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PALAEOMAGNETIC RESULTS FROM SOME PANCHET CLAY BEDS, KARANPURA COALFIELD, NORTHEASTERN INDIA*

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ABSTRACT

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Reversely magnetized Panchet clay samples of Early Triassic or possibly Late Permian age, from the North Karanpura coalfield (Damodar Valley, NE. India) revealed, after thermal cleaning, the mean direction: $D = 110.5°$, $I = +69°$ ($k = 49$, $\alpha_{95} = 6°$, $N = 13$). The corresponding pole position is: 59.5°W 7.5°S ($dp = 9°$, $dm = 10°$).

A probable remagnetization of some Indian Gondwana red beds, during Late Cretaceous to Early Tertiary times, by the Deccan Trap flood basalts is indicated.

INTRODUCTION

Many red-bed intercalations occur in the mainly continental Gondwana deposits (of Late Carboniferous to Middle Cretaceous age) on the Indian subcontinent. These Gondwana sediments are preserved in a number of downfaulted basins in Central and Eastern India (Fig. 1). Besides these extensive outcrops, some minor occurrences of Gondwana sediments are found throughout the Indian subcontinent, i.e., along the Himalayan border, in the Salt Range area, along the East Coast and on the Cutch and Kathiawar Peninsula.

It seems reasonable to suppose that the huge Deccan Trap effusives (Fig. 1, Table I) of an Early Tertiary age (60–65 m.y., Wellmann and McElhinny, 1970) affected the underlying Gondwana sediments by thermal or hydrothermal activities. The extensive Deccan Trap flood basalts cover an area of 500,000 km^2 in Western and Central India. The original extent of these lavas was much greater than the present outcrop (Wadia, 1953; Pascoe, 1963; Krishnan, 1968). Therefore, one might suspect that secondary Deccan Trap influences have hampered the cleaning of rock samples of several of the Gondwana red beds which could result in misleading interpretations.

However, the Gondwana outcrops in the Damodar Valley dealt with in this study are at very large distances (about 400 km) from the present Deccan Trap outliers, and no geological evidence for a possible former lava cover has been reported so far. The Damodar Valley red beds were supposed to be free from remagnetization.

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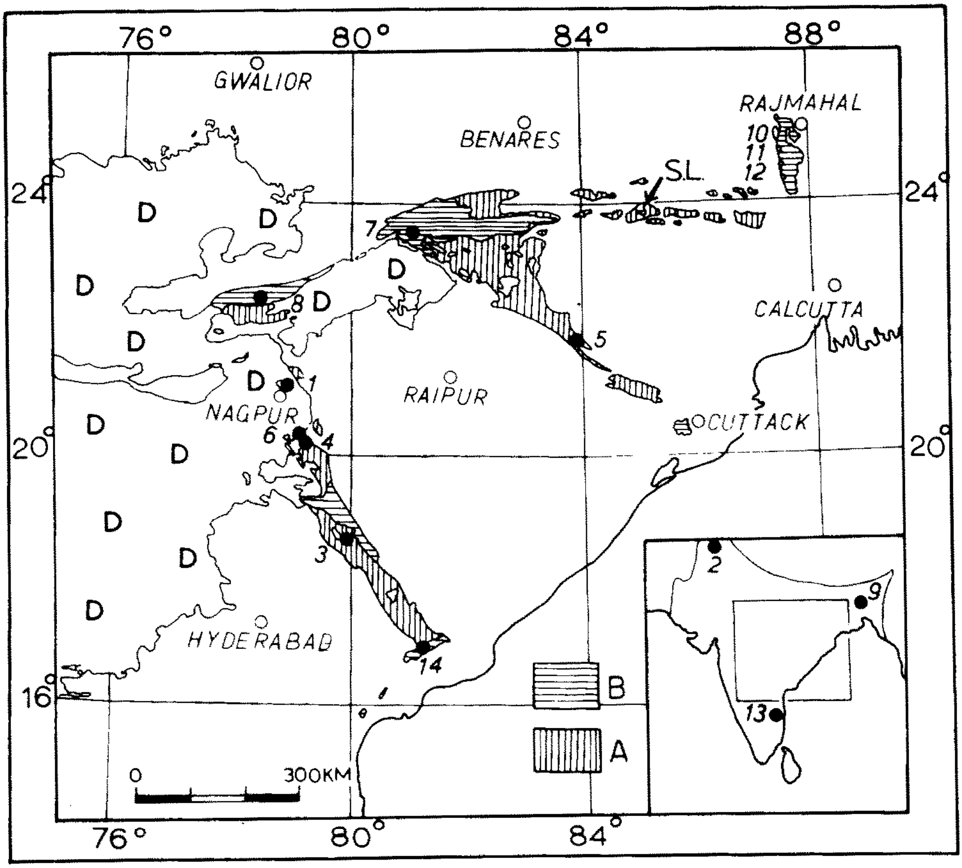

Fig. 1. Geological sketchmap of Gondwana outcrops in Eastern and Central India. *A* = Lower Gondwana outcrops, *B* = Upper Gondwana outcrops, *D* = Deccan Traps. Explanation of symbols: unshaded denotes basement; *S.L.*: sampling locality of Panchet clay beds in the N. Karanpura coalfield, present study. Numbers *1–14*: sampling localities from some other Gondwana formations as reported in previous palaeomagnetic studies. *1* = Talchir Series, Late Carboniferous, Wensink and Klootwijk (1968); *2* = Speckled Sandstones (Salt Range), Early to Late Permian, Wensink (1973); *3* = Kamthi beds (Godavary Valley), Late Permian, Verma and Bhalla (1968); *4* = Kamthi beds (Wardha Valley), Late Permian, Wensink (1968); *5* = Hingir beds, Late Permian, Athavale et al. (1970); *6* = Mangli beds, Early Triassic to Late Permian, Wensink (1968); *7* = Parsora beds, Late Triassic, Bhalla and Verma (1969); *8* = Pachmarhi beds, Late Triassic, Wensink (1968); *9* Sylhet Traps, Early Cretaceous, Athavale et al. (1963); *10* = Rajmahal Traps, Early Cretaceous, McDougall and McElhinny (1970); *11* = Rajmahal Traps, Early Cretaceous, Radhakrishnamurty (1970); *12* = Rajmahal Traps, Early Cretaceous, Klootwijk (1971); *13* = Satyavedu beds, Early–Middle Cretaceous, Mital et al. (1970); *14* = Tirupati beds, Early–Middle Cretaceous, Pullaiah and Verma (1967, 1970), Verma and Pullaiah (1967).

