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PALEOMAGNETISM OF METAMORPHIC ROCKS FROM THE PIQUETE REGION - RIBEIRA VALLEY, SOUTHEASTERN BRAZIL

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Paleomagnetic data are presented corresponding to 42 hand samples of metamorphic rocks exposed in the Piquete region (Ribeira Valley, Southeastern Brazil — 22°35'S, 45°15'W). K/Ar age determinations suggest a Late Cambrian-Early Ordovician age for the cooling phase of these metamorphic rocks. After paleomagnetic treatment, a reversed direction (considering the present position of South America) in 20 samples from 9 sites was isolated (Dm = 60.4°, Im = 68.0°, α_{95} = 6.8°) which yielded a paleomagnetic pole at Lat. = 0.8°S, Long. = 346.5°E (α_{95} = 10.2°). Most of the remaining samples presented unstable remanence. It is shown that the reversed direction may be representative of the cooling phase of these metamorphic rocks.

Apresenta-se resultados paleomagnéticos correspondentes a 42 amostras de mão de rochas metamórficas provenientes da região de Piquete (Vale do Ribeira, Sudeste do Brasil — 22°35'S, 45°15'W). As idades K/Ar sugerem que a fase de resfriamento destas rochas metamórficas ocorreu no Cambriano Superior-Ordoviciano Inferior. Após o tratamento paleomagnético, isolou-se uma direção reversa (considerando a posição atual da América do Sul) em 20 amostras de 9 sítios (Dm = 60,4°, Im = 68,0°, α_{95} = 6,8°), que resultou em um polo paleomagnético em Lat. = 0,8°S, Long. = 346,5°E, (α_{95} = 10,2°). A maior parte das outras amostras apresentou remanência instável. Concluiu-se que a direção remanescente encontrada pode ser representativa da fase de resfriamento destas rochas metamórficas.

INTRODUCTION

The Brasiliano cycle which corresponds to the Pan-African cycle, represents the latest geosynclinal folding episode which affected the South American platform. In the main event, there was a reworking affecting most of South America, which lasted from Late Proterozoic to Early Paleozoic (650-450 Ma), with its final cooling phase in the Ordovician (450-500 Ma).

Cordani & Brito Neves (1982) attributed an ensialic nature to many of the Brasiliano mobile belts and the paleomagnetic data may be important to clarify this geotectonic interpretation. Also the Late Pre-Cambrian and Early Paleozoic paleomagnetic data are yet scarce and insufficient for establishing the South American APW path for this period.

With the purpose of throwing light on these problems, a paleomagnetic analysis of metamorphic rocks exposed in the Piquete region (Ribeira Valley, Southeastern Brazil) is presented: these rocks are crystalline basement rocks, which were fully reworked during the Brasiliano cycle.

GEOLOGICAL SETTING AND SAMPLING

The crystalline basement of Southeastern Brazil, presents a complex configuration due to the superposition of thermo-tectonic events which affected the area. This fact complicates the lithological boundaries and the definition of units as showed by Cavalcante et al. (1979), Hasui et al. (1981) and Hasui et al. (1984).

