimentation rates per unit of time. Nagri—Chinji stratotype data from G.D. Johnson et al. (1982). Hasnot—Bhandar—Tatrot data modified from N.M. Johnson et al. (1982) and unpublished data.

pp. 241—244.

the lower portion of the recently defined *Selenoportax lydekkeri* interval zone and a portion of the underlying "*Hipparion* s.l." interval zone (Barry et al., 1982) from the central Potwar Plateau of Pakistan, which is within the Dhok Pathan type area. Comparison with the MPS of the Nagri stratotype indicates that the Haritalyangar local fauna occurs at least one million years later than the top of the Nagri. This correlation would define the Haritalyangar fauna as equivalent to that of the latest Dhok Pathan faunal zone in traditional terms. Further, comparison of the Haritalyangar MPS with that from the Hasnot—Bhandar—Tatrot area (N. M. Johnson et al., 1982) of the eastern Salt Range of Pakistan indicates contemporaneity between the Dhok Pathan facies underlying the "Bhandar Bone Bed" interval and the Haritalyangar local fauna. This was predicted with unusual prescience by W. D. Matthew in 1928 (Matthew, 1929) (Fig.10).

In the light of the above interpretations, historical reference to faunal collections made from the "Dangar scarp" may now be assigned chronostratigraphic ages of 7.6—7.2 m.y.; those made from the "Hari scarp" ("cuesta scarp of Haritalyangar", etc.) may be assigned chronostratigraphic ages of 7.3—6.9 m.y. A probable stratigraphic occurrence of selected hominoid specimens recovered from the Haritalyangar area and their assigned chronostratigraphic age is presented in Fig.11. These data are qualified and, being based on our review of available documentation and our own field mapping, represent our best estimation of the stratigraphic occurrence of these hominoid primates from Haritalyangar.

The Nahan Sandstone. Although it is not the intent of this analysis to comment on the sedimentary tectonics of the Siwalik Group in light of this chronostratigraphy, an important inference may be made as to the age of the pre-"Lower Alternations" sedimentary sequence illustrated in Figs.8 and 10. The so-called Nahan Sandstone, a massive sequence of multi-storied lateral accretion (channel) facies of great areal extent, developed from the Haritalyangar area in the northwest to near Dehra Dun in the southeast, has been problematic in its age interpretation. The formation, interpreted to be the result of deposition from a loosely sinuous, sand-bed stream regime dominated by high sedimentation rates and derived from a relatively proximal source terrane (Johnson and Vondra, 1972), is akin to the facies style of the Nagri Formation of the Potwar Plateau in Pakistan. The Nagri Formation at its stratotype, similarly characterized by the dominance of multistoried sandbodies, is distinctly different in facies style from its underlying and overlying fluvial facies which reflect a greater sinuosity, meanderbelt-dominated fluvial regime.

The Nagri at its stratotype and in equivalent facies exposed at Hasnot—Bhandar—Tatrot (Figs.2 and 10) appears to be roughly coeval with the Nahan Sandstone of the Haritalyangar area. Although we did not sample the Nahan in our study of the magnetic polarity stratigraphy of the Haritalyangar area, our lowest sample site occurs at the end of Nahan "time" and represents

