Geol. Bull. Univ. Peshawar, 1984, Vol. 17, pp. 145–152

PRELIMINARY PALEOMAGNETIC INVESTIGATIONS OF THE MANCHAR FORMATION, GAJ RIVER SECTION, KIRTHAR RANGE, PAKISTAN

M. JAVED KHAN[1], S. TASEER HUSSAIN[2], M. ARIF[3], & H. SHAHEED[3]

[1]Department of Geology, University of Peshawar, Pakistan.
[2]Department of Anatomy, College of Medicine, Howard University, Washington, D.C. 20059, USA.
[3]Geological Survey of Pakistan, Quetta, Pakistan.

ABSTRACT

The Manchar Formation, a Neogene molasse sequence in the Kirthar Range, consists of alternating units of sandstones and shales/siltstones/claystones, with some conglomerates. The "lower Manchar" has abundant sandstone units, the "middle Manchar" has abundant shale units, and the "upper Manchar" has abundant sandstone and conglomerate units. The "lower Manchar" is most fossiliferous, the "middle Manchar" has almost no fossils, and the "upper Manchar" has only a few fossils. Preliminary results of the paleomagnetic studies show that the fine-grained shale/siltstone/claystone units are suitable for magnetostratigraphic studies. Paleomagnetic studies show that NRM of many of the samples is composite of a secondary component of remanent magnetization, and a stable, hopefully primary, component of remanent magnetization. AF treatment of upto 400 Oe is helpful to remove the secondary component of remanent magnetization but the stable and primary component can't be obtained with certainity by AF treatment of upto 900 Oe. On the other hand PTD enables to remove the secondary magnetization by heating at 200°C, and also successfully isolates the stable, hopefully primary, component of remanent magnetization. Therefore all samples were subjected to a single step thermal demagnetization at 400°C, and stable components of remanent magnetization were obtained. These stable directions were used to establish a magnetic-polarity-reversal sequence. Based on the Middle to Late Miocene faunal contents of the Manchar Formation the observed magnetic-polarity-reversal sequence is correlated with the Magnetic Polarity Time Scale. This correlation suggests that the sampled part of the Manchar Formation ranges from 15.2 Ma. to 9–10 Ma.

INTRODUCTION

The stratigraphic sequence exposed along the Gaj river represents continuous series of rock formations spanning approximately from the Middle Eocene to Pliocene in age. These formations include (from oldest to youngest) the Kirthar Formation, Nari Formation, Gaj Formation, Manchar Formation, and Dada Conglomerate. Present studies are concentrated on the magnetic-polarity stratigraphy (MPS) of the Manchar Formation, and are based on preliminary paleomagnetic sampling. The results suggest that MPS can successfully be used for chronostratigraphic correlation of the Manchar Formation. Present interpretation of the results is tentative, however, and will be substantiated by further collection of paleomagnetic samples at a later stage.

The Manchar Formation represents a Neogene molasse sequence of the Kirthar Range. It was first described by Blanford (1876, 1879) after rocks adjacent to Manchar Lake, and later by Vredenburg (1906). Shah (1977) assigned the name "Siwalik Group" to the molasse sequence of Lower Indus Basin (including Kirthar Range). Following subdivision of the Siwalik Group in the Potwar Plateau, the Siwalik Group of the Lower Indus Basin also is divided into, from base to top, the Chinji, Nagri, Dhok Pathan, and Soan Formations (Shah, 1977). This was done mostly on the basis of lithologic similarities and homotaxial relationships, of the major lithological variations within the Siwalik Group. Fossil contents were given consideration but recent collection of vertebrate fauna by one of us (Hussain, S.T.) from the Kirthar Range does not substantiate the above mentioned subdivision of the Siwalik Group. Therefore we prefer to use the name "Manchar Formation" to avoid the confusion. In order to put absolute age limits on the Manchar Formation, paleomagnetic studies were initiated to date this molasse sequence on the basis of magnetic-polarity stratigraphy.

