

Figure 1. **a**, The logical interconnection of the host and nodal processors used for simulating the discrete Hopfield model of neural networks. The figure illustrates a system consisting of four processors ($P=4$), and the nodal interconnection topology is a directed ring. **b**, The domain decomposition strategy adopted here in parallelizing the discrete Hopfield model. The number of nodal processors (P) in the system is taken as four. The major data items to be partitioned are the interaction matrix J of size $n \times n$ and the network state vector σ of size n . The dashed lines divide the interaction matrix and the state vector into four parts, to be downloaded into the respective processors. For the sake of simplicity n is assumed to be exactly divisible by P . J^{im} and σ^m denote interaction submatrix of size $(n/P) \times (n/P)$ and network state subvector of size (n/P) respectively.

processors P is fixed and the problem size n is increased, then one always gets an increase in performance, and the speed-up approaches P asymptotically.

Table 1 gives the results of the simulation experiments. The times were obtained using the UNIX operating-system function 'clock'. Usually one observes a standard error of about one to two per cent in the values returned by this 'clock' function. The main source of this error is perhaps the time-slicing mechanism employed to schedule jobs in a multi-user environment. Hence the numerical order of the experimental speed-ups in the last two or three rows should not be taken seriously. Thus, excluding the order of the experimental speed-ups in the last two rows, the agreement between the theoretical and experimental data is quite good. These results show that the PACE architecture is very effective for simulating the discrete Hopfield model of neural networks.

1. Hopfield, J. J. and Tank, D. W., *Biol. Cybern.*, 1985, 52, 141.
2. Amit, D. J., Gutfreund, H. and Sompolinsky, H. *Phys. Rev.*, 1985, A32, 1007.
3. Venkataraman, G. and Athithan, G., *Pramana—J. Phys.*, 1991, 36, 1.
4. Neelakantan, K., Ghosh, P. P., Ganagi, M. S., Athithan, G., Atre, M. V. and Venkataraman, G., *Curr. Sci.*, 1990, 59, 982.
5. Ghosh, P. P., Ganagi, M. S. and Ashok, A., 'Simulator Users Manual', ANURAG report ANU/PACE/90/02, Hyderabad, 1990.
6. Fox, G. C., Johnson, M. A., Lyzenga, G. A., Otto, S. W., Salman, J. K. and Walker, D. W., *Solving Problems on Concurrent Processors*, Prentice-Hall International, New York, 1988, vol. 1.

ACKNOWLEDGEMENTS. I thank Dr G. Venkataraman and Dr M. V. Atre for reading the manuscript and suggesting improvements. I also thank Mr P. P. Ghosh for help at various stages of the work on PACE-8.

Received 13 September 1991; accepted 3 October 1991

Palaeomagnetism of calc-granulites from Sadanandapuram in the manganese ore belt of Vizianagaram District of Andhra Pradesh

A. Lakshmipati Raju and U. Kedareshwarudu

Department of Geophysics, Andhra University, Visakhapatnam 530 003, India

Calc-granulite is a prominent formation associated with manganese ore, in Eastern Ghats, in the Vizianagaram District of Andhra Pradesh. We carried out palaeomagnetic measurements on calc-granulites from Sadanandapuram in the manganese ore belt of Vizianagaram District. The corresponding palaeomagnetic pole is 14° N and 12° E and coincides with that of Visakhapatnam charnockites. We point out the inadequacy of available palaeomagnetic results from this part of Eastern Ghats Belt and stress the need for more palaeomagnetic investigations.

THE calc-granulites are regionally metamorphosed impure calcareous sediments consisting of calcite, wollastonite, diopside, garnet, quartz, scapolite, orthoclase, microcline and albite¹⁻³. Apatite, sphene, muscovite, pyrite, serpentine, biotite and chlorite are relatively in smaller proportions. Ferruginous and chloritic material are distributed around the grain boundary of calcite. We carried out palaeomagnetic measurements on the calc-granulites for the purpose of correlating them with other known results.