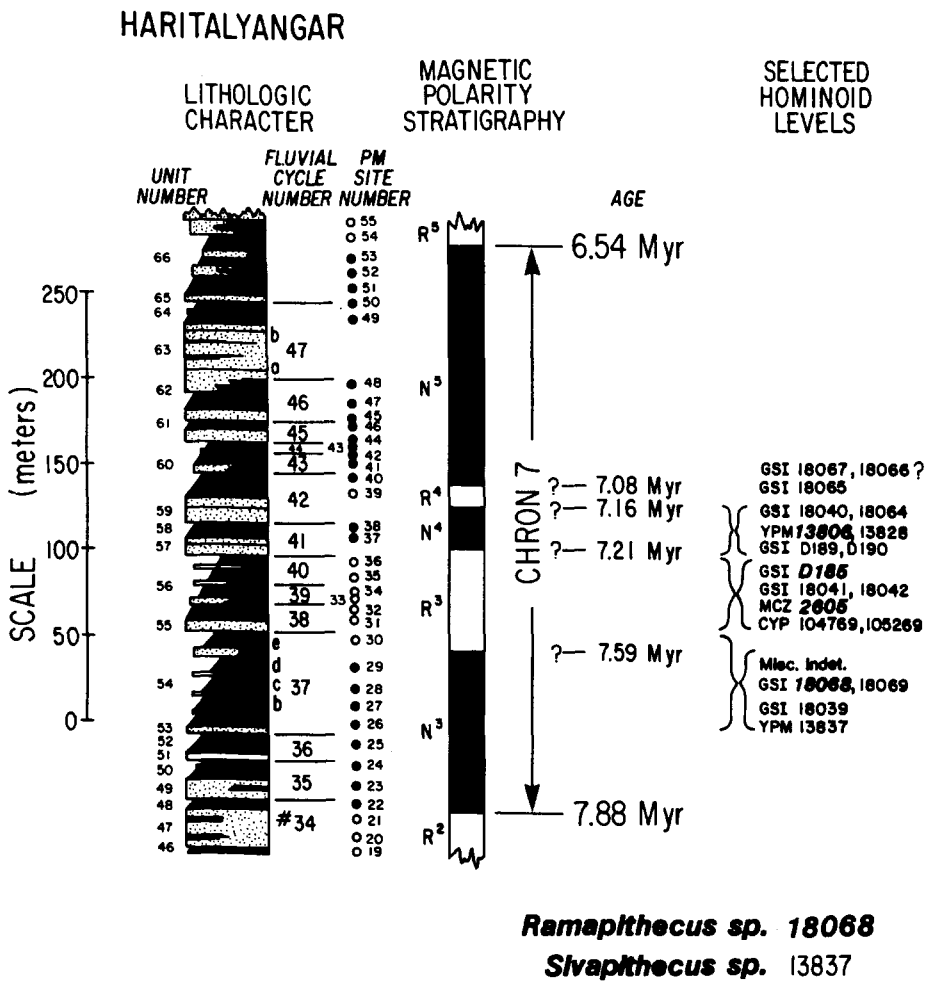

Fig.11. Stratigraphic position of selected hominoid primate specimens collected from the Haritalyangar area. Based on interpretation of published and unpublished field notes and maps. Approximate chronostratigraphic ages, determined from the magnetic polarity stratigraphy determined for the area (Figs.8 and 9) are indicated. See Figs.4 and 5 for geographic distribution.

an age of approximately 9.2 m.y. (the middle of magnetic Chron 9) (Fig.9). If the observed sedimentation rate of 30 cm per 1000 yr is extended to the base of the measured stratigraphic section exposed along the Makkan Khad where it cuts through the Jhangar Dhar west of Haritalyangar (Fig.8), the lowermost Nahan facies exposed in this area are at least as old as 10.8 m.y. (the upper part of magnetic Chron 10).

The temporal and facies similarities of the Nagri—Nahan formations (lithofacies) suggest that they may be responding to similar controls exerted by their respective source terranes. This parallelism in facies style may be linked

to the depositional controls exerted by the antecedent, ancestral Indus/ancestral Jhelum River systems on these two distinct facies of the Siwalik Group in the northwestern Himalaya.

SUMMARY

The development of a magnetic polarity stratigraphy for the Haritalyangar site raises the last appearance datum of *Sivapithecus indicus* and *S. sivalensis* and *Ramapithecus punjabicus* (Pilbeam et al., 1977; Tauxe, 1979; Pilbeam, 1982) in Asia by nearly 1 m.y. from about 8 m.y. ago to approximately 7 m.y. ago. An even younger age (6.3 m.y.) is assigned to the holotype specimen of *Gigantopithecus bilaspurensis.*

The "Nahan Sandstone" of the Haritalyangar area appears to be a temporal equivalent of the Nagri lithofacies of the Potwar Plateau of Pakistan. Accordingly, the "Lower and Upper Alternations" of the Haritalyangar area are similar to the Dhok Pathan lithofacies of Pakistan.

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REFERENCES

Barndt, J., Johnson, N. M., Johnson, G. D., Opdyke, N. D., Lindsay, E. H., Pilbeam, D. and Tahirkheli, R. A. K., 1978. The magnetic polarity stratigraphy and age of the Siwalik Group near Dhok Pathan Village, Potwar Plateau, Pakistan. Earth Planet. Sci. Lett., 41: 355—364.

Barry, J. C., Lindsay, E. H. and Jacobs, L. L., 1982. A biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 37: 95—130.

Brown, B., Gregory, W. K. and Hellman, M., 1924. On three incomplete anthropoid jaws from the Siwaliks, India. Am. Mus. Novit., 130: 1—9.

Chopra, S. R. K. and Kaul, S., 1975. New fossil *Dryopithecus* material from the Nagri beds at Haritalyangar (H.P.), India. Contemporary Primatology (Karger, Basel), pp. 2—11.

Chopra, S. R. K., Kaul, S. and Vasishat, R. N., 1979. Miocene tree shrews from the Indian Siwaliks. Nature, 281: 213—214.

Chopra, S. R. K. and Vasishat, R. N., 1979. Siwalik fossil tree shrew from Haritalyangar, India. Nature, 281: 214—215.

Colbert, E. H., 1935. Siwalik mammals in the American Museum of Natural History. Trans. Am. Philos. Soc., N.S., 26: 1—401.