Lithologically the Manchar Formation consists of an interbedded sequence of gray sandstone units and reddish-brown to pale brown shale/siltstone/claystone units, with some conglomerates. The most fossiliferous part of the Manchar Formation is the "lower Manchar" and is characterized by the dominance of sandstone units. The "middle Manchar" yielded almost no fossils and is characterized by the dominance of shale units. The "upper Manchar" yielded very few fossils and is characterized by the dominance of conglomerate and sandstone units. The lower contact of the Manchar Formation with the underlying Gaj Formation is conformable and transitional. The upper contact of the Manchar Formation varies from being transitional and conformable to a minor angular disconformity with the overlying Dada Conglomerate. As a whole the Manchar Formation is a distinct regressive sequence. The more sandy (?braided) river deposits at the lower part of the formation gradually pass into more coarse-grained and even conglomeratic river deposits. The fine-grained shale/siltstone/claystone units, which separate the fluvial sandstone units, were deposited within the flood plains. Vertebrate fossils (both small and large mammals) collected from the Manchar Formation are definitive for an age assessment and suggest Middle to Late Miocene age.

The Manchar Formation exposed along the Gaj river section has a maximum thickness of 2200m. Paleomagnetic samples were collected from 63 sites. Sampling was confined to the fine-grained flood-plain deposits of shale/siltstone/claystone units from lower 1700m of the formation. The upper 500m of the formation could not be sampled due to lack of flood-plain deposits. The sandstone units were not sampled because the coarse-grained nature of the magnetic grains renders them less promising for the preservation of original directions of remanent magnetization. The strata generally strike N–S and dip 30°–40°E.

PALEOMAGNETIC TECHNIQUES

Three to five samples were collected from each site. Directions of remanent magnetization were measured on the cryogenic magnetometer at Lamont-Doherty Geological Observatory of Columbia University (USA). After measuring Natural Remanent Magnetization (NRM) of all samples, some of these were arbitrarily selected for progressive Alternating Field (AF) demagnetization. A typical result of progressive AF demagnetization is shown in Fig. 1. The results of AF demagnetization show that AF demagnetization is helpful in removing only that component of remanent magnetization which is carried by magnetic grains of lower coercivity (less than 400 Oe). Whereas the remanent magnetization component carried by magnetic grains of higher coercivity (more than 500 Oe) is not much effected by AF treatment of upto 900 Oe. Therefore, another set of samples was arbitrarily selected for Partial Thermal Demagnetization (PTD). A typical result

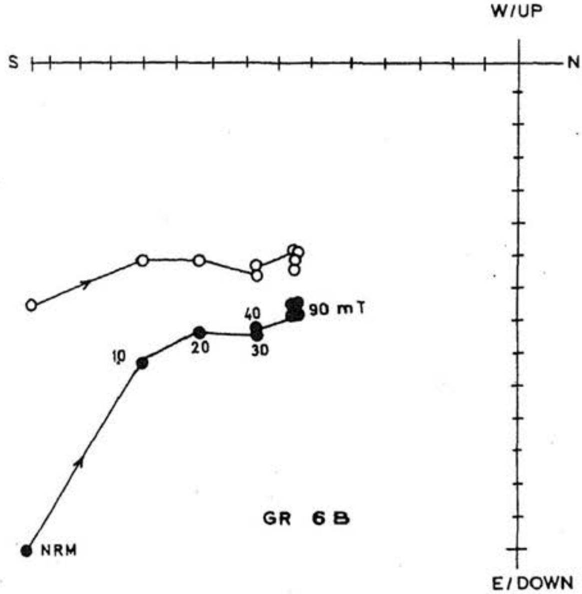


Fig. 1. Orthogonal projection diagram of AF demagnetization. Open (solid) circles represent projection of end points of demagnetization vectors on vertical (horizontal) planes. Intensity units are 10^{-4} A/m.

