# Magnetic Study of the Dolerite Dyke near Amarpur, Dhanbad (Bihar)

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*Summary* – The dolerite dyke of post-lower Gondwana age reported earlier by the authors [5][2]) has been taken for detailed magnetic study. Seven magnetic traverses have been taken across the dyke using Schmidt vertical force variometer. Negative anomalies varying from 1400 to 2200 gammas have been observed. Magnetic susceptibility of samples from the dyke has been determined on both cores and crushed material, using the Model MS-3 susceptibility bridge. The average susceptibility of 20 samples has been found to be $1930 \times 10^{-6}$ C.G.S. units. Direction and intensity of remanence on 10 oriented samples have been determined by an Astatic magnetometer. The average intensity of remanence has been found to be $3.13 \times 10^{-3}$ C.G.S. units and the average direction has a declination of 323° and inclination −68° (up dip). The Koenigsberger ratio varies from 1.6 to 5.6. The high negative magnetic anomalies have been explained in terms of remanence – that more than 80 % of the anomaly is due to remanence and that negative anomalies are due to negative inclination of remanent direction of the rocks. The magnetic direction for the dyke gave the position for Dhanbad as 51° south latitude in Jurassic period. This is in conformity with the deductions made by other workers from the palaeomagnetic studies of the Deccan and Rajmahal traps. The virtual geomagnetic pole in Jurassic period as deduced from the palaeomagnetism of the dyke has a position of latitude $8\frac{1}{2}$°N and longitude 71°W, in the southern Carribean. On palaeomagnetic evidence this dyke has been correlated with Rajmahal traps of eastern Bihar.

## *Introduction*

Two types of basic dykes have been reported in and around Jharia Coalfield by earlier workers (i) dykes of pre-Cambrian metabasic rocks [1–3] (mainly metanorite, metadolerite and epidiorite) and (ii) unmetamorphosed dolerite dykes [4], occurring in the coal-bearing lower Gondwana formations of the Jharia Coalfield, of post-Lower Gondwana age (Jurassic, Cretaceous or Tertiary). The two types differ in mode of occurrence, petrography and age. Dykes of the second type are usually found traversing the Gondwana rocks of the Jharia Coalfield.

A dolerite dyke of the second type has been found near Amarpur village (23°50′N: 86°31′E) near Dhanbad, and a note on the magnetic study of this dyke has been published earlier by the authors [5]. The present paper deals with the details of the investigation.

## *Geology*

The dyke as exposed on the surface varies in width from 65 to 90 feet and runs

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[2]) Numbers in brackets refer to References, pages 147/148.

for more than 6 miles in a NW–SE direction. It cuts across the Archean Metamorphics (locally felspathic and hornblende gneisses). The dyke is vertical and has three sets of joints.

Under the microscope the rock exhibits typical ophitic texture and magnetite occurs as euhedral crystals and irregularly margined rods.

After making a geological study in the field and in the laboratory, the authors assigned a Jurassic-Cretaceous age for this dyke.

## *Magnetic profiles*

Seven magnetic traverses were taken across half-a-mile length of the dyke (Fig. 1) with Schmidt vertical force variometer (scale const. 25 gammas/sc. div.). A station