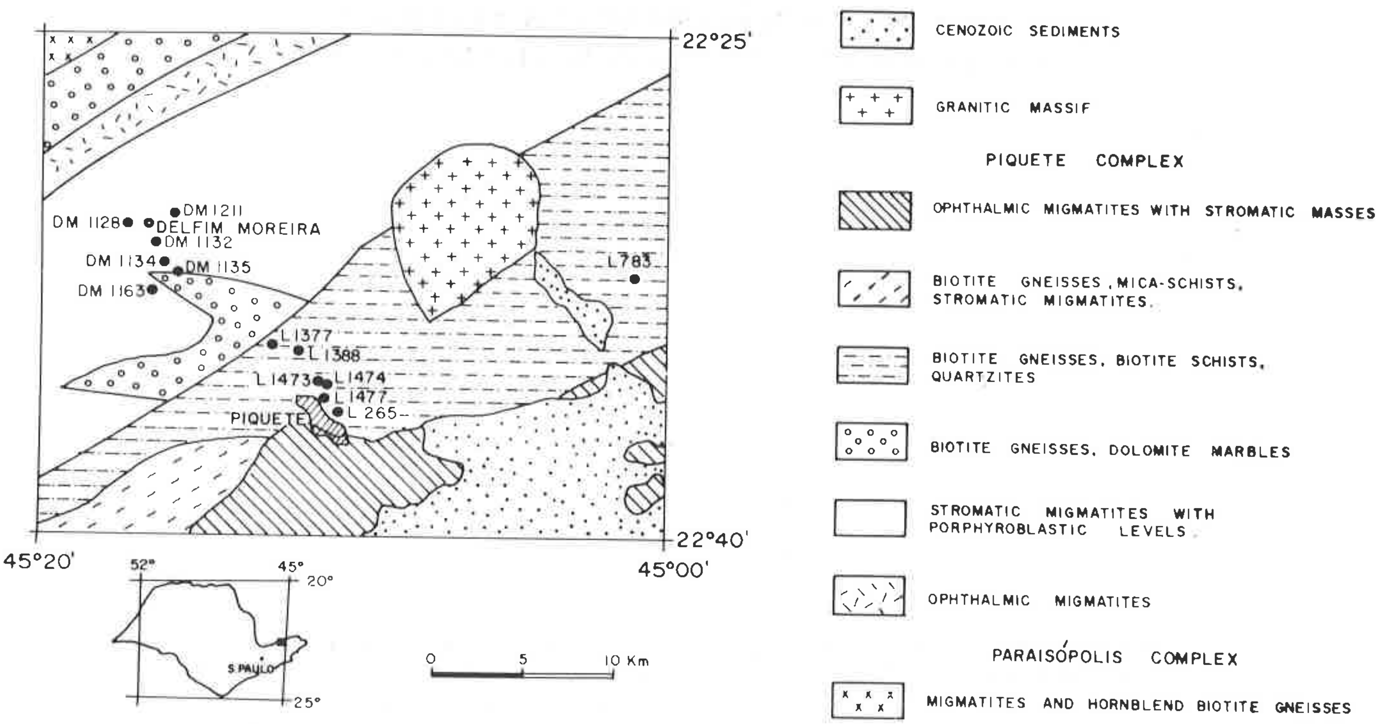

Figure 1 - Partial simplified version of the geological map after Cavalcante et al., 1979. The sampling sites are indicated by full circles.

The samples used in this study belong to the Piquete Complex, which is included in a larger suite of metamorphic rocks named Paraiba do Sul Assemblage (Cavalcante et al., 1979). This assemblage is composed, in general, of granitoids metamorphosed to amphibolite facies, metasediments (marbles, quartzites, etc.) and locally, granitical late tectonic igneous rocks.

Forty two hand samples which include migmatites, amphibolites, schists, quartzites and gneisses were collected at 13 sites near the towns of Cruzeiro, Delfim Moreira and Piquete (22º35'S, 45º15'W) close to the São Paulo-Minas Gerais State boundary (Southeastern Brazil, Fig. 1, Table 1). Samples were oriented by sun and magnetic compasses.

Table 1 — Sampling sites

SITE	SAMPLES	LITHOLOGY
L-783	CR-1 - CR-3	Schist
L-1477	CR-4 - CR-6	Quartzite
L-1474	CR-7 - CR-9	Biotite-Gneiss
DM-1135	CR-10 - CR-12	Migmatized amphibolite
DM-1134	CR-13 - CR-15	Migmatite
DM-1132	CR-16 - CR-19	Migmatite
DM-1128	CR-20 - CR-23	Migmatite
DM-1211	CR-24 - CR-26	Venitic migmatite
DM-1163	CR-27 - CR-30	Venitic migmatite
L-1377	CR-31 - CR-33	Qz. - biot. shist
L-1388	CR-34 - CR-36	Qz. - biot. schits
L-1473	CR-37 - CR-39	Qz. - biot. schits
L-265	CR-40 - CR-42	Porphyro blastic gneiss

POTASSIUM-ARGON DETERMINATIONS

There are several K/Ar dates on these metamorphic rocks. Dating was effected for biotite, amphibole and muscovite and the results range from 467.6 15.3 Ma to 531.7 13.5 Ma (Kawashita, K., unpublished data), with a peak value around 490-500 Ma. Biotite and amphiboles showed similar values suggesting a rather fast cooling for these metamorphic rocks.