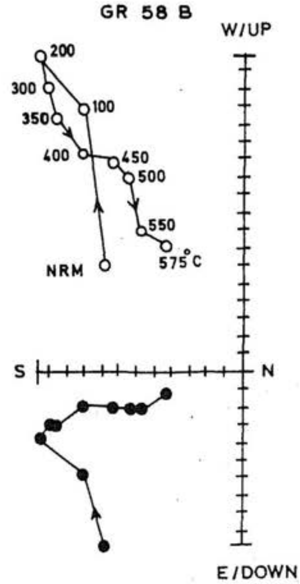


Fig. 2. Orthogonal projection diagram of PTD vectors. Plotting techniques are same as for Fig. 1.

of PTD is shown in Fig. 2, and suggests that NRM is composite of two components of magnetization; a secondary component of magnetization which is removed by heating at 200°C, and a stable, hopefully primary, component of remanent magnetization, which decays toward origin till 575°C heating. Therefore the remaining samples were subjected to a single step demagnetization at 400°C, to obtain stable directions of remanent magnetization. These directions were used to calculate the site-mean directions using Fisher's (1953) statistics. The sites which passed the randomness test (Watson,1956) were assigned as class–A type. The sites of three samples which fail the randomness test but have two samples with similar directions and a third deviant direction were assigned as class–B type. Alternatively the sites with five samples which fail the randomness test, but have three samples with similar directions and two deviant directions were assigned as class–B type. The sites with all samples having deviant directions were assigned as class–C type. Only class–A and B type sites were used for the interpretation of magnetic-polarity stratigraphy. The stable site-mean directions of class–A and B type sites were plotted on an equal angle streonet (Fig. 3). The almost antiparallel nature of the mean of all normal- and all reverse-polarity sites suggests that the

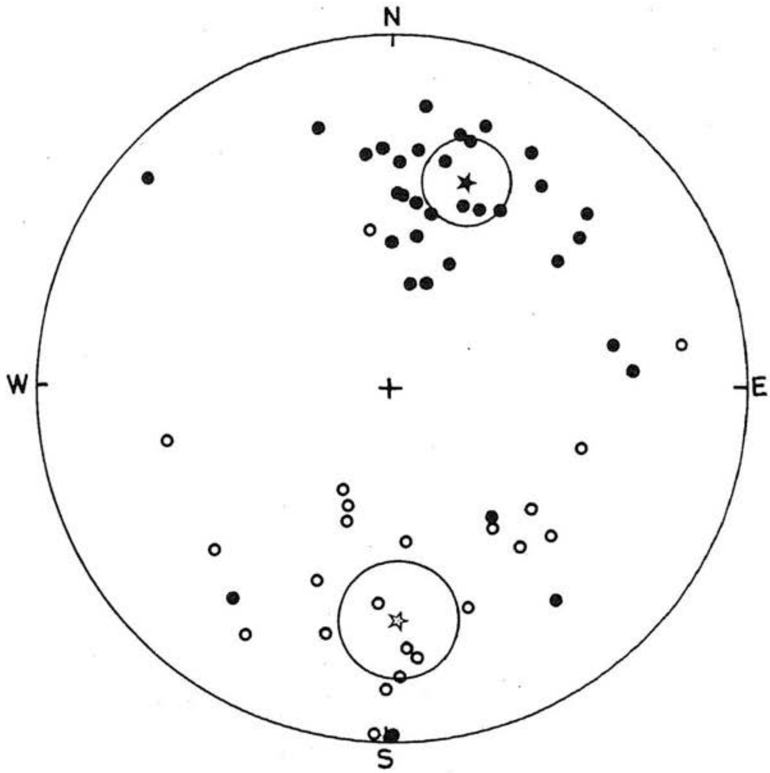


Fig. 3. Plot of bedding-corrected site-mean directions obtained after PTD at 400°C. Open (solid) circles are the plots on the upper (lower) hemisphere. Open (solid) stars are the mean of reverse (normal) polarity sites. The large circles represent the 95% confidence level.

directions of remanent magnetization were acquired, as a result of reversals of the Earth's magnetic field. Therefore the stable remanent magnetization directions are suitable for paleomagnetic studies. Hence the stable site-mean directions were used to calculate the latitudes of Virtual Geomagnetic Poles (VGP). The directions of remanent magnetization are given in Table 1.