Ten oriented block samples of calc-granulite were collected from Sadanandapuram (lat. $18^\circ 16' N$, long. $83^\circ 33' E$) in the manganese ore belt. Cylindrical specimens of 2.5 cm in diameter and 2.2 cm in length were drilled in the laboratory. At least two specimens were prepared from each sample. The natural remanent

magnetization (NRM) (J_n) of specimens was measured on a Spinner magnetometer. Volume magnetic susceptibility (K) was measured on a low field susceptibility apparatus⁴ at a field strength of 0.05 mT(H). The Koenigsberger ratios, Q_n (J_n/KH), were calculated.

The NRM intensities of calc-granulites are in the range 1.3×10^{-3} and 350×10^{-3} A/m. The magnetic susceptibilities are between 0.5×10^{-3} and 35.7×10^{-3} (SI) with an average of 9.4×10^{-3} . The Q_n ratios are from 0.24 to 8.6 and the average value is 2.7 (SI). From the specimen directions of all the specimens of a sample, a sample mean was calculated using Fisher's method⁵ and all the sample means from the site were projected on Schmidt's equal area net and presented in Figure 1, *a*. The specimens were subjected to A.F. demagnetization for isolating the stable component of remanent magnetism. The demagnetization was carried out in progressively increasing field strengths of 2.5, 5, 10, 15, 20, 30, 40, 60, 80 and 100 mT. The optimum demagnetizing field for effective removal of secondary components was decided by observing the vector rotation and the dispersion of directions.

The changes brought about in the remanent magnetic direction by successive field strengths for two specimens are shown in Figure 2, *a*. The decay in intensity during the same demagnetization operation is shown in Figure 2, *b*. It is observed that the vector rotation is minimum for demagnetizing fields of 5 to 30 mT. This is evident from Figure 2. Beyond 30 or 40 mT, the change in directions is random. Directions for a peak