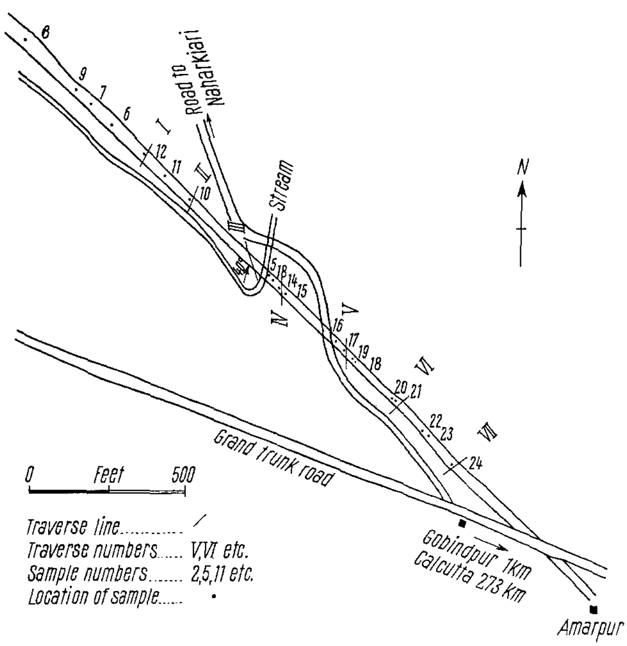
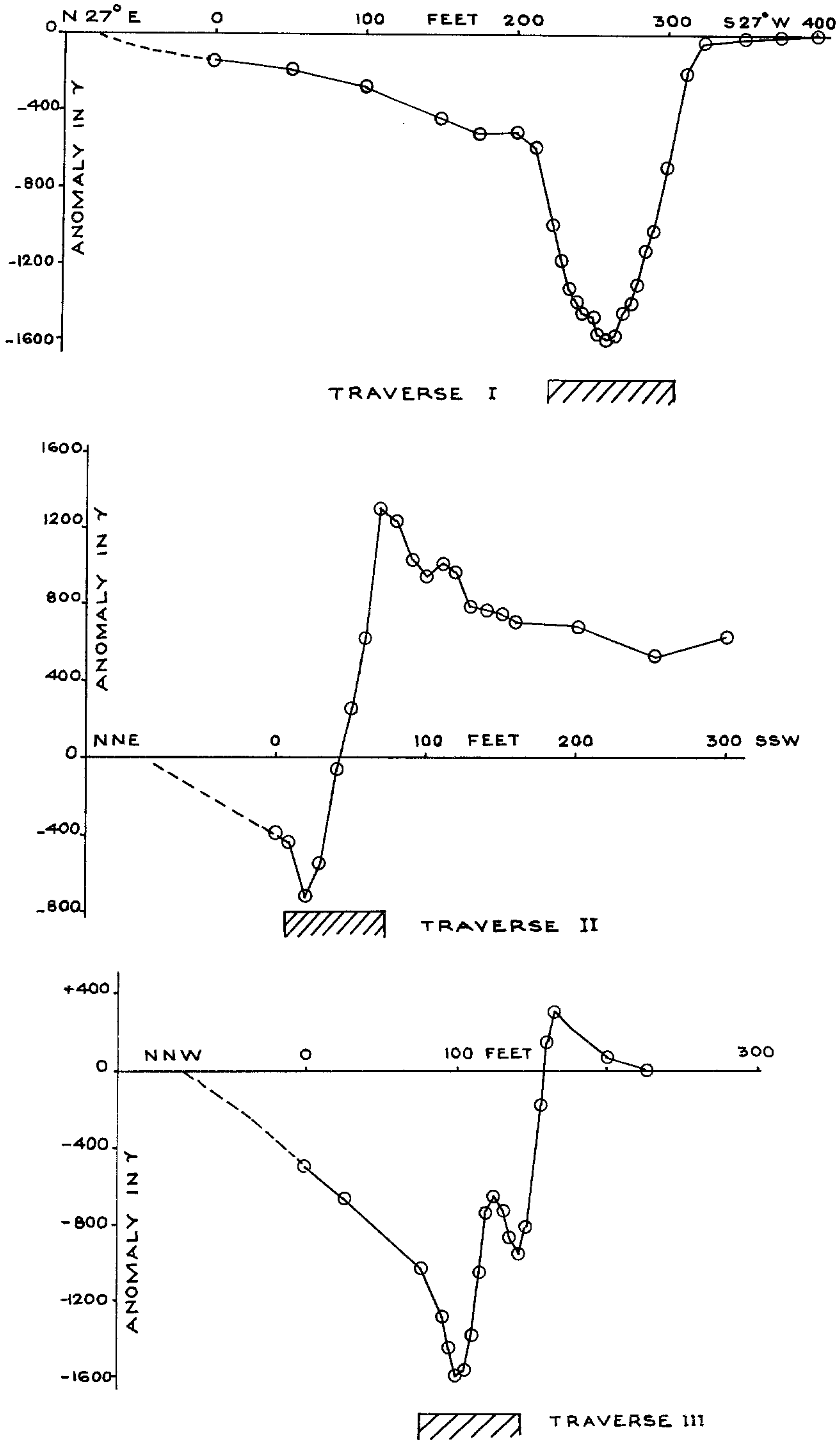



Figure 1
Sketch showing the location of magnetic traverses and samples

interval of 25 ft. or 100 ft. was taken and intermediate stations were taken wherever necessary. All the readings were reduced to a local base station, after making diurnal correction.