Therefore, samples were taken from Panchet red clays of an Early Triassic or possibly a Late Permian age from the North Karanpura coalfield (Fig. 1).

TABLE I

Stratigraphic columns of Central and Eastern India

Stratigraphic column N. Karanpura coalfield		Stratigraphic column central and Eastern India	Age
Dolerites and		Deccan Traps	Early Tertiary ----- (60–65 m.y.) Late Cretaceous
Ultrabasic intrusives	Upper Gondwanas	East Coast Gondwanas	Early–Middle Cretaceous
		Rajmahal Series (incl. volcanics)	Early Cretaceous (100–105 my)
Supra-Panchets (Mahadevas?)		Mahadeva Series	
∿∿∿∿∿ (unconformity)			
Panchet Series	Lower Gondwanas	Panchet Series	Early Triassic ---------- Late Permian
Damuda Series		Damuda Series	
Talchir Series		Talchir Series	Early Permian ---------- Late Carboniferous
∿∿∿∿∿ (unconformity)		∿∿∿∿∿ (unconformity)	
Basement		Basement	

GEOLOGICAL SETTING OF THE SAMPLING AREA

Continental sediments of an Early Gondwana age (Fig. 1, Table I) were deposited in the Damodar Valley coalfields (Jowett, 1925; Pascoe, 1959; Mehta et al., 1963; Mehta, 1964; Krishnan, 1968).

The upper part of the Panchet Series (Table I), from which the samples are taken, is characterized by red micaceous clays. Age estimations for the Panchet beds range from a Late Permian up to a Late Triassic age (Pascoe, 1959; Lele, 1964; Mehta, 1964; Rao, 1964; Krishnan, 1968). An Early Triassic age, based on the reptile fauna is mostly favoured. The Panchet palynological data, however, are different from well-established information from the Lower Triassic of other areas in the Gondwana realm, i.e., assemblages from the Salt Range (Balme, 1970), Madagascar (Goubin, 1965), and Australia (Balme, 1963). According to H. Visscher (personal communication, 1972), the recent palynological data from presumed Early Triassic deposits in India (Bharadwaj and Srivastava, 1969; Kar, 1970a, b) could well be indicative for a Late Permian age.

The main faulting and folding in the Karanpura area took place in post Panchet times, before the deposition of the so-called Supra-Panchet beds of an assumed Late Triassic (Mahadeva) age (Table I; Jowett, 1925).

Basic and ultra-basic intrusions are abundant throughout the Damodar Valley. An older suite of lamprophyres and mica-peridotites is thought to be associated with the Rajmahal Trap basalts of Early Cretaceous age (100–105 m.y., McDougall and McElhinny, 1970). Although these intrusions penetrated the Panchet beds, they are not observed in the restricted Supra-Panchet outcrops. It is not clear whether a younger suite of dolerites and sills represents the Rajmahal Trap phase or the Deccan Trap phase of igneous activity (Table I).

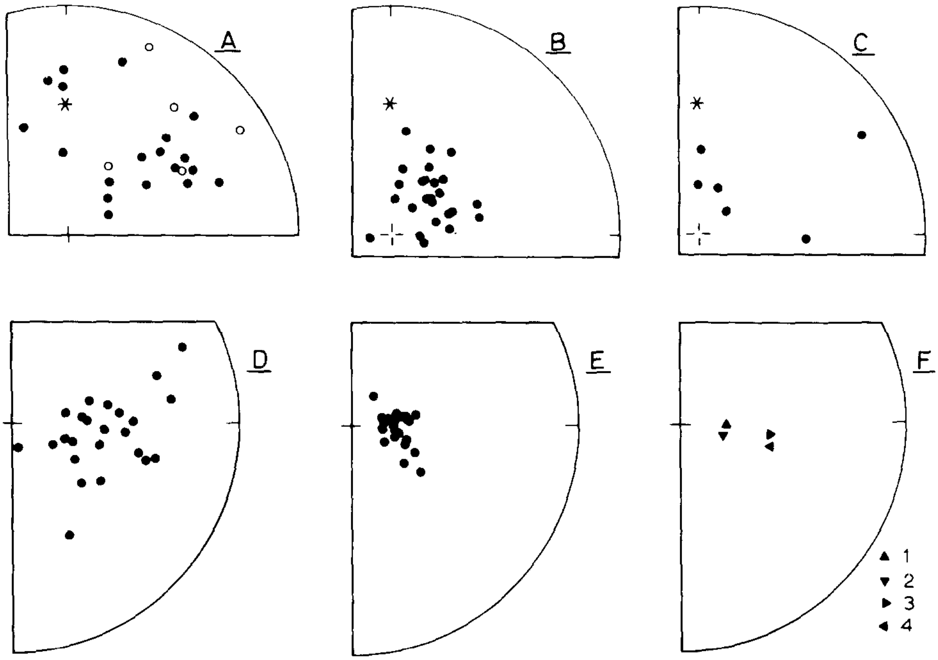

Fig. 2. Stereographic projections of specimen magnetization directions. Explanation of symbols: Open symbols denote directions pointing upwards; full symbols denote directions pointing downwards; asterisk denotes present local field direction at sampling locality, dipping 30° downwards. No tectonic correction was applied to specimen directions, denoted in figures A–E. A. Site 1, initial specimen directions. B. Site 2, initial specimen directions. C. A.F.-cleaned specimen directions from site-1 and site-2 specimens. D. Site 1, thermally cleaned specimen directions. E. Site 2, thermally cleaned specimen directions. F. Site-mean directions; site 1 before tectonic correction (*1*) and after tectonic correction (*2*); site 2 before tectonic correction (*3*) and after tectonic correction (*4*).