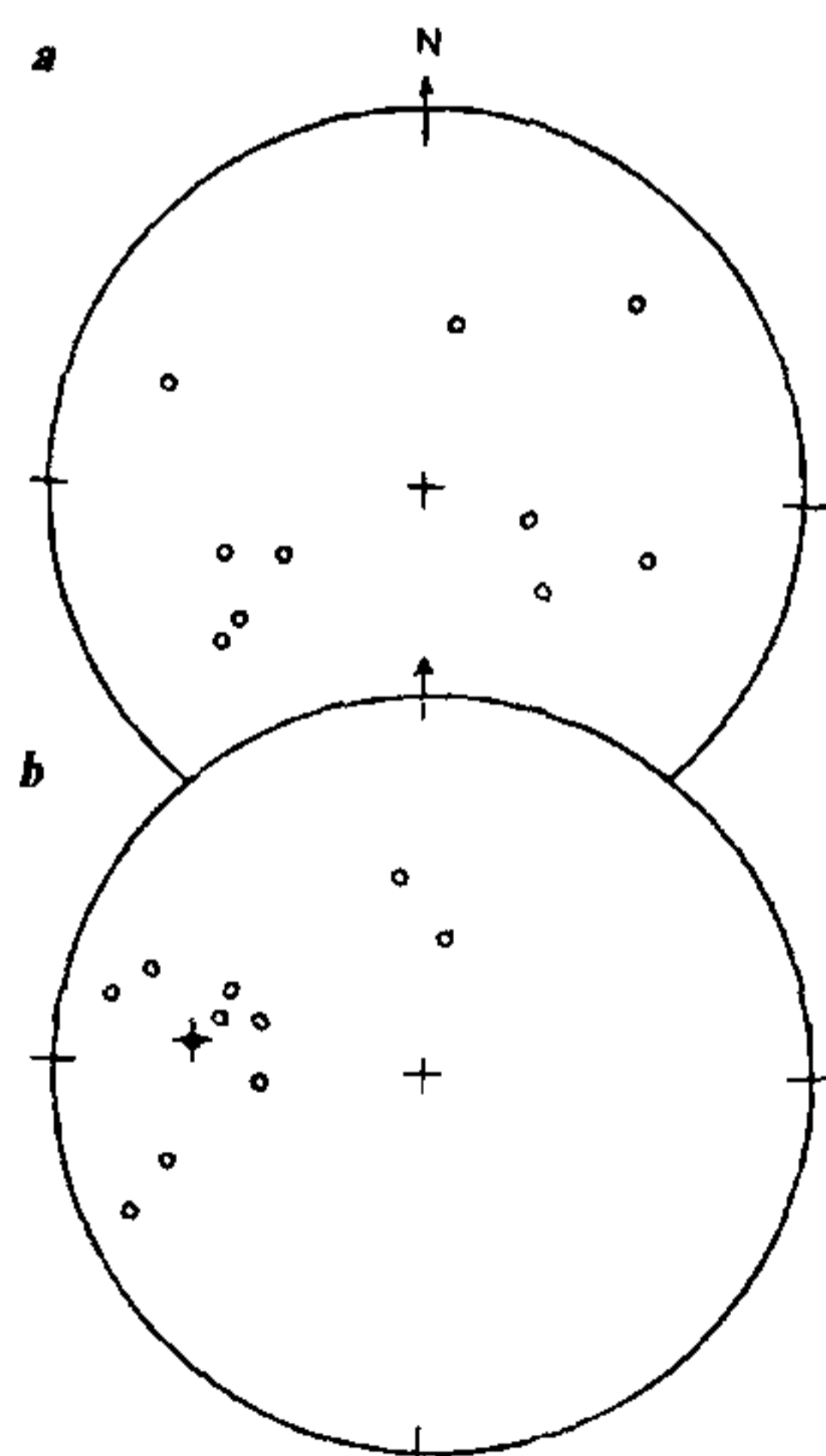


Figure 1. *a*, NRM directions. *b*, Direction after a.f. demagnetization. \times Mean direction.