THE PALEOMAGNETIC STUDY

About one hundred and twenty six specimens (cylinders of 2.5 cm diameter and height) were cut from the forty two samples. A spinner magnetometer was used to measure the remanent magnetization of these specimens. Thermal and alternating field demagnetizations were used to investigate the remanece of samples and nearly all the specimens were demagnetized in detail.

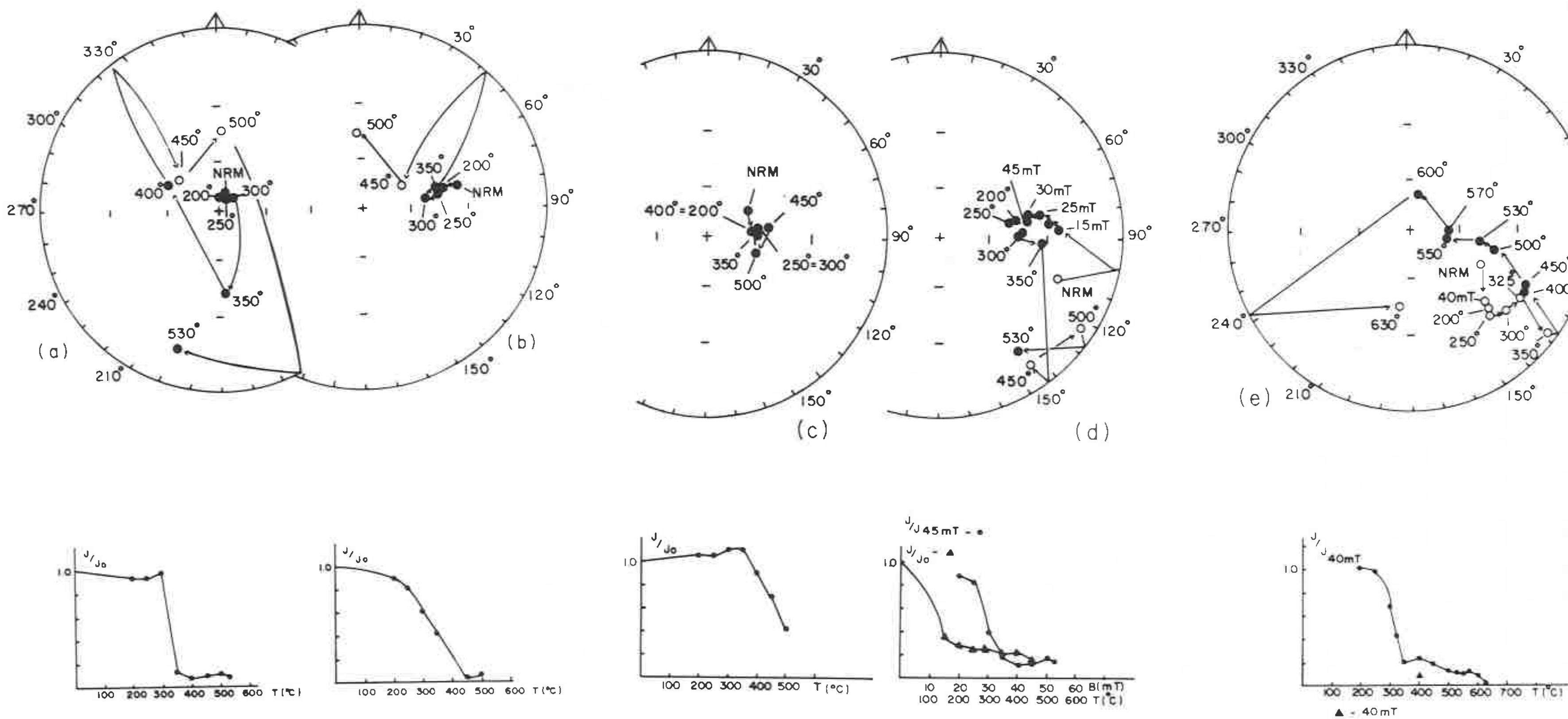

Figure 2 - Examples of the magnetic treatment. (a) sample CR-12-C1; (b) CR-36-C1; (c) CR-31-B2; (d) CR-29-C1; (e) CR-27-A1. The Wulff stereographic projection of magnetization directions during the treatment (top) and normalized intensity curve (battom) are shown for each sample. Open (full) circles are negative (positive) inclinations.