SAMPLING, LABORATORY TREATMENT AND METHOD OF ANALYSIS

Hand samples (35 in all) were collected from the Upper Panchet beds at two sites in the North Karanpura area from two micaceous red-clay horizons, each about half a meter thick, at the base of the Mahadeva escarpment, west of the small village of Barkagaon (23°51′N 85°12′E; Fig. 1). The beds had a southwards dip of 5–9°. The clays desintegrated directly in contact with water and prevented drilling, so hand samples were taken from unweathered exposures.

In the laboratory, 51 cores of 2.5 cm diameter and 2.2 cm height, were drilled from the samples. The drilling was performed without the cooling action of water. The specimens became slightly warm, but effects on the magnetization were negligible. Both A.F.- and thermal-cleaning methods were applied to the specimens, and measurements were carried out with the Utrecht astatic magnetometers. The directional analysis of data was made according to Zijderveld (1967) and Klootwijk (1971). All computations and plotting were carried out on the Philips Electrologica X-8 computer of the Utrecht State University and a Calcomp 507 plotter.

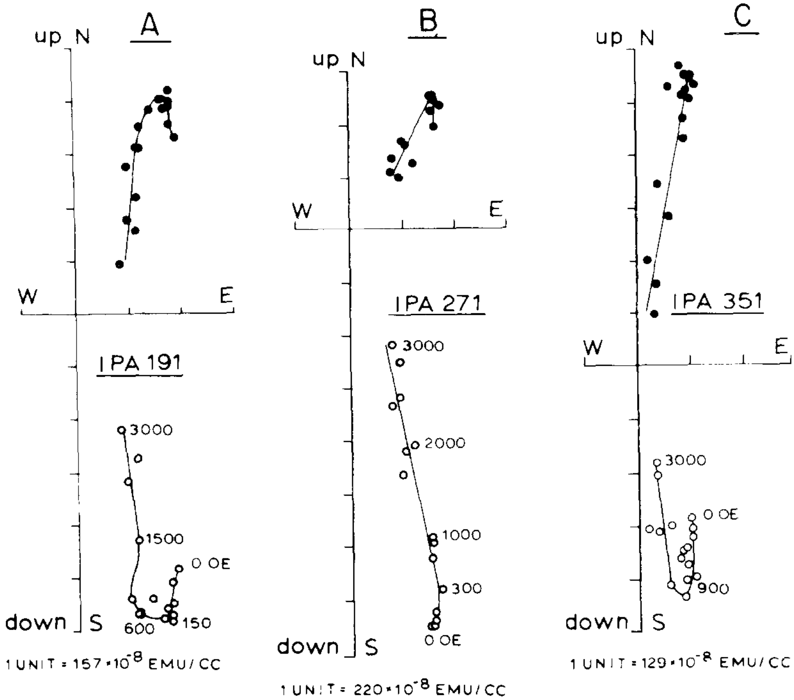

Fig. 3. Demagnetization diagrams of specimens cleaned with alternating fields. The points represent successive positions – in orthogonal projection – of the end of the resultant magnetization vector during progressive demagnetization. Circles denote projections on the vertical east–west plane. Dots denote projections on the horizontal plane. Numbers denote Oe-peak values of the applied alternating fields.

RESULTS

Site-2 specimens were coloured a deeper red than site-1 specimens, and intensities of magnetization were generally higher. The initial intensity of natural remanent magnetization of site-1 specimens ranged between 13 and $80 \cdot 10^{-7}$ e.m.u./cm^3 and that of site-2 specimens between 33 and $180 \cdot 10^{-7}$ e.m.u./cm^3. Initial intensities of induced magnetization ($H = 0.44$ Oe) ranged respectively between $65–105 \cdot 10^{-7}$ and $100–170 \cdot 10^{-7}$ e.m.u./cm^3. The initial directions were concentrated in the NE quadrant. Site-1 specimen directions, with both positive and negative inclinations, concentrated less well than site-2 specimens. The latter showed generally steeper downward directions (Fig. 2A, 2B).

Six specimens were progressively demagnetized by alternating fields to a 3000-Oe peak value. Internally consistent results for site-2 specimens were obtained after removal of an upwards-directed component at about 600-Oe peak value (Fig. 3A, 3B, 3C, 6A). However, the steeply downdipping directions have a northeast declination (Fig. 2C), being clearly aberrant from the Indian Gondwana results known at present. Continuation of the A.F.-cleaning with a subsequent thermal demagnetization (five specimens) up to the Curie point, revealed a clockwise change in declination to east or east-southeast directions