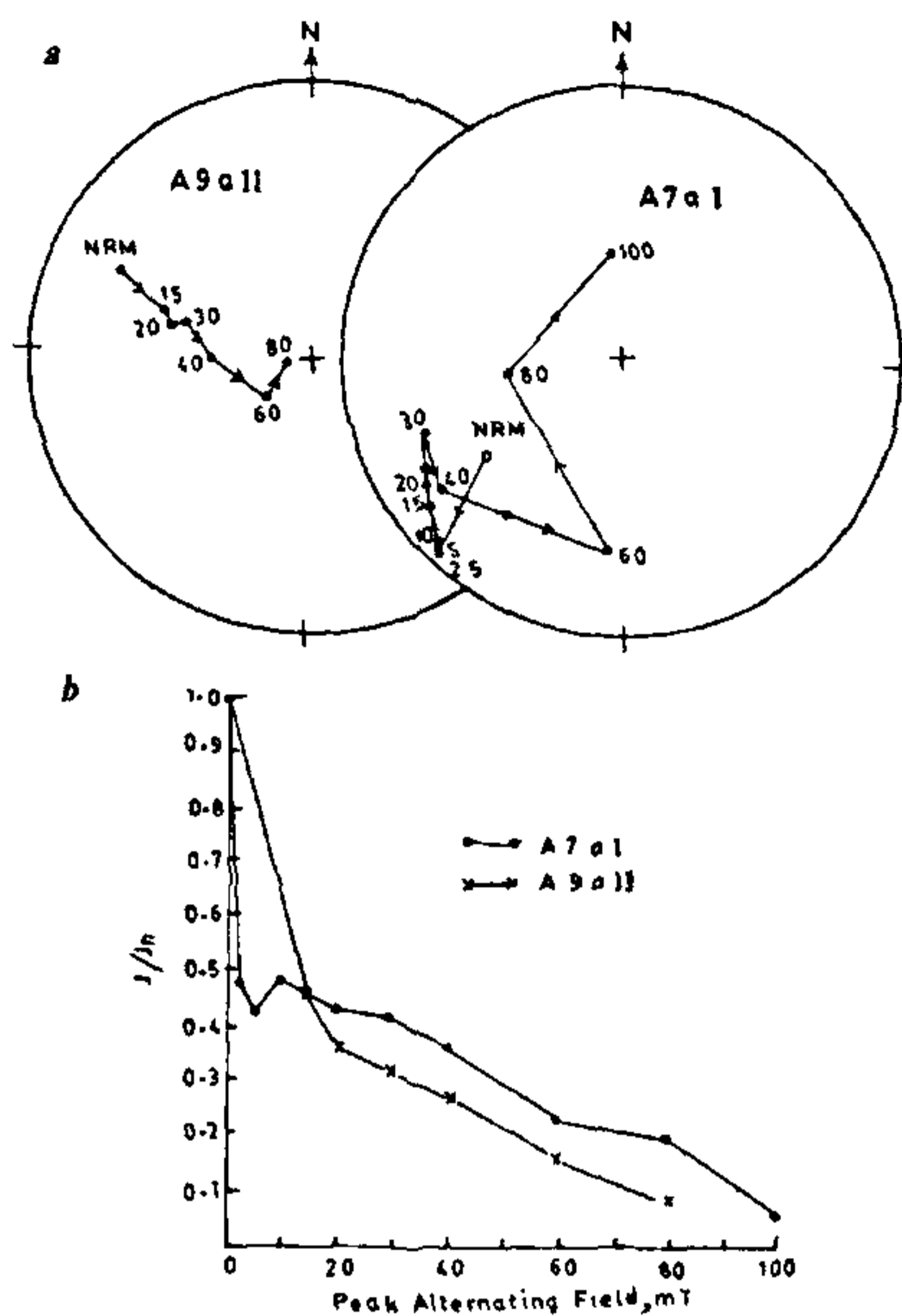


Figure 2. Changes in direction and normalized intensity with progressive a.f. demagnetization for two specimens.

alternating field of 30 mT have less dispersion than for any other field strength and they are shown in Figure 1, *b*. The mean direction obtained, the corresponding pole position and other palaeomagnetic parameters are listed in Table 1. The pole position almost coincides with that of one of the two mean directions reported for Visakhapatnam charnockites⁶ (Table 1).

The Eastern Ghats are composed of parallel layers of khondalites and charnockites and their variants. The evolutionary history of the charnockite-khondalite system is marked by successive geosynclinal facies of sediments and volcanic effusives with the associated intrusives. In the Eastern Ghats belt, at least three episodes of metamorphic activity⁷ are known to have occurred. Metamorphically, the rocks in this belt are of the granulite facies. The coincidence of the pole position of calc-granulites with that of Visakhapatnam charnockites probably means that the two formations were magnetized during the same period of metamorphism or other process. Though it is known that the two formations are affected by regional metamorphism, the coincidence of pole positions may further indicate that none of them has been disturbed as far as the magnetization is concerned by any local geological

Table 1. Magnetic properties and palaeomagnetic data of calc-granulites compared with those of Visakhapatnam charnockites

Rock type	$J_r \times 10^3$ A/m	$K \times 10^3$ (SI)	Q_n	D_m	I_m	k	α_{95}	λ_p	ϕ_p
Calc-granulite	1.3-350	0.5-35.7	0.24-8.6	278°	+38°	16.4	13°	24°N	12°N
Visakhapatnam charnockites (A) ⁶	—	—	—	280°	+35°	—	—	15°N	9°E

process. There are very few palaeomagnetic results reported from the Eastern Ghats belt of northern Andhra Pradesh. Though the geologic history of Eastern Ghats is known on a broader scale, there is need for palaeomagnetic investigations to bring out any local variations in metamorphic or tectonic activity.

