Paleomagnetic and Magnetostratigraphic Data from the Rosário do Sul Formation of the Rio Grande do Sul State, Brasil

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Abstract

The sedimentary Rosário do Sul Formation (southern Brasil), believed to be of Late Triassic age was sampled for paleomagnetic study from the in Rio Grande do Sul State of. In most sites both thermal and alternating field demagnetization in 12-17 steps revealed either a reversed or normal characteristic remanent magnetization (ChRM). Combining results yield 11 reversed (RSF-R) and 4 normal (RSF-N) magnetized sites and the later was interpreted as a secondary magnetization. This secondary magnetization was acquired during Early Cretaceous due to reheating or/and chemical remagnetization by the overlying thick sequences of the Serra Geral flood (SGF) basalt. The mean primary paleomagnetic direction calculated using only 11 reversed polarity sites (RFS-R) yields, Dec=166.3°, Inc=35° (α_{95}=5.9° and k=61), implying in a ~14° counter clockwise rotation in the declination and a shallow inclination. The mean inclination is shallow as expected due to compaction of the sediments by the overlying SGF basalt. The associated virtual geomagnetic pole is located at 71°E and 74°S. The rotated virtual geomagnetic pole of the primary magnetization (RSF-R*) do not match other South American poles of Triassic age. However, the rotated paleomagnetic pole (79.9°S, 127.13°E) is close to Middle- Late Jurassic VGP's calculated on volcanic deposits in South America.

INTRODUCTION

Sedimentary formations that varies in age from Devonian to Cretaceous are widely exposed mainly in the Paraná Basin of Southern Brasil. Their deposition is thought to have been caused mainly by the interplay of climatic, oceanographic, and tectonic factors, and that to hold valuable information about regional and global change of the ocean atmospheric system. Among these sedimentary formations, the Rosário do Sul Formation (RSF) is investigated for paleomagnetic work. The sampled section, RSF, is near Jaguari-Santiago (29.30°S, 54.50°W). The sedimentary deposits of the RSF is composed of reddish to whitish brown sandstone and believed to be Middle to Late Triassic in age (Schneider et al., 1974). The RSF sediments underlies in unconformity with the Rio do Rastro formation (Fig. 1). On the top, RSF is capped by the Santa Maria Formation, considered to be Middle Triassic as a result of the fossil tetrapods found in it (Bortoluzzi and Barberena, 1967) and overlying either by the Botucatu Sandstones which comprises the largest known aeolean deposit in the region (Fig. 1) and although locally it may found underlying directly the Serra Geral Flood (SGF) basalt formation which has been radiometrically dated as mainly 133-132 Ma (Renne et al., 1996).
Hand-samples oriented with both sun and magnetic compass were taken from each stratigraphic level, labeled as JS93 up to JS120 (comprising of 27 sites with a vertical thickness of 47 m). Samples being spaced more or less uniformly, 1 to 2 m, across the sampled section. Three to seven cylindrical standard paleomagnetic specimens from each hand-sample were drilled in the laboratory and yield a total of 160 specimens. A pair of specimens from each site were subjected to pilot thermal and alternating field demagnetization in 12-17 steps up to 680°C or 170 mT. Natural Remanent Magnetization (NRM) is measured by using a 2G cryogenic magnetometer both at the paleomagnetic laboratory of the University of São Paulo (IAG-USP) and in the magnetically shielded room facility of the Berkeley Geochronology Center (Berkeley, California). Standard analytical techniques such as orthogonal vector diagrams (Zijderveld, 1967), linear trajectories of principal magnetic component analysis (Kirschvink, 1980) and Fisherian statistics (Fisher, 1953) were employed to analyze the paleomagnetic data.

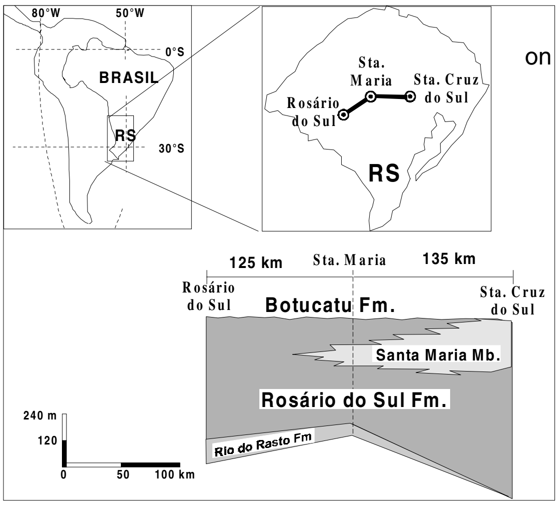


Figure 1. Areas of occurence of the Rosário do Sul formation (based on Schneider et al., 1974).