Table 2. Paleomagnetic results.

SITE	N	n	CHARACTERISTIC MEAN DIRECTION					VIRTUAL GEOMAGNETIC POLE	
			DEC. (°)	INC. (°)	K	α95 (°)	P	LONG. (°E)	LAT. (°S)
L-783	-	-	unstable remanence					-	-
L-1477	-	-	unstable remanence					-	-
L-1474	2	3	47.7	78.9	90.8	26.5	R	330.6	7.6
DM-1135	2	6	42.7	75.4	58.6	33.2	R	333.1	1.6
DM-1134	-	-	unstable remanence					-	-
DM-1132	2	6	67.0	55.2	1067.2	7.6	R	3.2	- 3.9
DM-1128	-	-		-	-	-	-	-	-
DM-1211	3	11	24.6	69.1	47.1	18.1	R	329.8	- 11.6
DM-1163	3	9	73.3	61.0	26.5	24.4	R	0.2	3.5
L-1377	2	4	64.9	65.8	16.6	65.7	R	352.0	1.4
L-1388	2	6	77.8	56.7	46.9	37.2	R	6.0	4.4
L-1473	1	4	66.5	67.7	-	-	R	350.5	3.6
L-265	3	5	42.2	75.2	93.5	12.8	R	333.1	1.1
MEAN			60.4	68.0	57.2	6.8		346.5	0.8

N - Number of samples
n - Number of specimes
P - Polarity (R - Reverse)

K = 26.1
α95 = 10.2°

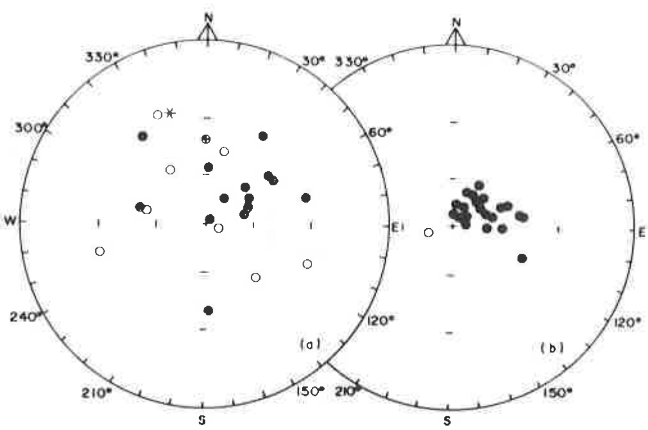

Figure 3 — Sample mean directions of the Natural Remanent Magnetization (a) and of the Characteristic Remanent Magnetization (b) obtained after treatment. Open (full) circles are negative (positive) inclinations. The symbols * and ⊕ are the present geomagnetic field and the dipolar field, respectively.

All the samples from sites L-783, L-1477 and DM-1134 and samples CR-8 (site L-1474), CR-11 (site DM-1135), CR-16, CR-17 (site DM-1132), CR-20 (site DM-1128), CR-30 (site DM-1163), CR-33 (site L-1377), CR-34 (site L-1388), CR-37 and CR-39 (site L-1473) showed unstable remanence and were excluded. For the other samples it was possible to isolate a consistent reverse direction (considering the present position of South America). Fig. 2 shows some examples of the laboratory treatment.

Many specimens have unstable magnetization after treatment at 300-350°C, as it can be seen in the examples of Fig. 2. Also, a considerable decrease in the intensity of remanence was noticed at about 350°C (sample CR-12-C1, Fig. 2), which suggests that maghemite could be significantly present in these samples. However, for some samples, this reverse direction was isolated at higher temperatures, as observed, for example, in specimen CR-27-C1 (Fig.2). Although this direction had been isolated for only two steps of demagnetization (550-570°C), it appears also for other specimes of sample CR-27.