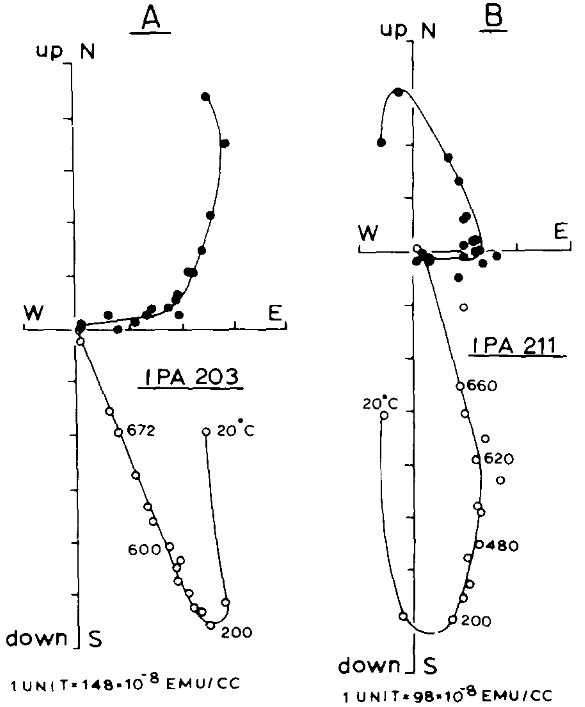

Fig. 4. Thermally cleaned site-2 specimens. For explanation see Fig. 3. Numbers denote successive peak values of applied temperatures.

(Fig. 5B). The resulting characteristic directions coincide well with the progressive thermal-demagnetization results from five specimens, not subjected before to A.F.-cleaning.

The A.F. and thermal directions have strongly divergent declination values (Fig. 2C, 2D, 2E). Only the thermal results are in accordance with other Early Gondwana directions (Wensink, 1968; Wensink and Klootwijk, 1968; Athavale et al., 1970). The results from the A.F.-cleaning therefore proved to be very confusing, the more so because the vector graphs give the impression that only one component had remained. However, continued A.F.-demagnetization of, for instance, samples IPA 191 and IPA 271 (Fig. 3A, 3B), above the present maximum obtainable 3200-Oe peak value, might separate a component with an eastward declination, being thus comparable with the thermal results. All secondary-magnetization components appeared to be eliminated during thermal cleaning at about 600°C (Fig. 4, 5). One observes a sharp decay of the remanent magnetization from 640°C onwards (Fig. 6B, 6C). In order to compute reliable characteristic directions, the remaining specimens (40) were cleaned by thermal methods, in 8–14 steps, from 630–650°C to the Curie point, lying between 675° and 700°C.

The progressive thermal-demagnetization results of site-1 specimens showed some scatter, probably resulting from measurement errors due to the very small intensity of magnetization. The resulting directions from site-2 specimens concentrated nicely with steep

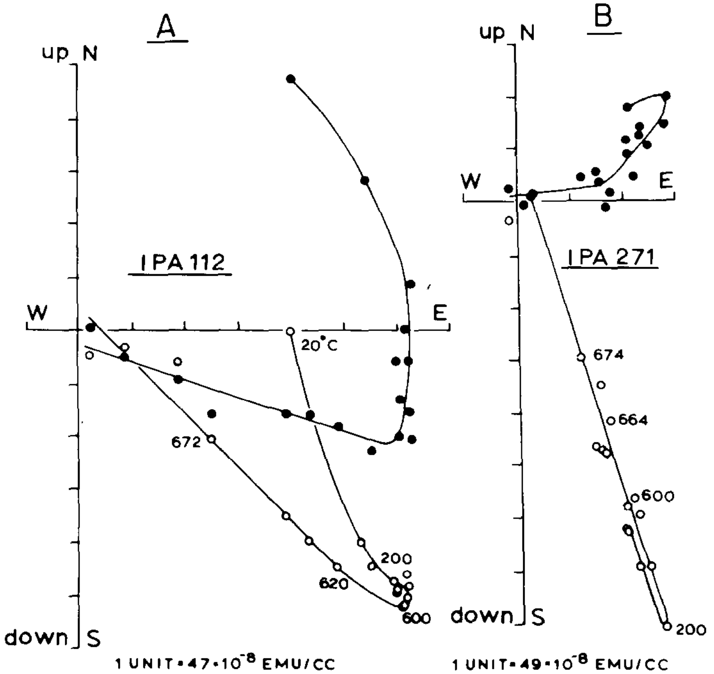

Fig. 5. Thermally cleaned site-1 and site-2 specimens. For explanation see Fig. 3 and 4. A. Site-1 specimen. B. Site-2 specimen, progressive thermal demagnetization of already A.F.-treated specimen, see Fig. 3B.

downward dips (Fig. 2E), whereas site-1 specimen directions concentrated less well, and had generally lower dips (Fig. 2D).

The thermal-demagnetization graphs (Fig. 4, 5) revealed two secondary magnetizations. First, a large secondary component, upwards and northwards directed, which was eliminated at about 200°C. From that temperature onwards, the inclination values remain constant during progressive thermal-demagnetization treatment. However, the declination values show a progressive shift to easterly directions, remaining constant from 600°C onwards. Thus, another secondary and downdipping northwards-directed component becomes eliminated between 200° and 600°C.

The former secondary component is presumably related to either the Rajmahal Trap direction ($D = 314.5°, I = -64.5°$; Klootwijk, 1971) or more probably to the upper Deccan Trap direction ($D = 335°, I = -45°$; Wensink and Klootwijk, 1971; Fig. 7). The latter secondary component might represent the combined effects of a viscous local field direction, 30° downdipping at the sampling locality, and a Deccan or Rajmahal Trap component. The probable secondary Deccan or Rajmahal Trap directions are remarkable, as the samples were taken from the base of the several hundreds of meters high escarpment, capped by the Supra-Panchet deposits which predate the Rajmahal or Deccan Trap eruption phase. Thus, these secondary components cannot originate from a direct contact with a possible formerly overlying basalt cover. Therefore, these secondary components might