The magnetic profiles are shown in Fig. 2. The position of the exposed part of the dyke on the traverse line is indicated in each profile.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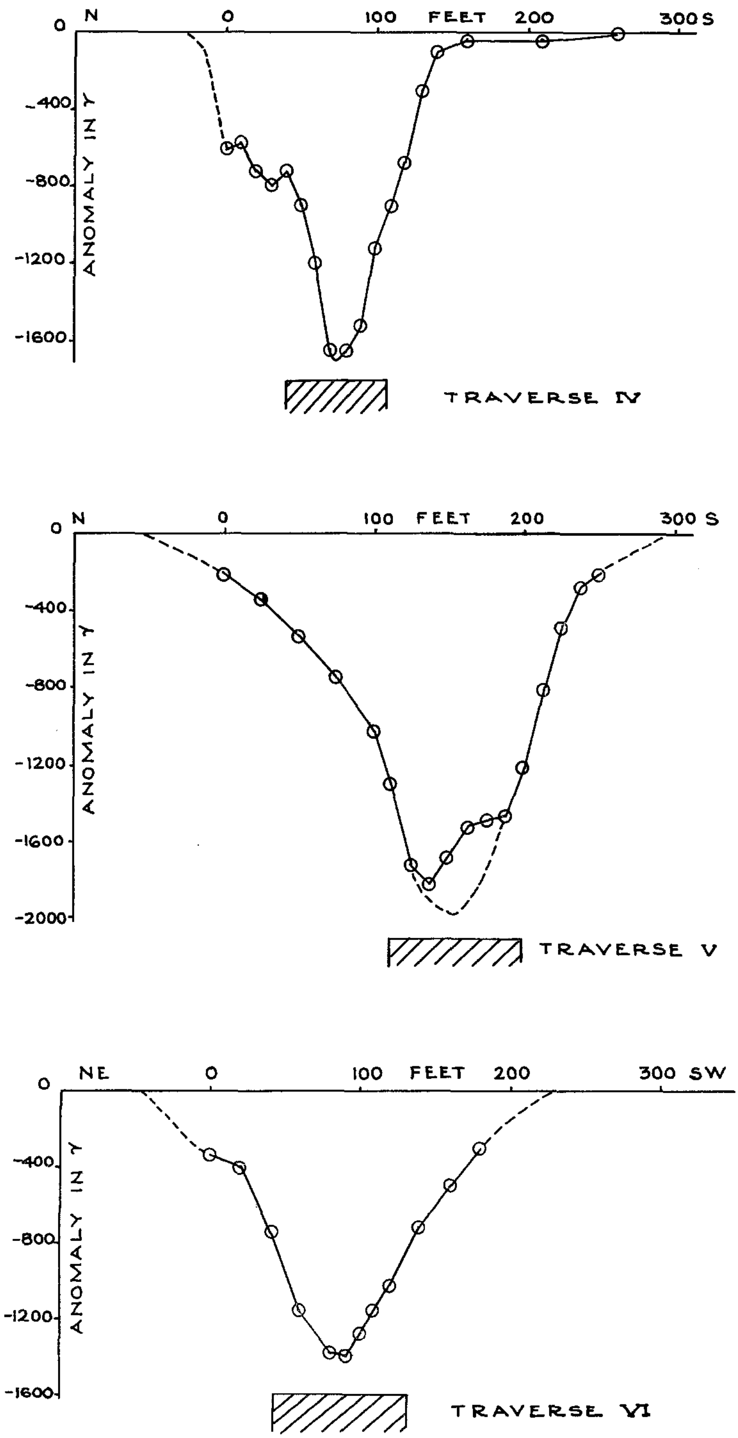

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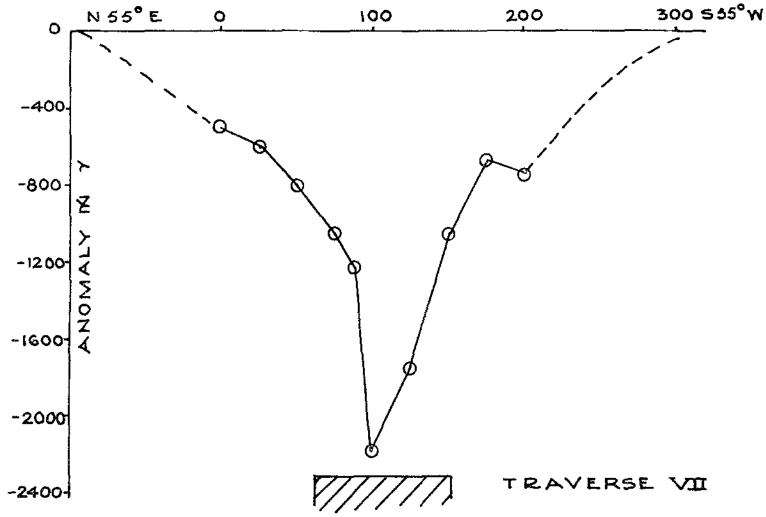


Figure 2
Magnetic profiles across the dyke

*Magnetic susceptibility*

The volume susceptibility has been determined with the Magnetic susceptibility bridge Model MS-3 made by the Geophysical Specialities Co., Minnesota. In this bridge the measurement is made in a magnetic field of the same order as the earth's field. The field is produced by alternating current and as such the instrument neither measures nor is affected by remanent magnetism. The samples to be measured can either be in the form of long cores (about $3\frac{1}{2}$ inches long) or chips or powder. In case of chips or powder the material is filled in a flat bottomed glass tube.

In this investigation 20 crushed samples and 7 cores have been used for susceptibility measurement. The samples have been crushed in a rock crusher. The following procedure has been adopted due to magnetic mortar. The crushed material has been sieved into 4 fractions with 4, 10 and 20 mesh sieves (Taylor's standard screens). The finest fraction ($-20$ fraction) contained iron filings derived from the crusher. Consequently, this fraction gave a high susceptibility value and hence it has been rejected. It has been found that the values of the remaining three individual fractions differ very little from one another and hence the average value of the three fractions has been taken to represent the susceptibility of the sample. It has also been found that these average values are very nearly the same as the values obtained for the cores of the respective samples (see Table 1).