TABLE 1. DIRECTIONS OF REMANENT MAGNETIZATION after partial thermal demagnetization at 400°C (bedding corrected). Only class–A and –B type sites are used to get the mean directions.
Explanation: N = number of sites, D = declination, I = inclination, K = precision parameter, α 95 = 95% confidence limit.

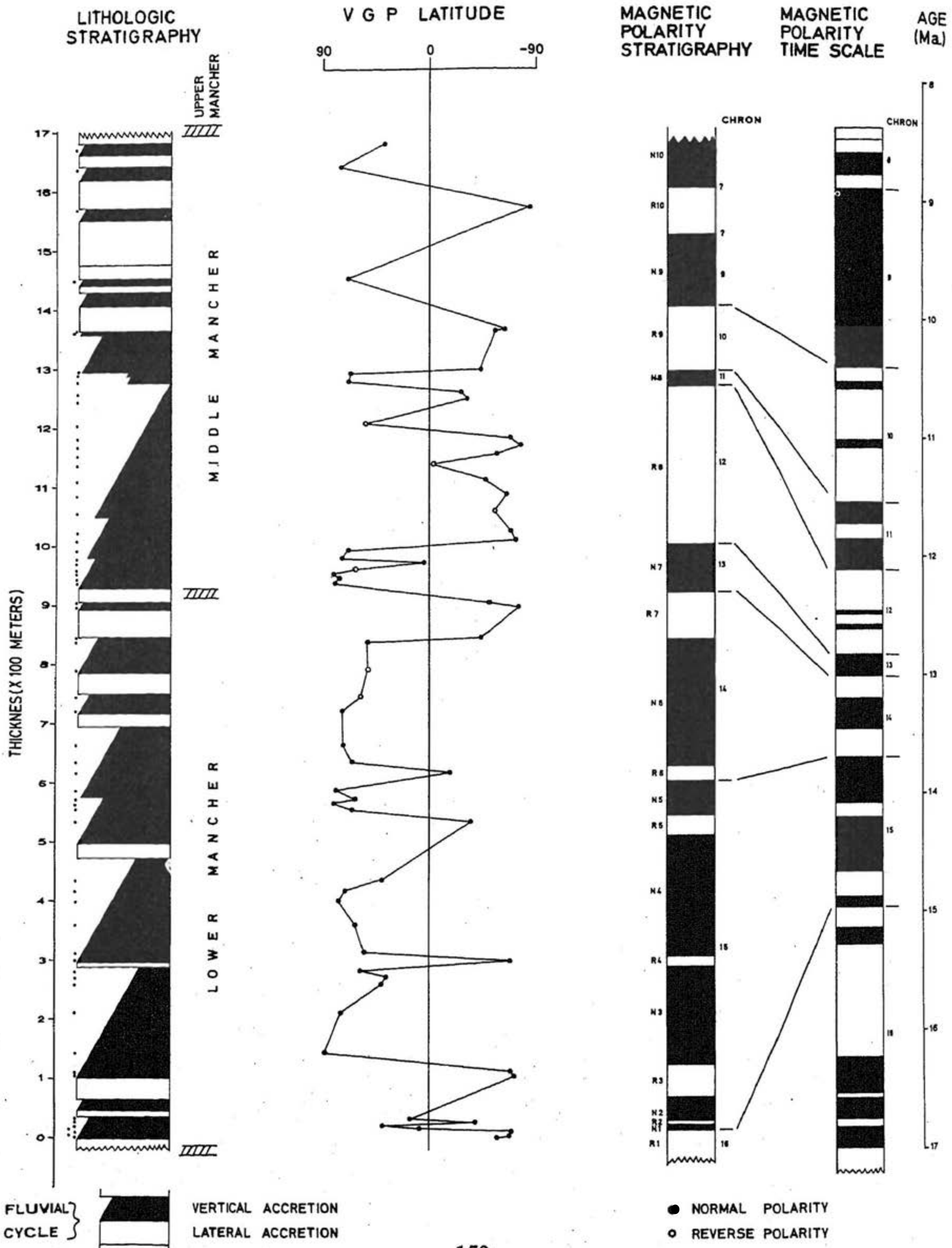
	N	D	I	K	α 95
Normal	32	19.5	26.9	7.0	10.3
Reverse	25	177.1	–23.7	4.9	14.6