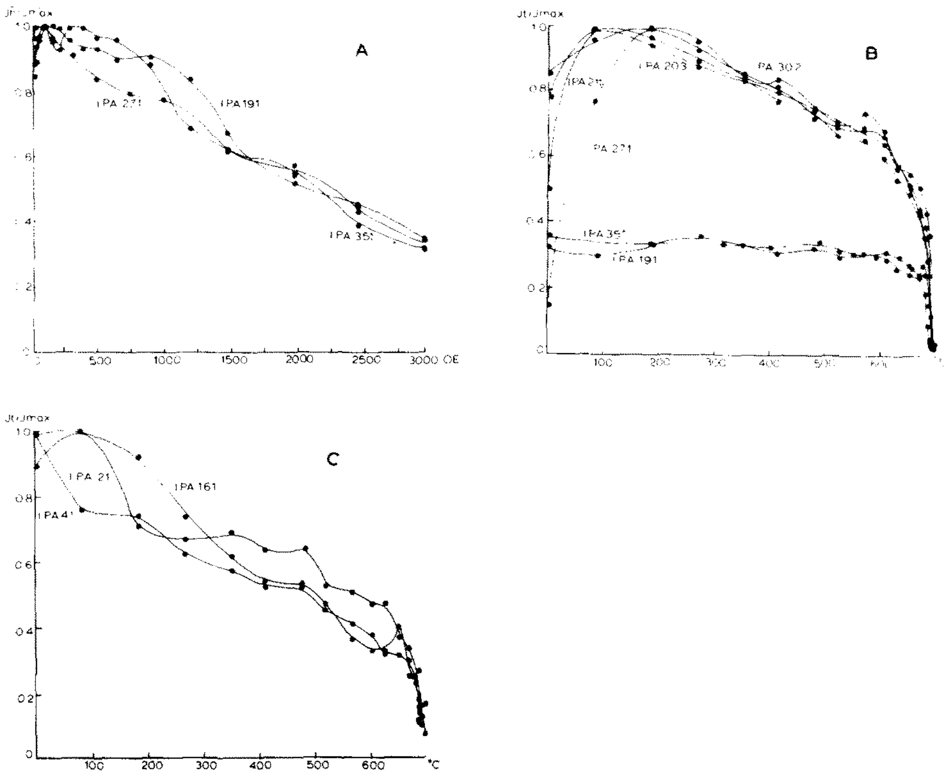

Fig. 6. A. Normalized intensity decay curves of total remanent magnetization during A.F.-cleaning. B. Idem, during thermal cleaning of some site-1 specimens. C. Idem, during thermal cleaning of some site-2 specimens. The curves for specimens 191 and 351 are thermal continuations of the A.F.-curves of Fig. 6A.

be due to either regional heating, associated with flood basalt extrusion, or to hydrothermal influences, probably associated with the Damodar Valley dykes and sills.

The characteristic component, obtained above 630°C after removal of both secondary components, generally represents more than 50% of the initial intensity (Fig. 6) and has a direction in accordance with other Early Gondwana results. Therefore, this characteristic component is considered to represent the primary magnetization.

The resulting mean directions are listed in Table II.

TABLE II

Mean directions of site-1 and site-2 specimens of Panchet clay beds, North Karanpura Coalfield

Site	No.	Declination	Inclination	α_{95}	k	Pole position	dp	dm
1	15	107.5°	+44.5°	8°	23	−35.5°W + 4° N	7°	10°
2	13	110.5°	+69°	6°	49	−59.5°W − 7.5°S	9°	10°
1 and 2	228	108.5°	+56°	7°	19	−45° W − 0.5°S	7°	9°

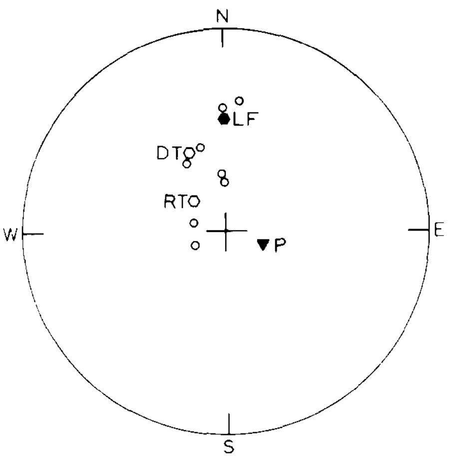

Fig. 7. Stereographic projection of secondary magnetization directions, eliminated between 20 and 200°C, showing either Rajmahal Trap or Deccan Trap affinities. *P* = mean Panchet direction, pointing downwards. *LF* = present local field direction at the sampling locality, dipping downwards. *RT* = Rajmahal Trap direction, pointing upwards. *DT* = Deccan Trap direction, pointing upwards. Circles: Secondary directions from Panchet rocks (specimens), pointing upwards.

The mean inclinations of site-1 and site-2 specimens differ by about 20°, whereas the declination values coincide (Fig. 2F). In view of the higher intensity and better grouping, the steeper site-2 mean direction is considered to be most meaningful. Maybe the primary and secondary magnetization components in site-1 specimens could not be fully separated from each other, due to the low intensity of magnetization, resulting in a poorer grouping and a less steep mean direction.