PALEOMAGNETIC RESULTS

Demagnetization

Directions of natural remanent magnetization (NRM) is measured on 160 cylindrical samples and were highly scattered with intensities of NRM range from 0.002 to 180 mA/m, a typical range for weakly magnetized sandstone. Characteristic remanent magnetization (ChRM) components isolated from pilot thermal and AF demagnetization of sister specimens showed the same trajectories during demagnetization (Fig. 2a,b) and therefore a complete and detailed step of AF demagnetization were applied in the rest of specimens from each sites.

The majority of samples have two magnetic components: a low coercivity component accounts by a significant decrease of magnetization intensity below 300°C or 30 mT. A ChRM was commonly unblocked in the temperature range from 300 to 600 °C (above 20 mT) (Fig. 2a,b). ChRM is easily resolved in reversed polarity samples with a linear decay to the origin (Fig. 2a,b). However, the ChRM is difficult to isolate from normal magnetized samples even if its polarity is clear from the demagnetization curve (Fig. 2c). The directions of this component, however, are grouped and generally fall far from the overprint direction of the present day geomagnetic field direction. We attribute this pattern to partial overlap of unblocking spectra of the recent overprint and the ChRM.

In 12 sites which corresponds to the top-most part of the section, apart from removal of an unstable remanence in low coercitivity ranges, no consistent directions of magnetization of the ChRM could not be identified (not shown here), and the entire data from these part of the section were discarded.

VIRTUAL GEOMAGNETIC POLE

The ChRM directions resolved from the rest of the sampling set consists a total of 15 sites of which 11 sites have a reversed polarity and the remaining 4 sites have normal polarity. The ChRM directions of reversed polarity samples are well grouped at each site (Fig. 2a,b), therefore site-mean directions were defined by using the principal component analysis, PCA (Kirschvink, 1980). Whereas in normal polarity sites both PCA and remagnetization circles were used (McFadden and McElhinny, 1988).

The calculated site-means for the reversed polarity sites (RSF-R) are well defined and reported in Table 1. The overall mean paleomagnetic direction for the 11 RSF-R sites after making antipodes yields Dec=346.3°, Inc=-35°, α_{95}=5.9°, k=60.5. This direction is significantly deviate in declination (by ~14°, counter-clockwise rotation) from the present day geomagnetic field of the site (i.e., Dec=350.2°, Inc=-29.8°) and shows an inclination shallowing than that expected from the geocentric axial dipole of the site (i.e., Inc=-48.3°). Shallow inclination is expected due to compaction of the sediments by the overlying thick deposit of the SGF basalt. However the significant counter-clockwise rotation of the mean declination is difficult to explain unless evidences for local block rotation or the uncompleted removal of viscous magnetization acquired subsequently due to remagnetization. The unblocking temperature spectra indicate that magnetite is likely to be the magnetic carrier of the ChRM in reversed polarity sites. What ever the case is, the corresponding virtual geomagnetic pole for RSF-R give plat=74°S and plong=71°E (labeled as RSF-R in Table 2).

Unlike the reversed polarity sites the ChRM resolved from normal polarity sites (RSF-N), occurring in the middle part of the section, are more scattered and might be affected by remagnetization because of reheating, chemical alteration or both. In these sites the presence of hematite can be deduced from the behavior of the decay in intensity curves during thermal demagnetization (not shown here). The resetting of magnetization in RSF-N sites, however, can not be substantially later than the ChRM acquisition of the overlying SGF basalt. Otherwise the direction and polarity of the ChRM of the RSF-N sediments might be different from that of the overlying SGF basalt. For SGF at Jaguari-Santiago (JS) Ernesto et al., (1990) reported a mean ChRM direction of Dec=350°, Inc=-43.5°, N=6, α_{95}=7.2°, k=87 which is not significantly different with the mean ChRM of the RSF-N. In addition the remagnetization scenario in RSF-N is supported by the significant difference of the pole position derived from the RSF-N with other Triassic to Jurassic poles so far reported in South America (Table 2). Thus, we believe that acquisition of the ChRM in RSF-N sites are penecontemporaneous with the solidification of the underlying SGF basalt. Therefore, we suggest that the normal polarity directions observed at the RSF is a later remagnetization, might be Early Cretaceous, and only the reverse directions (RSF-R) should be considered as a primary late Triassic to Middle Jurassic magnetization.