MAGNETIC-POLARITY STRATIGRAPHY

The latitudes of VGP were plotted against stratigraphic thickness to establish a magnetic-polarity-reversal sequence (Fig. 4). The sites with positive (negative) sign of VGP latitudes are assigned normal (reverse) magnetic polarity. This resulted in the establishment of 20 magnetozones marked by 19 polarity-reversal boundaries. As these results are based on a reconnaissance trip for paleomagnetic sampling, the interpretation is tentative. No drastic change in interpretation is expected, however, after sampling the stratigraphic sequence at more closer interval than the present one. Nevertheless, closely spaced sampling may slightly change the position of reversal boundaries, particularly in the upper part of the sequence.

CORRELATION

The Manchar Formation has yielded vertebrate fauna to us and Raza *et al.* (1984), which suggest that this molasse sequence was deposited durnig Middle to Late Miocene time. This age is substantiated by the collection of Early Miocene (Aquitanian-Burdigalian) fauna from the underlying Gaj Formation (Pascoe, 1964; Khan, 1968; Iqbal, 1980), and by the fact that the Gaj-Manchar contact is conformable and transitional. As the Early/Middle Miocene boundary falls in chron 16 (Berggren *et al.,* 1983), it is most likely that the Gaj-Manchar contact is not older than 16.6 Ma. Base of the observed magnetic polarity reversal sequence, however, is expected to be younger than about 15.5 Ma., because the lowermost thick sandstone unit is not sampled for paleomagnetic studies. Based on these



LITHOLOGIC STRATIGRAPHY
V G P LATITUDE
MAGNETIC POLARITY STRATIGRAPHY
MAGNETIC POLARITY TIME SCALE
AGE (Ma)
90
0
-90
UPPER MANCHER
MIDDLE MANCHER
LOWER MANCHER
THICKNES (X 100 METERS)
CHRON
FLUVIAL CYCLE
VERTICAL ACCRETION
LATERAL ACCRETION
NORMAL POLARITY
REVERSE POLARITY

observations and interpretations, the observed magnetic polarity reversal sequence is correlated with the Magnetic Polarity Time Scale (MPTS) of Berggren *et al.* (1983) as shown in Fig. 4. This correlation suggests that magnetozone R1 represents the upper part of chron 16; and chrons 15 through 10 have been observed. Because of the widely spaced sampling sites it is highly likely that mostly normal polarity sites above chron 10 represent chron 9. Considering the fact that only class–A and –B type sites are used for establishing the magnetic-polarity-reversal sequence, and that observed magnetic-polarity stratigraphy substantially supports Middle to Late Miocene faunal age, it is most likely that the proposed correlation of MPS is most appropriate inspite of being tentative. This correlation suggests that the measured part of the Manchar Formation ranges in age from about 15.3 Ma. to 9–10 Ma. Correlation of MPS with the fauna shows that *Hipparion* (FAD), *Listriodon* (LAD), and *Conohynous* (LAD) are systematically about 2.5 Ma. older in this area as compared to their occurrence in the Potwar plateau (Barry *et al.*, 1982). This rather startling observation suggested further work. Detailed interpretation and its implications will be discussed after the stratigraphic sequence is resampled and a precise MPS is established.