INTERPRETATION

A palaeolatitude map of the Indian subcontinent according to the Panchet pole (site-2) is plotted in Fig. 8. In Fig. 9A and B, the positions of the Indian subcontinent according to all Indian Gondwana results known at present (no. 1–14 and 16) are plotted in Aitoff projection. It appears that the Panchet pole (no. 16, –59.5°W –7.5°S) is coincident with the Mangli-beds pole (no. 6, –55.5°W –7.5°S; Wensink, 1968). This was to be expected since both formations are correlated on fossil evidence (Pascoe, 1959; Chandra et al., 1964; Krishnan, 1968). The Panchet pole also lies close to a preliminary pole from the Speckled Sandstones (Salt Range, W. Pakistan, no. 2, –51°W –9°S; Wensink, 1973, personal communication, 1972). Although generally an Early Permian age has been assumed for the Speckled Sandstones (Krishnan 1968), there are indications (H. Visscher, personal communication, 1972) supporting Schuchert (1929) who considered the lower part of the Permian succession of the Salt Range to be considerably younger. The new information on the fusulinids of the Lower Productus Limestone (Amb Formation) by Douglass (1970), as well as the palynological assemblages from the Speckled Sandstones

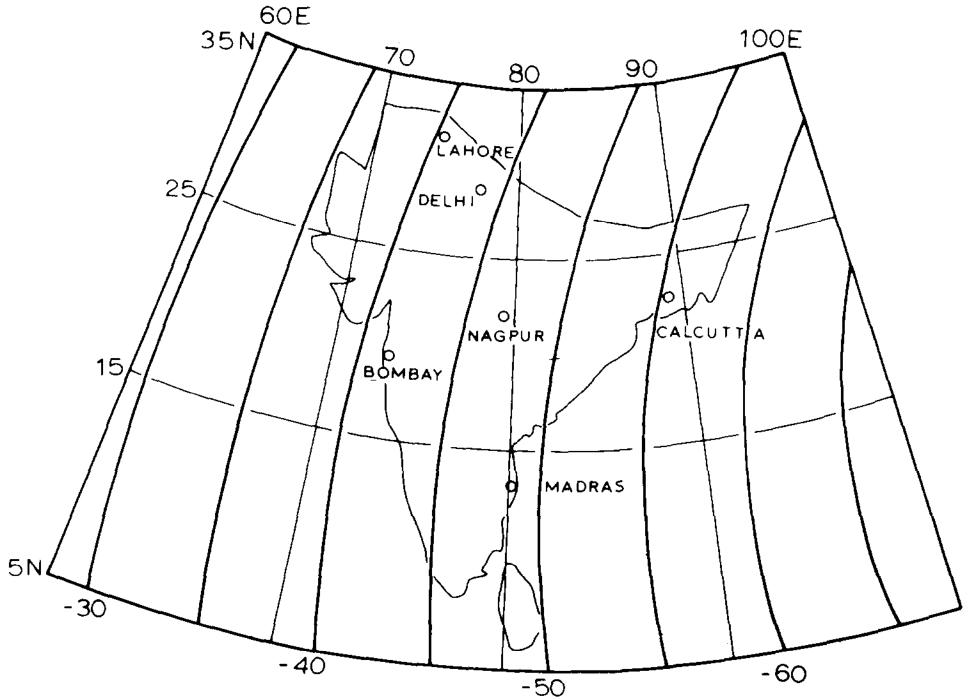

Fig. 8. Palaeolatitude map for the Indian subcontinent during Panchet time, according to the central axial dipole field formulae.

(Venkatachala and Kar, 1968) and the Lower Productus Limestone (Balme, 1970) could well be interpreted as Late Permian. In view of palynological indications for a possible Late Permian age of the Panchet beds, the agreement amongst the three palaeomagnetic results mentioned seems acceptable.

The position of the Indian subcontinent as deduced from the Late Permian Kamthi beds (no. 4; Verma and Bhalla, 1968), and from the correlated Hingir beds (no. 9; Athavale et al., 1970), and from the Late Triassic Parsora beds (no. 7; Bhalla and Verma, 1969), approaches the position indicated by the Deccan Trap results (no. 18, 19; Wensink and Klootwijk, 1971). The probability of a younger magnetic age has been mentioned for the Late Permian Kamthi results from the Godavary Valley (Athavale et al., 1970). This is in agreement with findings of partially or totally remagnetized Gondwana red beds in the Wardha–Godavary Valley, due to a past Deccan Trap cover. An extensive collection of Kamthi samples, representing in part a resampling of the beds studied by Wensink (1968), has been studied (Klootwijk, in prep.). Much care was taken to eliminate the very hard secondary Deccan Trap component in these samples, and preliminary results indicate a lower angle of rotation than the one deduced by Wensink (1968). A younger magnetic age seems acceptable also for the Pachmarhi results (no. 8; Wensink, 1968), of Late Triassic age, in view of the intercalation of secondary ironstone bands in the Pachmarhi sand-