Table 1 gives the magnetic susceptibility values of the 20 samples collected from the dyke. Here, only the average values of the three fractions $+4$, $-4+10$; $-10+20$ are given. Column 4 gives the susceptibility of the long core obtained from the same sample. Assuming that this is the actual value of susceptibility of the sample,

Table 1

*Magnetic susceptibility of samples*

| S.No. | Sample No. | $K \times 10^6$ C.G.S. units of crushed samples | of cores | %age of error |
|---|---|---|---|---|
| 1 | A 5 | 1716 | 1855 | 7.5 |
| 2 | A 6 | 1913 | | |
| 3 | A 7 | 1829 | 1942 | 5.8 |
| 4 | A 8 | 2062 | 2258 | 8.7 |
| 5 | A 9 | 1790 | | |
| 6 | A10 | 2027 | | |
| 7 | A11 | 1879 | 1863 | |
| 8 | A12 | 1954 | 2066 | 5.4 |
| 9 | A13 | 1574 | | |
| 10 | A14 | 1585 | | |
| 11 | A15 | 1897 | | |
| 12 | A16 | 2106 | | |
| 13 | A17 | 2065 | | |
| 14 | A18 | 1806 | | |
| 15 | A19 | 1905 | | |
| 16 | A20 | 1908 | | |
| 17 | A21 | 1642 | | |
| 18 | A22 | 1975 | | |
| 19 | A23 | 1982 | 2080 | 4.7 |
| 20 | A24 | 1878 | 2187 | 14.1 |
| | Average of 20 samples | 1940 | | |

the amount by which the average value (column 3) falls short of this is shown as percentage error in column 5. It can be seen from the table that except in case of one sample, all the average values of the fractions are lower than the values for the corresponding cores. This appears to be due to the loss of little magnetite into the finest fraction $(-20)$ during crushing and sieving.

*Remanence*

This is the magnetization acquired by the rocks during their formation and subsequently. In case of igneous rocks it is mainly and quite often thermo-remanence. The direction and magnitude of this quantity in relation to the present geomagnetic field is determined on oriented samples.

In the present investigation, 10 oriented samples have been collected from different portions of the dyke taking the usual precautions (Fig. 1). Cylindrical cores one inch in diameter have been obtained from each rock sample by cutting with a drilling machine. From each rock sample one to three cores have been cut. The cores have been sliced with the help of a diamond saw to give cylinders one inch long. Cylindrical specimens, one inch long and one inch in diameter are thus available for measurement of remanence.

The remanence has been determined with an astatic magnetometer assembled in this laboratory by the authors. It has a sensitivity of $2.353 \times 10^{-5}$ C.G.S. units/millimeter of scale division for a distance of 2.3 cm of the specimen from the centre of the lower magnet. The scale is kept at a distance of about a metre from the mirror. The arrangement (b) described by COLLISON and CREER on page 171 of the book edited by RUNCORN [6], has been used in the present investigation. In this arrangement the specimen is kept on one side of the lower magnet. The astatic magnetometer has been calibrated by passing a known current in a coil of the dimensions same as those of the specimen and kept in its place.

The measurement of the direction of magnetization was done on the three major components N–S, E–W, and vertical ($X$, $Y$ and $Z$ directions respectively) with reference to the N–S marking on the specimen. For each component, measurement was made in both directions, such as $+X$ and $-X$ directions and the effect of induced magnetization calculated and removed. In order to get the best estimate of the value of remanence ($J_n$) for a particular component the average of four readings in each of the two directions of the component was taken. Thus for each specimen 24 readings were taken as described by BLUNDELL [7]. This procedure reduces the effect of non-uniform magnetization within the specimen and improves the accuracy of the measurement. The remanent magnetization in the three directions has been calculated together with the sign. Declination ($D$), inclination ($I$) and resultant intensity ($R$) of the remanence have been calculated.

The magnetic stability of the specimens has been tested by remeasurement of NRM after one month with the specimens stored in the reversed direction (BLUNDELL [7]). It has been found in the present investigation that there is practically no difference in the two sets of readings (one set taken after storing for a month in normal position and the other set in reversed position). One sample which has been found to be unstable has been rejected.

