cannot be employed to throw light on the mode of genesis of the amphibolites concerned.

5. The $Fe_2O_3/(FeO + Fe_2O_3)$ ratio indicates that the brown amphibole is characterised by a higher state of oxidation than the other two amphiboles.

6. According to Leake[11] and Walker *et al.*[12], amphibolites with more than about 250 ppm of Cr and 200 ppm of Ni, low Niggli *k* values, and high amount of TiO_2 are likely to be ortho-amphibolites. The brown amphibole satisfies the requirement fully, and is most likely an ortho-amphibolite. That the blue-green and the yellow-green amphiboles do not satisfy this requirement does not, however, unambiguously indicate their original sedimentary nature.

7. When the present data are plotted on TiO_2 *vs* Cr, and TiO_2 *vs* Ni scatter plot of Leake[11], the blue-green and yellow-green amphiboles fall in the range of pelites, indicating that they might be para-amphibolites. The brown amphibole falls in the ortho-amphibolites range (and plots along with the Karroo dolerites). Both para and ortho-amphibolites show similar trends in the Ni *vs* Cr scatter plot[11] and hence no conclusion could be drawn from this plot.

8. The Na_2O/K_2O, K/Sr and TiO_2/Cr ratios of the brown amphibole are markedly different from the other two amphiboles and may be used as criteria for derivation from igneous parentage. It should, however, be pointed out that as observed by Leake[11], individual analysis cannot be employed to determine uniquely whether a given amphibolite is of igneous or sedimentary origin.

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APPLICATION OF PALAEOMAGNETISM IN ESTIMATING THE AGE OF THE DOLERITE DYKES OF THE PENINSULAR INDIA

Dolerite dykes traverse the granites and gneisses in almost every part of the Peninsula. Their ages have been discussed from time to time by several workers, and different conclusions have been drawn. Foote (1880), Hatch (1902), Rama Rao (1940), Pichamuthu (1959), Janardan (1964), and Kripanidhi (1968) relegated them to pre-Cuddapah age. Holland (1897), Wetherel (1904), Smeeth (1915) Coulson (1933), Pascoe (1950), Ramanathan (1955) and Ziauddin (1969) are of the opinion that the dykes were contemporaneous with the Cuddapah traps, and hence of Cuddapah age. Murthy (1955) argues that these dykes belong to two ages, (1) those intruded immediately after the formation of the charnockites and (2) those intruded during the Cuddapah period. Sadasivaiah and Ikramuddin (1966) assigned the Deccan trap age for the dykes of Bidadi-Harohalli area. Palaeomagnetic results obtained on the dyke samples of the Tirupati area, by the present author, have furnished data for solving the problem of the age of the Peninsular dykes.

Oriented samples were collected from 25 dykes for palaeomagnetic work. The intensity and direction of remanent magnetization of the dyke samples were measured using astatic magnetometers of suitable sensitivity at Tata Institute of Fundamental Research, Bombay. Out of 25 dykes, 14 yielded consistent directions and 10 yielded inconsistent directions. One dyke is very weak and its remanent mangnetization could not be measured even with the most sensitive magnetometer available in the Institute. Out of 14 consistent dykes, 4 dykes (Group I dykes) are normally magnetized, 7 dykes (Group II dykes) are reversely magnetized, and the remaining 3 dykes (Group III dykes) show an intermediate direction, azimuth being around 280° east of north with negative dips around 20°, suggesting that the consistent dykes fall into three distinct groups indicative of three different phases of dyke intrusion.

The specimens were subjected to AC demagnetization to test the stability of their natural remanent magnetization (NRM). It is found that the dykes which exhibited consistent directions, initially, remained so after demagnetising in 75 and 150 oe fields. The slight spread in NRM directions is reduced after AC cleaning of the specimens, indicating that the secondary component present has been removed. The AC cleaned directions for the consistent dykes are shown in Fig. 1, and