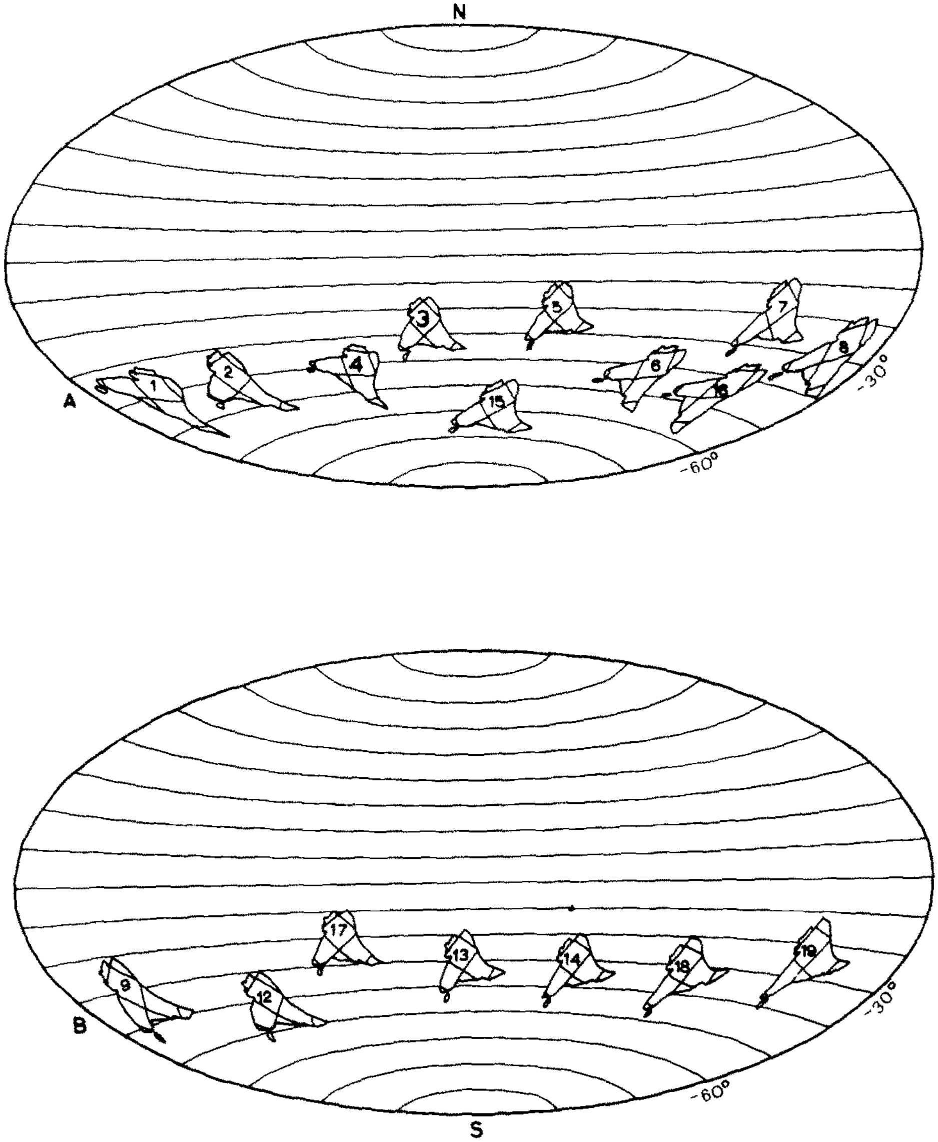

Fig. 9. Comparison of orientation and position of the Indian subcontinent according to palaeomagnetic data from some Gondwana formations (no. 1–14, 15?, 16, 17?) and Deccan Trap results (18, 19). The longitudinal positions of the subcontinent are arbitrarily, but from left to right the positions correspond with data from successively younger formations. Some projectional distortion of India is due to the applied Aitoff-projection. For explanation of numbers 1–14 see caption to Fig. 1. *15* = Tadoba beds, unknown age; Wensink (1968); *16* = Panchet beds, Early Triassic–Late Permian, present paper; *17* = Rajahmundry flows, may be of Deccan Trap age, Athavale et al., (1970). *18* = Lower Deccan Traps, south of Poona, 60–65 m.y., Wensink and Klootwijk (1971). *19* = Upper Deccan Traps, south of Poona, 60–65 m.y., Wensink and Klootwijk (1971).
The position and orientation of no. 2 is according to the pole position: –57°W –2°S (Wensink 1972), which recently has been recalculated as: –51°W –9°S (Wensink 1973).

stone beds. This result yielded a position of the Indian subcontinent about 10° to the north of the position as deduced from the younger, Early Cretaceous, Rajmahal Traps (no. 12; Klootwijk, 1971).

The above discussion warns of the possible presence of hard, younger magnetization components in the Indian Gondwana material; careful and elaborate thermal demagnetization is a necessity. The results and interpretations of the Indian Gondwana material available at present seems partly ambiguous. Comparison of some presumably reliable Early Gondwana red beds results from the Indian subcontinent (Fig. 9), i.e., the Mangli beds (no. 6), the Panchet beds (no. 16), and the preliminary results from the Speckled Sandstones (no. 2), together with the Rajmahal Trap (no. 12) and Deccan Trap (no. 18, 19) results, reveals that the Indian subcontinent underwent a gradual anti-clockwise rotation and a northward movement during the Mesozoic and Early Tertiary. The irregular jerky latitudinal positions of the Indian subcontinent as deduced from separate studies on Gondwana material (Fig. 9), then seems due to some incompletely cleaned results.

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REFERENCES

Athavale, R.N., Radhakrishnamurty, C. and Sahasrabudhe, P.W., 1963. Palaeomagnetism of some Indian rocks. *Geophys. J*, 7: 304–313.

Athavale, R.N., Verma, R.K., Bhalla, M.S. and Pullaiah, G., 1970. Drift of the Indian sub-continent since Precambrian times. In: S.K. Runcorn (Editor), *Palaeogeophysics*. Academic Press, London, pp. 291–305.

Balme, B.E., 1963. Plant microfossils from the Lower Triassic of Western Australia. *Palaeontology*, 6: 12–40.

Balme, B.E., 1970. Palynology of Permian and Triassic strata in the Salt Range and Surghar Range, West Pakistan. In: B. Kummel and C. Teichert (Editors), *Permian and Triassic of West Pakistan. Dept. Geol., Univ. Kansas., Spec. Publ.*, 4: 305–453.

Bhalla, M.S. and Verma, R.K., 1969. Palaeomagnetism of Triassic Parsora sandstones from India. *Phys. Earth Planet. Inter.*, 2: 138–146.

Bharadwaj, D.C. and Srivastava, S.C., 1969. A Triassic mioflora from India. *Palaeontographica, B*, 125: 119–149.

Chandra, A., Khan, A.M. and Gopal, Singh., 1964. Distribution of microspores in the Lower Gondwana formations of India. *Proc. Int. Geol. Congr., 22nd, New Delhi*, 9; pp. 26–37.

Douglass, R.C., 1970. Morphologic studies of fusulinids from the Lower Permian of West Pakistan. *U.S. Geol. Surv., Prof. Pap.*, 643 (G): 1–11.