The average value of remanence (both direction and magnitude) of two or more

Table 2

*Average values of direction and intensity of N.R.M. and $Q_n$ values of samples*

| Sl.No. | Sample No. | $D$ | $I$ | $J_n \times 10^3$ | $J_i \times 10^3$ | $Q_n$ | $J_n^z \times 10^3$ | $J_i^z \times 10^3$ | $Q^z_n$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A 5 | 17 | −62 | 3.62 | 0.77 | 4.7 | 3.20 | 0.43 | 7.4 |
| 2 | A 6 | 350 | −84 | 3.02 | 0.86 | 3.5 | 2.42 | 0.48 | 5.1 |
| 3 | A 7 | 327 | −62 | 3.48 | 0.82 | 4.2 | 3.06 | 0.46 | 6.7 |
| 4 | A 8 | 44 | −20 | 1.44 | 0.93 | 1.6 | 0.59 | 0.52 | 1.2 |
| 5 | A10 | 282 | −55 | 5.07 | 0.91 | 5.6 | 4.18 | 0.51 | 8.3 |
| 6 | A11 | 296 | −71 | 4.05 | 0.85 | 4.8 | 3.85 | 0.47 | 8.2 |
| 7 | A12 | 299 | −78 | 1.91 | 0.88 | 2.2 | 1.88 | 0.49 | 3.9 |
| 8 | A22 | 338 | −58 | 2.56 | 0.89 | 2.9 | 2.12 | 0.49 | 4.3 |
| 9 | A23 | 329 | −75 | −2.64 | 0.89 | 3.0 | 2.59 | 0.50 | 5.2 |
| 10 | A24 | 325 | −61 | 3.55 | 0.85 | 4.2 | 3.15 | 0.47 | 6.7 |

Table 3

*Range, mean intensity and average direction of N.R.M. of samples*

| No. of samples | $J_n \times 10^3$ C.G.S. units | | Mean direction of N.R.M. | |
|---|---|---|---|---|
| | Range | Mean | $D$ | $I$ |
| 8*) | 1.44 – 5.07 | 3.13 | 323 | – 68 |

*) For the purpose of calculation of $J_n$ all the 10 samples have been considered, while for mean direction A6 and A8 have been omitted. A6 is unstable and A8 is very much deviated from the rest.

cylindrical specimens obtained from one rock sample has been taken as the remanence of the sample and it is this value that is shown in table 2. Table 3 gives the range, mean intensity and the average direction of NRM of the samples. The following notation is used:

- $D$ Magnetic declination in degrees, of NRM, measured clock-wise from geographic north.
- $I$ Magnetic inclination in degrees, of NRM, +ve or –ve according as the north-seeking pole in pointing down or up
- $J_n$ intensity of NRM
- $J_i$ intensity of induced magnetization.
- $Q$ Koenigsberger ratio, $J_n/J_i$
- $J_n^z$ intensity of NRM in vertical direction.
- $J_i^z$ intensity of induced magnetization for vertical component of the earth's field at the place.
- $Q_n^z$ Koenigsberger ratio taking the vertical components, $J_n^z/J_i^z$.

### *Interpretation of magnetic profiles*

In the induction theory of interpretation, the magnetic anomalies are explained taking into consideration susceptibility, dimensions, disposition of geologic bodies and strength and direction of the earth's field. If the geologic body has little remanence in the direction of the earth's field the picture is not much altered. But the interpretation becomes complicated if the remanent field is not in the direction of the induced field. However, if the strength of remanent magnetization very much exceeds the strength of induced magnetization, the induction theory does not give a correct picture.

The intensity of magnetization, $J$ of a rock body is given by:

$$J = J_i \pm J_n$$

where $J_n$ is the intensity of natural remanent magnetization and $J_i$ the intensity of induced magnetization and they are vector quantities. $J_n$ can be one or more of the following: T.R.M., I.R.M., C.R.M., P.R.M. and depositional magnetization. The ratio $J_n/J_i$ (Koenigsberger ratio) depends on the nature and quantity of various ferromagnetic minerals, their grain size etc. Koenigsberger found that most lavas have a high ratio of remanent to induced magnetization. BRUCKSHAW and ROBERTSON [8] found for the Mull dykes a direction of magnetization significantly different from the present geomagnetic field. They found that remanent magnetization is responsible for the measured profile and this has completely dominated the induced magnetization. GIRDLER and PETER [9], while giving an example from the Gulf of Aden, emphasized the importance of the ratio of remanent to induced magnetization and the direction of remanent magnetization for the correct interpretation of magnetic anomalies. GREEN [10] stressed the importance of remanent magnetization for getting a satisfactory geologic picture. JAGDEO SINGH and KRISHNA RAO [3] found pronounced magnetic anomalies over portions of a metadolerite dyke in Dhanbad, showing high remanence (80% to 90% of total magnetization). COX and DOEL [11] found for basalt in hole EM7 of the Mohole project, a high Koenigsberger ratio, the average induced magnetization not exceeding 5% of the remanent magnetization. They stressed the importance of the Koenigsberber ratio in the interpretation of magnetic anomalies.

All these instances show that remanence cannot be neglected in the interpretation of magnetic anomalies.