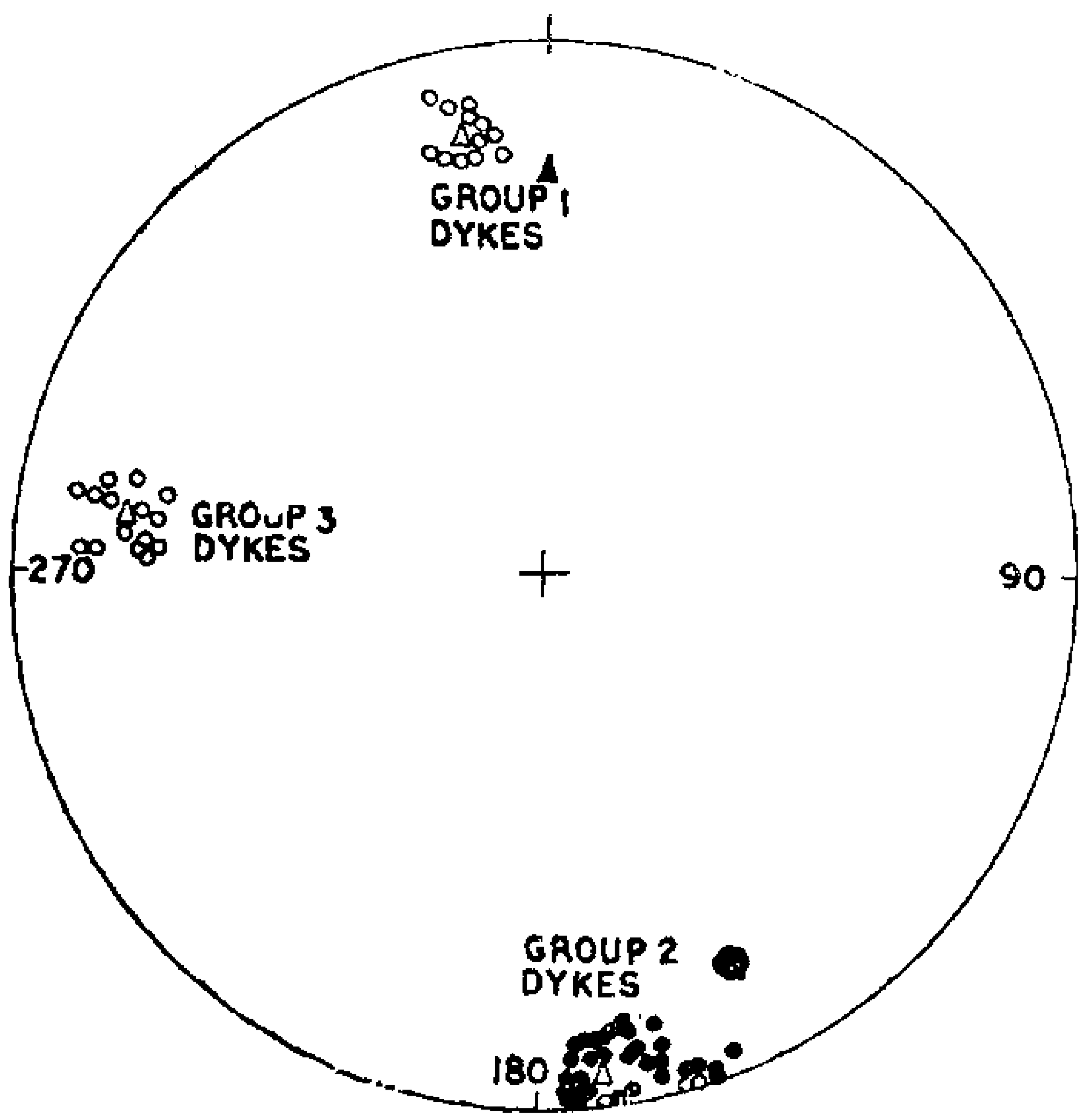

FIG. 1. AC cleaned directions for the consistent dykes of the Tirupati area. O, upward dips; ●, downward dips; △, mean of the cleaned directions; ▲, present dipole.

TABLE I

Mean magnetic directions of the Tirupati dolerite dykes

	No of samples	Mean directions: Azimuth	Mean directions: Dip	Cone of confidence
Group I dykes	16	349°	−17°	3°
„ II dykes	42	171°	9°	1°
„ III dykes	18	278°	−22°	4°

their mean magnetic directions are given in Table I. On the other hand, the dykes which do not possess consistency, initially, could not be improved even after AC cleaning in fields high enough to demagnetize them completely.

Specimens from 14 dykes were subjected to thermal demagnetization. As in AC demagnetization, the consistent dykes are remarkably stable until the whole magnetism in the specimens was destroyed. On the other hand, the inconsistent dykes, which did not improve after AC cleaning, have not come round to any common order even after thermal cleaning.