Dutta, A. K., Basu, P. K. and Sastry, M. V. A., 1976. On the new finds of hominids and additional finds of pongids from the Siwaliks of Ramnagar area, Udhampur District, J. and K. State. Indian J. Earth Sci., 3: 234—235.

Flynn, L. J., 1982. A revision of fossil rhizomyid rodents from northern India and their correlation to a rhizomyid biochronology of Pakistan. Geobios, 15: 583—588.

Gill, W. D., 1951. The tectonics of the Sub-Himalayan fault zone in the northern Potwar region and in the Kangra district of the Punjab. Q. J. Geol. Soc. (London), 107: 395—421.

Gregory, W. K., Hellman, M. and Lewis, G. E., 1938. Fossil anthropoids of the Yale—Cambridge India expedition of 1935. Carnegie Inst. Wash. Publ., 495: 1—27.

Johnson, G. D., 1977. Paleopedology of *Ramapithecus*-bearing sediments, North India. Geol. Rundsch., 66: 192—216.

Johnson, G. D. and Vondra, C. F., 1972. Siwalik sediments in a portion of the Punjab re-entrant: The sequence of Haritalyangar, District Bilaspur, H.P. Himalayan Geol., 2: 118—144.

Johnson, G. D., Vondra, C. F., Bown, T. M. and Meyer, G. M., 1969. Field notes and maps compiled during the Chandigarh—Yale Project of 1968—1969.

Johnson, G. D., Johnson, N. M., Opdyke, N. D. and Tahirkheli, R. A. K., 1979. Magnetic reversal stratigraphy and sedimentary tectonic history of the Upper Siwalik Group eastern Salt Range and southwestern Kashmir. In: A. Farah and K. A. DeJong (Editors), Geodynamics of Pakistan. Geol. Surv. Pakistan (Quetta), pp. 149—165.

Johnson, G. D., Zeitler, P., Naeser, C. W., Johnson, N. M., Summers, D. M., Frost, C. D., Opdyke, N. D. and Tahirkheli, R. A. K., 1982. The occurrence and fission-track ages of Late Neogene and Quaternary volcanic sediments, Siwalik Group, northern Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 37: 63—93.

Johnson, N. M. and McGee, V. E., 1983. Magnetic polarity stratigraphy: Stochastic properties of data, sampling problems and the evaluation of interpretations. J. Geophys. Res., 88: 1213—1221.

Johnson, N. M., Opdyke, N. D. and Lindsay, E. H., 1975. Magnetic polarity stratigraphy of Pliocene/Pleistocene terrestrial deposits and vertebrate faunas, San Pedro Valley, Arizona. Geol. Soc. Am. Bull., 86: 5—12.

Johnson, N. M., Opdyke, N. D., Johnson, G. D., Lindsay, E. H. and Tahirkheli, R. A. K., 1982. Magnetic polarity stratigraphy and ages of Siwalik Group rocks of the Potwar Plateau, Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 37: 17—42.

LaBrecque, J. L., Kent, D. V. and Conde, S. C., 1977. Revised magnetic polarity time scale for the late Cretaceous and Cenozoic. Geology, 5: 330—335.

Lewis, G. E., 1933. Field notes and maps compiled during the Yale—North India Expedition of 1931—1933 (unpublished).

Lewis, G. E., 1934. Preliminary notice of new man-like apes from India. Am. J. Sci., 27: 161—179.

Lewis, G. E., 1936. A new species of *Sugrivapithecus*. Am. J. Sci., 31: 450—452.

Mankinen, F. A. and Dalrymple, G. B., 1979. Revised geomagnetic polarity time scale for the interval 0—5 m.y. B.P. J. Geophys. Res., 84, B2: 617—626.

Matthew, W. D., 1929. Critical observations upon Siwalik mammals. Bull. Am. Mus. Nat. Hist., 56: 437—560.

Molyneux, L., 1971. A complete results magnetometer for measuring the remanent magnetism of rocks. Geophys. J. R. Astron. Soc., 24: 1—5.

Opdyke, N. D., Lindsay, E. H., Johnson, N. M. and Downs, T., 1977. The paleomagnetism and magnetic polarity stratigraphy of the mammal-bearing section of Anza Borrego State Park, California. Quaternary Res., 7: 316—329.

Opdyke, N. D., Lindsay, E., Johnson, G. D., Johnson, N., Tahirkheli, R. A. K. and Mirza, M. A., 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the Upper Siwalik Subgroup of northern Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 27: 1—34.

Opdyke, N. D., Johnson, N. M., Johnson, G. D., Lindsay, E. H. and Tahirkheli, R. A. K., 1982. Paleomagnetism of the Middle Siwalik formations of northern Pakistan and rota-

tion of the Salt Range decollement. Palaeogeogr., Palaeoclimatol., Palaeoecol., 37: 1—15.