In case of intrusive dykes whose extent may be considered as infinite in the direction of strike (two-dimensional bodies) magnetized lines are assumed in the interpretation of magnetic anomalies. For magnetic plates of great depth extent, only the magnetized line at the upper end is considered. However, this line is not situated at the upper surface of the plate but is situated some distance below the surface. In the interpretation of magnetic data, the 'depth' refers to the depth of the magnetized line but not the depth to the top of the body. In case of deeply buried bodies, the depth to the pole is very nearly same as the depth to the top of the body. But, in case of outcropping dyke, serious errors will result by this assumption. The line theory makes no assumption regarding the origin of the poles in a magnetized body. It is valid for any strength and direction of magnetization, regardless of origin of the pole (HEILAND [12, page 389].

If the magnetization is due to induction in the earth's field, neglecting the transverse magnetization, the vertical magnetic anomaly, $\Delta Z_p$, at a point $P$ on a line at right angles to the strike of the plate, is given by the formula,

$$\Delta Z_p = \frac{2\,k\,z_0\,b\,d}{x^2 + d^2} = \frac{2\,J_i^z\,b\,d}{x^2 + d^2} \tag{1}$$

where, $k$, $Z_0$, $b$, $d$ and $x$ stand for susceptibility, vertical component of the earth's field, breadth (or thickness) of the plate, depth to the magnetized line, and distance along the profile line from a point directly above the magnetized line pole. The remanent magnetization $J_n^z$ may be substituted for $k\,Z_0$ $(=J_i^z)$, when it is appreciably greater than the induced magnetization (HEILAND [12, page 387]). The maximum anomaly occurs directly above the line pole and by setting $x=0$ in the above equation,

$$\Delta Z_{\max} = \frac{2\,k\,Z_0\,b}{d} \tag{2}$$

The depth rule in case of line pole is $d=x$, where $x$ is the distance at which

$$\Delta Z_p = \tfrac{1}{2}\,\Delta Z_{\max} \tag{3}$$

Taking both the induced and remanent magnetizations and neglecting the transverse components of these magnetizations, the formula (1) becomes,

$$\Delta Z = \frac{2\,b\,d}{x^2 + d^2}\,(J_i^z \pm J_n^z) \tag{4}$$

the $\pm$ sign indicates normal or reverse polarization respectively.

The values of some of the magnetic elements at Dhanbad are as follows:

| | |
|---|---|
| Total intensity, | $F=0.45$ oest. |
| vert. comp, | $Z=0.25$ oest. |
| Hor. comp, | $H=0.37$ oest. |
| Declination, | $D=0°$ |
| Inclination, | $I=+34°$ |

The breadth (or thickness of the dyke varies from 65 ft. to 90 ft. with an average value of 80 ft. The thickness of overburden varies from 0 to 4 ft. As the depth extent of the dyke is here considered infinite, the magnetic line pole will not be at the surface. From table 2 it is clear that Koenigsberger ratio in the vertical direction ($Q_n^z$), in general, is about 6, i.e. about 85% to 90% of the anomaly is caused by remanence. The magnetic profiles, except in case of traverse II, are single minima. Applying the depth rule, the depth to the magnetic line has been obtained from the magnetic profiles of

Table 4

*Intensity of N.R.M. and depth to the magnetic line as expected from the anomalies over traverses taken across the dyke*

| So. No. | Traverse No. | max $\Delta Z$ in $r$ | breadth, $b$ in feet | depth, d in feet | Representative sample No. | Expected $J_n^z \times 10^3$ C.G.S. | Actual †) $J_n^z \times 10^3$ C.G.S. |
|---|---|---|---|---|---|---|---|
| 1 | I | −1600 | 80 | 38 | A12 | 3.32 | 1.88 |
| 2 | III | −1600 | 65 | 50 | A 5 | 5.67 | 3.20 |
| 3 | IV | −1700 | 65 | 30 | A 5 | 3.34 | 3.20 |
| 4 | V | −1980 | 90 | 52 | A 5 | 5.52 | 3.20 |
| 5 | VI | −1400 | 90 | 50 | A22, 23 | 3.41 | 2.35*) |
| 6 | VII | −2200 | 90 | 35 | A24 | 3.80 | 3.15 |
| | Average | −1750 | 80 | 42.5**) | | | |

*) Average of samples A22 and A23
**) Taken as 40 for the purpose of calculation
†) from table 2.

individual traverses and this has been found to vary from 30 to 52 ft with an average value of 52.4 ft. (The height of the magnetometer above the ground surface, 3 ft has been neglected.)

In this calculation, the intensity of remanent magnetization is assumed to be uniform in the vertical direction.

It is clear from table 1 that the magnetic susceptibility of the material of the dyke is uniform within reasonable limits, the average value being $1930 \times 10^{-6}$ C.G.S. units. Taking the average breadth of the dyke as 80 ft and average depth of the pole as 40 ft (table 4) the nature of anomaly due to induced magnetization that would be expected over a vertical dyke of infinite depth extent and of such dimensions is shown as continuous curve in fig. 3. This curve has been constructed using the formula 1,

$$\Delta Z_p = \frac{2\,k\,Z_0\,b\,d}{x^2 + d^2}\,.$$

The maximum anomaly works out to be +193 gammas. The total to induced magnetization ratio (as inferred from the average value of $Q_n^z = 6$) is about 7:1 and the corresponding average anomalies (as given in table 4) is 1750:193, i.e. about 9:1. It is remarkable that these two ratios are nearly same. This apparently means that remanence and susceptibility are fairly uniform within reasonable limits in the vertical direction also.