Field characters indicate that the group III dykes are the youngest in the region as they intersect all the other dykes. The directions shown by these dykes are similar to the directions obtained by Prasad (1966) for Cuddapah shales baked by traps. This indicates that the group III dykes and the baked Cuddapah shales are magnetized more or less at the same time. Therefore, it may be said that the group III dykes are contemporaneous to Cuddapah traps.

In the field it is observed that the group I and group II dykes cut across the granites and gneisses of the Tirupati area, which are the equivalents of the Closepet granites. Group III dykes intersect dykes of group I and II. Therefore, the group I and II dykes are younger than the Closepet granites but older than group III (Cuddapah) dykes. Between group I and II, group II dykes are found to be younger than group I dykes, based on the evidence from a multiple intrusion (Anjanappa and Suryanarayana, 1971). The multiple intrusion is formed by the injection of a later dyke along the centre of the earlier one. The younger dyke which has chilled contacts with the older one is reversely magnetized whereas the older dyke is normally magnetized. Based on this evidence it is considered that all the dykes which are normally magnetized are older than the reversely magnetized ones.

Field and petrographical study of the inconsistent dykes (group IV dykes) indicate that they are metadolerites and are the oldest of all the dykes in the region. They have the characteristics of Archaean amphibolites and hornblende-schists. They may be correlated with the hornblende- and pyroxene-granulites which have intruded at the close of the Peninsular gneiss period.

From the above observations it is evident that there are four phases of dyke intrusion in the Tirupati region. Group IV dykes are oldest, being formed at the close of the

Peninsular gneiss period; whereas group III dykes are the youngest formed during the Cuddapah period. Group I and II dykes, formed at the closing stages of the Archaean period, represent intermediate phases between group III and IV.

For quite a long time the consensus of opinion among many earlier workers was that there were only two phases of dyke intrusion in the Peninsula. The observations made by the present author in the field and laboratory suggest that there are at least four phases of dyke intrusion in the Tirupati area. Similar conclusions may be drawn for all the dykes of the Peninsula, since the Tirupati area, the dykes of which are investigated, form an integral part of the Peninsula.

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A GEOCHRONOLOGICAL MAP OF INDIA

ALL available radiometric dates (Aswathanarayana[1-3]; Crawford and Compston[4,5]; Grasty and Leelanandam[6]; Holmes[7-9]; Mehta and Nagpal [10a,b]; Pichamuthu[11]; Sarkar[12]; Sarkar *et al.*[13-18]; Saxena and Miller[19]; Spooner[20]; and Vinogradov and Tugarinov[21]) have been plotted on a geological map of India. Generalised structural trends are superimposed on the geology.

The following important features have been observed:

1. The oldest continental nuclei in three regions, *viz.*, Rajasthan, Bihar and South India appear to be greater than 3,000 million years old. Apparent ages in the range 2450–2900 million years are also prominent in all three nuclei.

2. The generalised contours of equal ages are related to the regional trends in the South India, Eastern Ghats. Rajasthan and Bundelkhand. Distinctly aberrant trends are observed only in Bihar. This may be due to:
   (*a*) Lack of sufficient radiometric data and/or
   (*b*) The sequence of metamorphic events have been very different in some areas.

3. In the north-western Himalayan region the dates recorded by Saxena and Miller[19] and in Nepal by Gansser[22] suggest that these areas have been subjected to orogenies and metamorphism besides the Tertiary. In Simla region whilst the significance of the apparent ages > 4,000 m.y. remains doubtful, the accumulating evidence does suggest that late Proterozoic, Caledonian, Hercynian and Middle Mesozoic orogenic disturbances and metamorphism occurred before the widespread Tertiary event. One date of 728 m.y. from Nepal may suggest the presence of Pre-Cambrian nucleus in that region. Saxena's contention[23,24] that the imprints of Proterozoic, Caledonian, Hercynian and Mesozoic disturbances, based upon geological observation, can be seen in Himalayas seems to be supported by the geochronological data available to date.

The geochronological map of India also suggests that the oldest continental nuclei contain rocks formed earlier than 3,000 m.y. and that the generalised cantours of equal apparent ages appear to follow regional structural trends in most cases.

A detailed account of the geological history of the Indian sub-continent in the light of the radiometric data will be published separately.