Fig. 3 shows the plot of the mean magnetization direction for each sample. Only one sample (CR-21) showed normal polarity which is approximately opposite to the characteristic reversed directions (Fig. 3). However another sample (CR-23) belonging to the same site (DM-1128) showed a reversed direction but far from the main group. Since the other samples from this site yielded no consistent results, all samples were rejected.

The mean magnetization direction and the virtual geomagnetic pole for each site were calculated giving unit weight to each sample. The results are summarized in Table 2. A mean direction of Dm = 60.4°, Im = 68.0° (α_{95} = 6.8°) was obtained which yielded the paleomagnetic pole CR located at Lat. = 0.8°S, Long = 346.5°E (α_{95} = 10.2°). Fisher's (1953) method was used in the statistical treatment.

INTERPRETATION

The paleomagnetic study of these Pre-Cambrian rocks fully reworked during the Brasiliano cycle (650-450 Ma), disclosed a unstable remanence behavior in many samples. However, it was possible to isolate a consistent reverse direction (Table 2) for samples from 9 sites which is quite different from the present geomagnetic field.

The Pre-Cambrian and Lower Paleozoic South American paleomagnetic data are yet scarce and insufficient for establishing any polar path for this time interval. However, the paleomagnetic data support the idea that Gondwana existed during Lower Paleozoic (McWilliams, 1981). Furthermore, the geological and geochronological evidences show that at least Africa and South America were part of the same geotectonic unit during Proterozoic and Paleozoic (Torquato & Cordani, 1981). In this way it is reasonable to compare South American poles to an African APW path. Fig. 4 shows the drift curve proposed by McWilliams & Kröner (1981) for Southern Africa during the 900-500 Ma interval and slightly modified (in the 600-500 Ma portion) by D'Agrella (1984). This curve is extended to younger ages (hatched part) using the Gondwana curve defined by Morel & Irving (1978).

The CR pole is compared to the APW path in Fig.4 after rotation to Africa (22.6° N, 21.2° E)), according to Smith & Hallam (1970), and an age of about 450 Ma is suggested for the characteristic magnetization. This age represents the end of the Brasiliano cycle cooling phase, as showed by radiometric determinations.

Another fact coherent with the identification of this age with the origin of the magnetic direction, is related to the magnetic behavior of these samples. As already remarked, the large decrease observed in the intensity of magnetization during the demagnetization process at temperatures around 300-350°C, suggests that maghemite is possibly the main magnetic carrier of many samples. If this is so, heating above 300°C after the formation of that mineral are not likely, since this would cause a transformation of maghemite. In this way it is reasonable to admit an age of 450 Ma for the characteristic magnetization.

After the Brasiliano cycle (Late Proterozoic and Early Paleozoic), the next tectonic important event was the Wealdenian reactivation in the South American platform which is related to the South Atlantic opening. However, this event does not appear to have affected these metamorphic rocks, since the characteristic magnetic direction reported here is quite different from the Mesozoic directions (Ernesto, 1985, Valencio et al., 1983).