Except sample no. A8, all the samples have steep negative inclinations. Transverse magnetization is here neglected because of steep inclination (−68° on an average). Thus, the magnetic anomalies varying from 1400 gammas to 2200 gammas (Fig. 2) can be explained by negative inclination of remanent magnetic field. Taking into account the average values of both the remanent and induced magnetization in the

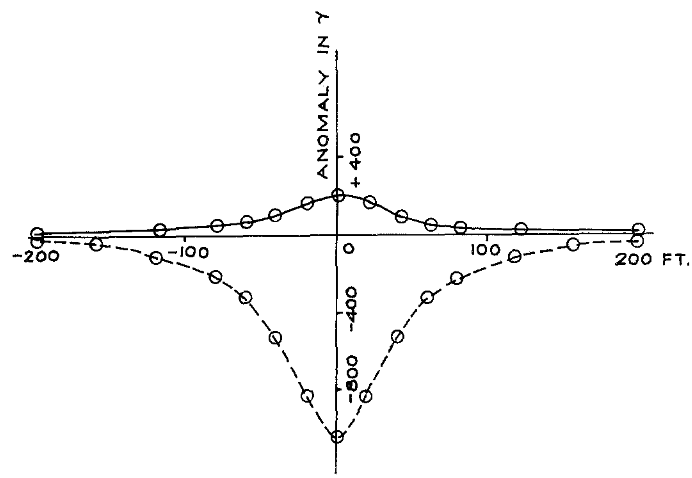


Figure 3
Curves expected over the dyke due to induced and total (resultant) magnetization in the vertical direction

vertical direction, the curve in broken line in Fig. 3 (here called total magnetization) has been constructed using the formula 4,

$$\Delta Z = \frac{2\,b\,d}{x^2 + d^2}\,(J_i^z - J_n^z).$$

The values of quantities used in this calculation are :

$b$ = 80 ft.

$d$ = 40 ft.

$J_i^z = 1930 \times 0.25 \times 10^{-6} = 0.48 \times 10^{-3}$ C.G.S. units (from table 1).

$J_n^z = 3.13 \times 10^{-3}$ C.G.S. units (from table 2).

The maximum anomaly (at $x=0$) works out to be $-1060$ gammas.

If the dyke were to be magnetized by induction in the earth's field only, the expected anomaly due to induced magnetization would be +193 gammas. But the curve in broken line in Fig. 3 explains the pronounced negative anomalies obtained on all traverses except on traverse II.

The profile for traverse 11 has the characteristics of transverse magnetization. Sample no. A10, collected form traverse II, has a remanent magnetic declination of 282° (i.e. roughly towards west) and this is probably responsible for the transverse magnetization giving such a curve. Samples A12 from traverse I and A11 in-between traverses I and II, have similar declination (table 2) but traverse I gives a distinct negative anomaly. This is probably because of the steep negative inclinations of 78° and 71° of the samples and the relative contribution of the horizontal magnetization is less. Perhaps the declination in the samples from the surface is not representative of those below. This is a tentative explanation.

The samples collected are only representative of the uppermost part of the dyke. But the anomaly reflects the average intensity of the dyke to great depths and also of any other formation close-by. For each traverse the intensity of N.R.M. that would be expected from the anomaly has been calculated using the formula no. 4 (taking into account the intensity of induced magnetization also) and shown in table 4. The actual intensity of N.R.M. of the representative samples has also been shown in the same table for comparison. In all cases it can easily be noticed that the expected intensity is only slightly higher than the actual intensity but the ratio is always less than 2. This is probably because of the approximation done in the calculation of depth from the magnetic curves, by neglecting the effect of induced magnetization.

## *Palaeomagnetism*

The use of rock magnetism to investigate the past magnetic field of the earth began a few decades ago. Since then this line of work has been taken up throughout the world. There are now good reasons for supposing that the directions of magnetization in some rock formations reflect the directions of the earth's magnetic field at the time of formation.

Although the hypothesis of continental drift has been criticised it is once again gaining strength. Evidence derived from palaeomagnetic data has a particular bearing on the hypothesis of continental drift, since it is entirely independent of the geological arguments that have been put forward so far.

DEUTSCH, RADAKRISHNAMURTY and SAHASRABUDHE [13] deduced from palaeomagnetic investigation on parts of Deccan traps that India has drifted northward through 50° of latitude and rotated 25° anti-clockwise since their formation, i.e. within the last 70 million years. Similar results have been obtained by CLEGG, DEUTSCH and GRIFFITHS [14] on parts of Deccan traps and CLEGG, RADHAKRISHNAMURTY and SAHASRABUDHE [15] on Rajmahal traps.