1. Krishna Rao, J. S. R. and Sastry, A. V. R., *Proc. Indian Acad. Sci.*, 1964, 59, 222.
2. Rao, G. V., *Bull. Geol. Surv. India, Series-A, Econ. Geol.*, 1969, 35, 14.
3. Murthy, D. S. N. and Kanungo, D. N., *Geophys. Res. Bull.*, 1981, 19, 293.

4. Likhite, S. D. and Radhakrishna Murthy, C., *Geophys. Res. Bull.*, 1965, 3, 1.
5. Fisher, R. A., *Proc. R. Soc. London*, 1953, A217, 295.
6. Bhimasankaram, V. L. S., *Curr. Sci.*, 1964, 33, 465.
7. Sarkar, S. N., *Precambrian Stratigraphy and Geochronology of Peninsular India*, Dhanbad Publishers, Dhanbad, 1968.

ACKNOWLEDGEMENTS. The measurements reported were made in the Palaeomagnetic Laboratory of the National Geophysical Research Institute, Hyderabad. We are grateful to the Director, NGRI, for providing the facility. The cooperation extended by Dr G. V. S. P. Rao of NGRI is thankfully acknowledged.

Received 25 June 1991; revised accepted 18 December 1991

Discovery of Proterozoic boninite from Jagannathpur volcanic suite, Singhbhum craton, Eastern India

Shabber H. Alvi and M. Raza

Department of Geology, Aligarh Muslim University, Aligarh 202 002, India

Jagannathpur volcanic suite occurs as faulted out-liers within the Noamundi-Koira sequence of banded iron formation of the Singhbhum craton. Recent chemical studies have delineated some quartz normative samples from this suite which, similar to boninites, have high MgO, Ni and Cr content at an intermediate SiO_2 . These are differentiated along a calc-alkaline trend and their low $\text{CaO}/\text{Al}_2\text{O}_3$, Ti/Zr , Ti/Y and high Zr/Y ratios along with the high LILE and Zr are comparable with those of modern boninites. We infer that they are derived from MORB-type mantle source and represent an early phase of arc volcanism.

ALTHOUGH Proterozoic volcanism has a significant position in the geologic record of the Singhbhum craton¹ various volcanic suites have not received adequate attention. Their chemical affinity and/or tectonic setting has not yet been interpreted in terms of plate tectonics. Recently, in course of a geochemical study on Jagannathpur volcanic suite², samples containing low TiO_2 attracted much attention because of their possible tectonic significance in relation to the origin of ophiolites³ and because of their recognition as

distinctive, if not a diagnostic feature of boninitic lavas⁴⁻⁶. This prompted us to identify some boninite samples from this suite. Here we report the boninite discovery and discuss its significance.

On the western side of Singhbhum Granite, Jagannathpur volcanic suite occurs as faulted out-liers within the Noamundi-Koira sequence of banded iron formation⁷. It has been dated to be 1629 ± 30 Mys (million years) by K-Ar method⁸. Unlike the other Proterozoic suites of the region, viz. Dalma, Ongarbira, Dhanjori, Simlipal and Bonai volcanic suites, it does not have any sedimentary rock association and is free from regional metamorphism. It appears to be made up of a large number of block lava flows, individual flow sets have a plan width of 100 to 200 m. Banerjee⁷ identified the number of flows between 25 and 30. Less abundance of vesicles in the flows and lack of pyroclastics suggest that volcanism was predominantly nonviolent and had low volatile content.

Cameron *et al.*⁹ used mineralogical and petrographical features to identify boninites. As these features mainly reflect the modes of eruption and consolidation of a volcanic rock, they vary widely in any magma type and hence they may not be considered reliable^{4,10}. The chemical characteristics more consistently reflect the genetic differences between boninite and other magma types^{4,5,10-12}.

The most striking features of the samples (Table 1) are the high concentrations of refractory elements such as MgO, Ni and Cr combined with silica saturation and high values of large ion lithophile elements. Al_2O_3