Pascoe, E. H., 1964. Manual of the Geology of India and Burma, 3rd ed. Geol. Surv. India, Calcutta, 3: 1757—1801.

Pilbeam, D. R., 1978. Rethinking human origins. Discovery (Peabody Mus. Nat. Hist., Yale Univ.), 13: 2—9.

Pilbeam, D. R., 1982. New hominoid skull material from the Miocene of Pakistan. Nature, 295: 232—234.

Pilbeam, D. R., Meyer, G. E., Badgley, C., Rose, M. D., Pickford, M. H. L., Behrensmeyer, A. K. and Shah, S. M. I., 1977. New hominoid primates from the Siwaliks of Pakistan and their bearing on hominoid evolution. Nature, 270: 689—695.

Pilbeam, D. R., Behrensmeyer, A. K., Barry, J. C. and Shah, S. M. I., 1979. Miocene sediments and faunas of Pakistan. Postilla, 179: 1—45.

Pilbeam, D. R., Rose, M. D., Badgley, C. and Lipschutz, B., 1980. Miocene hominids from Pakistan. Postilla, 181: 1—94.

Pilgrim, G. E., 1910. Preliminary notes on a revised classification of the Tertiary freshwater deposits of India. Rec. Geol. Surv. India, 11(1): 63—71.

Pilgrim, G. E., 1915. New Siwalik primates and their bearing on the questions of evolution of man and the anthropoidea. Rec. Geol. Surv. India, 45(1): 1—74.

Pilgrim, G. E., 1927. A *Sivapithecus* palate and other primate fossils from India. Palaeontol. Ind., N.S., 14: 1—24.

Pilgrim, G. E., 1934. Correlation of ossiferous sections in the Upper Cenozoic of India. Am. Mus. Novit., 704: 1—4.

Prasad, K. N., 1962. Fossil primates from the Siwalik beds near Haritalyangar, Himachal Pradesh, India. J. Geol. Soc. India, 3: 86—96.

Prasad, K. N., 1964. Upper Miocene anthropoids from the Siwalik beds of Haritalyangar, Himachal Pradesh, India. Palaeontology, 7: 124—134.

Prasad, K. N., 1969. Critical observations on the fossil anthropoids from the Siwalik System of India. Folia Primatol., 10: 288—317.

Prasad, K.N., 1970. The vertebrate fauna from the Siwalik beds of Haritalyangar, Himachal Pradesh, India. Palaeontol. India, N.S., 34: 1—55.

Simons, E. L., 1968. On the mandible of *Ramapithecus*. In: G. Kuhn (Editor), Evolution and Hominization. Fischer-Verlag, Jena, 2nd ed., pp. 139—149.

Simons, E. L. and Chopra, S. R. K., 1969a. A preliminary announcement of a new *Gigantopithecus* species from India. Proc. 2nd Int. Congr. Primatol. (Atlanta, 1968), 2: 135—142.

Simons, E. L. and Chopra, S. R. K., 1969b. *Gigantopithecus* (Pongidae, Hominoidea) a new species from north India. Postilla, 138: 1—18.

Simons, E. L. and Pilbeam, D. R., 1965. Preliminary revision of the Dryopithecinae (Pongidae, Anthropoidea). Folia Primatol., 3: 81—152.

Simons, E. L. and Ettel, P. C., 1970. *Gigantopithecus*. Sci. Am., 222: 76—85.

Simons, E. L. and Pilbeam, D. R., 1971. A gorilla-sized ape from the Miocene of India. Science, 173: 23—27.

Tattersall, I. M. and Simons, E. L., 1969. Notes on some little known primate fossils from India. Folia Primatol., 10: 146—153.

Tauxe, L., 1979. A new date for *Ramapithecus*. Nature, 282: 399—401.

Tauxe, L. and Opdyke, N. D., 1982. A time framework based on magnetostratigraphy for the Siwalik sediments of the Khaur area, northern Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol., 37: 43—61.

Tauxe, L., Kent, D. V. and Opdyke, N. D., 1980. Magnetic components contributing to the NRM of Middle Siwalik red beds. Earth Planet. Sci. Lett., 47: 279—284.

Vasishat, R. N., Gaur, R. and Chopra, S. R. K., 1978. Community structure of Middle Siwalik vertebrates from Haritalyangar (H.P.), India. Palaeogeogr., Palaeoclimatol., Palaeoecol., 23: 131—140.

Zijderveld, J. D. A., 1967. Demagnetization of rocks: Analysis of results. In: D. W. Collinson, K. M. Creer and S. K. Runcorn (Editors), Methods in Paleomagnetism. Elsevier, Amsterdam, pp. 254—286.