The statistical analysis proposed by FISHER [16] has been used in this investigation. The radius of circle of confidence, ($\alpha_{95}$) has been calculated at 95% probability level.

The results of palaeomagnetic investigation of Amarpur dolerite dyke are shown in table 5. For the sake of comparison the results of palaeomagnetic investigation of upper Rajmahal traps of eastern Bihar as given by COX and DOELL [17] are also shown in the table. (The notation used by COX and DOELL is used in this table). It is very interesting to note that the magnetic direction of the Amarpur dyke is correlating closely with that of the upper Rajmahal traps as also the pole position. Fig. 4 is the stereographic projection of the magnetic direction for the samples from this dyke.

The normal magnetization in horizontal direction and steep negative inclination (−68°) show that these rocks acquired thermo-remanence in the normal geomagnetic field in the southern hemisphere when the dyke cooled in Jurassic or Cretaceous period.

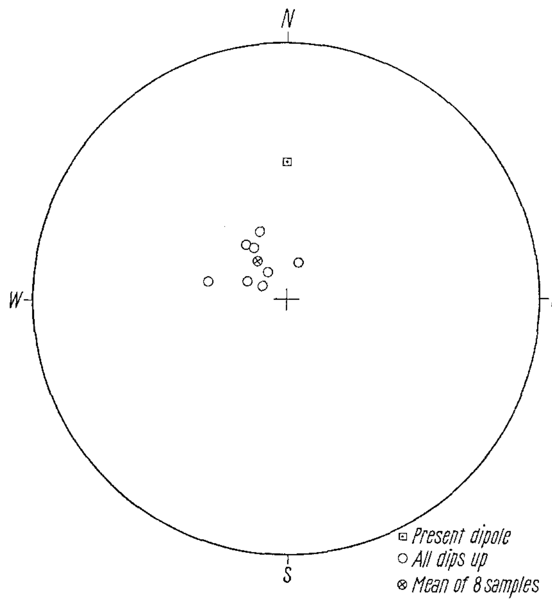


Figure 4
Amarpur dolerite: Stereographic projection

Table 5

*Magnetic directions and pole positions obtained from palaeomagnetism of Amarpur dolerite and Upper Rajmahal traps*

| Rocks sampled. | Locality | | Magnetic direction | | | | | Pole position | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lat. | Long. | $D$ | $I$ | $\alpha_{95}$ | $k$ | $N$ | Lat. | Long. | $P$ | $\delta_m$ | $\delta_p$ | $\lambda$ |
| Amarpur dolerite | 24N | $86\frac{1}{2}$E | 323 | −68 | $10\frac{1}{2}$ | 29.4 | 8 | $8\frac{1}{2}$N | 71W | S | $17\frac{1}{2}$ | $14\frac{1}{2}$ | 51S |
| Upper Rajmahal Traps | 25N | 88E | 327 | −64 | 4 | 36 | 33 | 13N | 69W | S | $6\frac{1}{2}$ | 5 | 46S |

If the mean direction of magnetization is taken to correspond to that of a geomagnetic axial dipole field at the time of intrusion of the dyke, it follows that the Amarpur area had a southern latitude of 51° at that time. Alternatively, if the area had been at 51°N, India had rotated clockwise by 143° and the earth's field had been reversed, the same result would have been obtained; however, this appears to be less likely than the former, viz. a southern latitude, a normal field and 37° rotation. The corresponding ancient position of the north geographic pole, computed on the polar wandering hypothesis, lies in the southern Carribean at latitude $8\frac{1}{2}$°N, longitude 71°W, very close to point IX in Fig. 2 of CLEGG *et al.* [15].

The magnetic direction for the Amarpur dyke is in consonance with the proposed drift of the Indian land mass since Jurassic time.

## *Conclusion*

1. The direction and intensity of NRM of samples from this dyke is quite uniform. Susceptibility also is quite uniform.

2. About 75% of total magnetization of the samples is due to remanence, as indicated by the Koenigsberger ratio.

3. Negative vertical anomalies across the dyke, ranging from −1400 to −2200 gammas are due to negative magnetic inclination of remanent magnetization. A major part of the anomaly and in many cases more than 80%, is due to remanence.

4. On palaeomagnetic evidence this dyke has been correlated with the Rajmahal traps.

5. The magnetic direction for Amarpur dyke gives the position for Dhanbad as 51° south latitude in Jurassic period.

This is in conformity with the deductions made by other workers from palaeomagnetic studies of the Deccan and Rajmahal traps.

6. The virtual geomagnetic pole in Jurassic period, as deduced from the palaeomagnetism of Amarpur dyke, has a position latitude $8\frac{1}{2}$°N and longitude 71°W, in the southern Carribean. This position almost coincides with the position given by the workers on Rajmahal traps of eastern Bihar.

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