CONCLUSION

Preliminary results of the paleomagnetic studies show that the fine-grained flood-plain deposits of the Manchar Formation can successfully be used for the magnetostratigraphic studies. After a reconnaissance trip paleomagnetic sampling, a magnetic-polarity-reversal sequence is established based on the stable directions of remanent magnetization, obtained after PTD at 400°C. Knowing the presence of Middle to Late Miocene vertebrate fauna in the Manchar Formation, the observed magnetic-polarity-reversal sequence is correlated with MPTS. This correlation shows that, excluding the upper 500m, the Manchar Formation ranges in age from about 15.3 Ma. to 9–10 Ma. This correlation suggests that the vertebrate fauna e.g. *Hipparion* (FAD), *Listriodon* (LAD), and *Conohynous* (LAD) are about 2.5 Ma. older in this area as compared to their occurrence in the Potwar plateau. Therefore more detailed paleomagnetic sampling is needed for a precise interpretation of the age of the Manchar Formation, and its implications on the faunal evolution.

Acknowledgements. Financial support for these studies was provided by grants from Smithsonian Institution and NSF (USA) to S. Taseer Hussain and Noye M. Johnson, respectively. Denis V. Kent is thanked for permission to use the Paleomagnetic Laboratory at LDGO.

Fig. 4. Plot of VGP latitudes against stratigraphic thickness. The black (white) blocks in the lithologic stratigraphic column represent vertical accretion — shale/siltstone/claystone (lateral accretion — sandstone) deposits of the molasse sequence. Open circle VGP latitude plots represent class-C sites. Black (white) columns of MPS represent normal (reverse) magnetic polarities. The boundaries of magnetic polarity reversals are based on intermediate position between two successive sites having opposite polarities MPTS after Berggren *et al.* (1983).

REFERENCES

Barry, J.C., Lindslay, E.H., & Jacobs, L.L., 1982. A biostratigraphic zonation of the middle and upper Siwaliks of the Potwar Plateau of northern Pakistan. Paleo. Paleo. Paleo. 37, 95—130.

Berggren, W.A., Kent, D.V., Flynn, J.V., & Van Couvering, J.A., 1983. Cenozoic geochronology. In 'Geochronology and the Geologic Time Scale' (Snelling, N.J., ed.), Geol. Soc. Lond. Special Publication (in press).

Blanford, W.T., 1876. On the geology of Sind. Geol. Surv. India Mem. 9, 8—22.

———, 1879. The geology of western Sind. Ibid., Mem. 17, 1—196.

Fisher, R.A., 1953. Dispersion on a sphere. Proc. R. Soc. Lond., A—217, 295—303.

Iqbal, M.W.A., 1980. Oligo-Miocene bivalves & gastropods from Kirthar province, Lower Indus Basin, Pakistan. Geol. Surv. Pak. Recs. 51, 1—59.

Khan, M.H., 1968. The dating and correlation of the Nari and the Gaj Formations. Geol. Bull. Univ. Punjab 7, 57—65.

Pascoe, C.E., 1964. A manual of the geology of India and Burma, Vol. III. Indian Government Press, Calcutta, 1—886.

Raza, S.M., Barry, J.C., Meyer, G., & Martin, L., 1984. Preliminary report on the geology and vertebrate fauna of the Miocene Manchar Formation, Sind, Pakistan, (in press).

Shah, S.M.I. (ed.), 1977. Stratigraphy of Pakistan. Geol. Surv. Pak. Mem. 12, 1—138.

Vredenburg, E.W., 1906. The classification of Tertiary system in Sind with reference to the zonal distribution of the Eocene Echinoidea described by Duncan and Sladen. India Geol. Surv. Recs. 34, 172—198.

Watson, G.S., 1953. A test of randomness of directions. Geophys. Suppl. 7, 160—161.