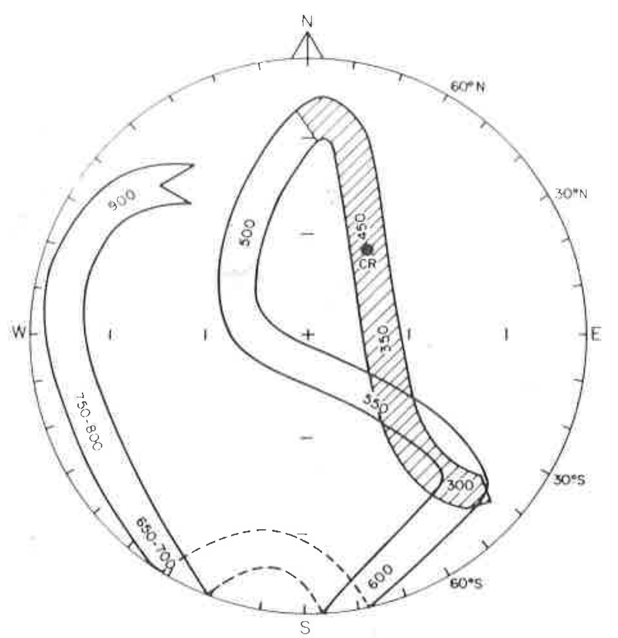

Figure 4 — African apparent polar wander path for the Upper Proterozoic and Early Paleozoic (900-500 Ma), as suggested by D'Agrella (1984), extended to younger ages, using part of the curve defined by Morel & Irving (1978). CR represents the rotated paleomagnetic pole (according to Smith & Hallam, 1970) obtained in this study: pole at Lat. = 22.6°N, Long. = 21.2°E. Lambert projection.

REFERENCES

CAVALCANTE, J.C., CUNHA, H.C.S., CHIEREGATI, L.A., KAEFER, L.Q., ROCHA, J.M., DAITX, E.C., COUTINHO, M.G.N., YAMAMOTO, K., DRUMOND, J.B.V., ROSA, D.B. & RAMALHO, R. - 1979 - Projeto Sapucaí - Geologia. Relatório final, São Paulo, DNPM-CPRM, nº 4, 299 pp.

CORDANI, U.G. & BRITO NEVES, B.B. - 1982 - The geologic evolution of South America during the Archaean and Early Proterozoic. Rev. Bras. de Geoc. **12** : 78-88.

D'AGRELLA, M.S. - 1984 - Estudo paleomagnético dos Grupos Itajaí, Castro, Camaquã e Bom Jardim. MSc dissertation, IAG/USP.

ERNESTO, M. - 1985 - Paleomagnetismo da Formação Serra

Geral: Contribuição ao estudo do processo de abertura do Atlântico Sul. Ph.D. thesis, IAG/USP, Brazil.

FISHER, R.A. - 1953 - Dispersion on a sphere. Proc. Roy. Soc. (London), ser. A, **217** : 295-305.

HASUI, Y., DANTAS, A.S.L., CARNEIRO, C.D.R., & BISTRICHI, C.A. - 1981 - O embasamento Pré-Cambriano e Eopaleozóico em São Paulo. In: Mapa Geológico do Estado de São Paulo, (Almeida, F.F.M. de, Hasui, Y., Ponçano, W.L., Dantas, A.S.L., Carneiro, C.D.R., Melo, M.S. e Bistrichi, C.A.), IPT, **1** : 12-45.

HASUI, Y., FONSECA, M.J.G. & RAMALHO, R. - 1984 - A parte central da região de dobramentos Sudeste e o maciço mediano de Guaxupé. In: Geologia do Brasil (Schobbenhaus, C., Campos, D.A., Derze, G.R. & Asmus, H.E. - eds.), Brasilia, DNPM, 307-328.

MCWILLIAMS, M.O. - 1981 - Paleomagnetism and Precambrian evolution of Gondwana. In: Precambrian plate tectonics (A. Kröner, ed.), Elsevier, Amsterdam: 649-687.

MCWILLIAMS, M.O. & KRÖNER, A. - 1981 - Paleomagnetism and tectonic evolution of the Pan-African Damara Belt. Southern Africa. J. Geophys. Res., **86** : 5147-5162.

MOREL, P. & IRVING, E. - 1978 - Tentative paleocontinental maps for the Early Phanerozoic and Proterozoic. J. Geol., **86** : 535-561.

SMITH, A. G. & HALLAM, A. - 1970 - The fit of the southern continents. Nature, **225** : 139-144.

TORQUATO, J.R. & CORDANI, U.G. - 1981 - Brazil-Africa geological links. Earth Sci. Rev., **17** : 155-176.

VALENCIO, D.A., VILAS, J.F. & PACCA, I.G. - 1983 - The significance of the palaeomagnetism of Jurassic-Cretaceous rocks from South America: predrift movements, hairpins and magnetostratigraphy. Geophys. J.R. Astr. Soc., **73** : 135-151.