Goubin, N., 1965. Description et répartition des principaux pollenites permiens, triassiques et jurassiques des sondages du Bassin de Morondava (Madagascar). *Rev. Inst. Franc. Pet.*, 20: 1415–1461.

Jowett, A., 1925. On the geological structures of the Karanpura Coalfields, Bihar and Orissa. *Mem. Geol. Surv. India,* 52: 1–144.

Kar, R.K., 1970a. Sporae dispersae from Panchet (Lower Triassic) age in the bore-core no. RE 9, Raniganj coalfield, Bengal, India. *Palaeobotanist,* 18: 50–62.

Kar, R.K., 1970b. Palynological distinction between Upper Permian and Lower Triassic in Raniganj coalfield, Bengal, India. *Palaeobotanist,* 18: 118–126.

Klootwijk, C.T., 1971. Palaeomagnetism of the –Upper Gondwana– Rajmahal Traps, NE India. *Tectonophysics,* 12: 449–467.

Klootwijk, C.T., (in preparation). Palaeomagnetism of Upper Permian Red beds in the Waroha Valley, Central India.

Krishnan, M.S., 1968. *Geology of India and Burma.* Higginbothams, Madras, 5th ed., 289 pp.

Lele, K.M., 1964. The problem of Middle Gondwanas in India. *Proc. Int. Geol. Congr., 22nd, New Delhi, 9,* pp. 26–37.

McDougall, I. and McElhinny, M.W., 1970. The Rajmahal Traps of India, K–Ar ages and palaeomagnetism. *Earth Planet. Sci. Lett.,* 8: 371–378.

Mehta, D.R.S., 1964. Gondwanas in India. *Proc. Int. Geol. Congr., 22nd, New Delhi,* 24 pp.

Mehta, D.R.S., Joshi, K.C. and Gokerlam, A.R., 1963. A revision of the geology and coal resources of the Karanpura coalfield. *Mem. Geol. Surv. India,* 89: 208 pp.

Mital, G.S., Verma, R.K. and Pullaiah, G., 1970. Palaeomagnetic study of Satyavedu sandstones of Cretaceous age from Andhra Pradesh, India. *Geofis. Pura Appl.,* 81: 177–191.

Pascoe, E.H., 1959. *A Manual of the Geology of India and Burma, 2.* Government Press, Delhi, pp. 485–1343.

Pascoe, E.H., 1963. *A Manual of the Geology of India and Burma, 3.* Government Press, Delhi, pp. 1343–2129.

Pullaiah, G. and Verma, R.K., 1967. The magnetic properties of Tirupati Sandstone formation from Godavary Valley, India. *Earth Planet. Sci. Lett.,* 3: 67–74.

Pullaiah, G. and Verma, R.K., 1970. Geomagnetic field reversal in Cretaceous Tirupati Sandstone formation from India. *Phys. Earth Planet. Inter.,* 2: 158–162.

Radhakrishnamurty, C., 1970. Laboratory studies for ascertaining the suitability of rocks for palaeomagnetism. In: S.K. Runcorn (Editor), *Palaeogeophysics.* Academic Press, London, pp. 235–241.

Rao, P.V., 1964. Geology and mineral resources of India. *Proc. Int. Geol. Congr., 22nd, New Delhi,* 44 pp.

Schuchert, C., 1929. Review of the Late Palaeozoic formations and faunas with special reference to the ice-age of Middle Permian time. *Bull. Geol. Soc. Am.,* 38: 769–886.

Venkatachala, B.S. and Kar, R.K., 1968. Palynology of the Kathwai shales, Salt Range, West Pakistan, 1. Shales 25 ft, above the Talchir boulder bed. *Palaeobotanist,* 16: 156–166.

Verma, R.K. and Bhalla, M.S., 1968. Palaeomagnetism of Kamthi Sandstones of Upper Permian age from Godavary Valley. *J. Geophys. Res.,* 73: 703–709.

Verma, R.K. and Pullaiah, G., 1967. Palaeomagnetism of Tirupati Sandstones from the Godavary Valley, India. *Earth Planet, Sci. Lett.* 2: 310–316.

Visscher, H., 1972. Personal communication. Section of Palaeobotany and Palynology. State University Utrecht.

Wadia, D.N., 1953. *Geology of India.* Macmillan, London, 3rd ed. 532 pp.

Wensink, H., 1968. Palaeomagnetism of some Gondwana red beds from Central India. *Palaeogeogr. Palaeoclimat. Palaeoecol.,* 5: 323–343.

Wensink, H., 1972. Personal communication. Geological Institute, State University Utrecht.

Wensink, H., 1973. The India-Pakistan subcontinent and the Gondwana reconstructions based on Palaeomagnetic results. In: D.H. Tarling and S.K. Runcorn (Editors), *Implications of Continental Drift to the Earth Sciences, 1.* Academic Press, London, pp. 103–116.

Wensink, H. and Klootwijk, C.T., 1968. The Palaeomagnetism of the Talchir Series of the Lower Gondwana System, Central India. *Earth Planet. Sci. Lett.*, 4:191–196.
Wensink, H. and Klootwijk, C.T., 1971. Palaeomagnetism of the Deccan Traps in the Western Ghats near Poona (India). *Tectonophysics*, 11: 175–190.
Wellman, P. and McElhinny, M.W., 1970. K–Ar age of the Deccan Traps, India. *Nature*, 227: 595–596.
Zijderveld, J.D.A., 1967. A.c. demagnetization of rocks, analysis of results. In: D.W. Collinson, K.M. Creer and S.K. Runcorn (Editors), *Methods in Palaeomagnetism*. Elsevier, Amsterdam, pp. 254–286.