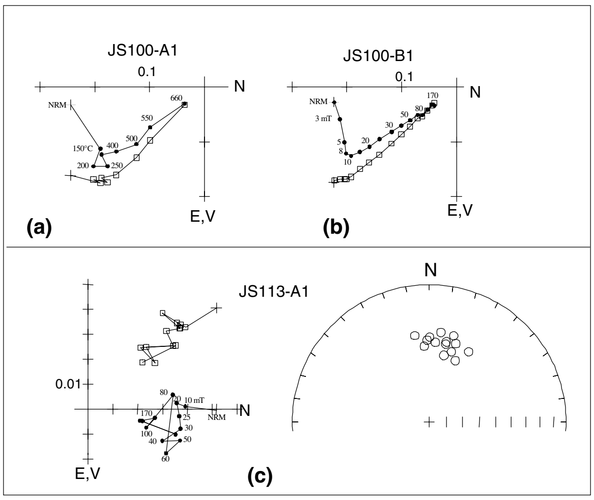
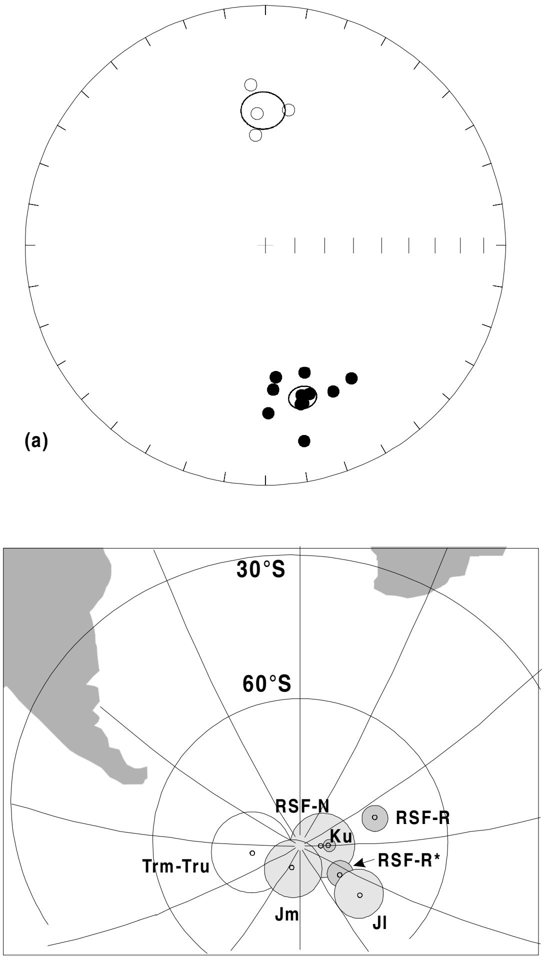


Figure 2. Representative orthogonal plots of thermal and AF demagnetization of RSF. Solid circles (open boxes) are projections of vector end points on horizontal (vertical) planes. In (c) equal area projection is used to show the detailed behavior of the orthogonal plot shown on its left.

In Table 2 and Fig. 3b, we have shown a compiled mean apparent polar wander path (APWP) and paleomagnetic reference pole of South America for the Middle (Trm) and late Triassic (Tru, Rapalini et al., 1993), Middle (Jm, Vilas, 1974) and late Jurassic (Jl, Vizán et al., 1990) and Early Cretaceous (Ku, Raposo & Ernesto, 1995)

The position of both RSF-N and RSF-R in relation to these VGP's are shown in figure 3b. The pole position RSF-N is identical to the 133-131 Ma (Ku) geomagnetic pole of the Paraná Flood basalt except RSF-N has significantly large error in α_{95} due to the small number of sites or remagnetization as suggested above. Because the mean VGP of the Paraná Flood basalt constitutes a very well defined Early Cretaceous reference pole for South America we prefer to correlate the secondary magnetization of RSF-N as Early Cretaceous (Ku), i.e. ~132 Ma.



(b)

Figure 3. (a) Equal area projection of ChRM site mean directions of RSF; (b) Southern hemisphere equal-area projection showing Late Carboniferous (Cu), to Early Cretaceous (Ku) South American Reference poles, keyed to table 2.

Unlike the RSF-N, the pole position of RSF-R is far from both the Ku, Jm and Jl poles (Fig. 3b). If we make a 14° clockwise rotation to the mean declination of RSF-R, the new pole RSF-R* will be close to both the Jm and Jl poles than the Ku (Fig. 3b). Therefore it's reasonable to make this rotational correction to correlate it with the Jurassic pole.

MAGNETOSTRATIGRAPHY

Accepting that the ChRM resolved for the normal polarity sites are Early Cretaceous and penecontemporaneous with the solidification of the lavas, the magnetostratigraphy of the RSF is simple and straight forward. The whole formation consists of one magnetozone: a reversed zone of about 17m in the lower part of the section and the rest 30m of the section is remagnetized by the underlying Serra Geral normal polarity flood basalt. If this is true, the primary magnetization of the RSF-R might correlate with the reversed chron observed in Middle to Late Jurassic geomagnetic polarity time scale, GPTS (Harland et al., 1982). However, the upper part of the section needs to be restudied because the original purpose of this study was to derive paleomagnetic poles, and our sampling was not as intensive as it has to be to resolve the magnetostratigraphy. Finally it is necessary to stress that normal polarity magnetization reported for the Santa Maria Member (Creer, 1967) should be reconsidered in future in light of this study.

Table 1. Site mean paleomagnetic data of the Rosário do Sul Formation (RSF), Rio Grande du Sul State, Brasil (29.30°S, 54.50°W).

Site	N	D (°)	I (°)	k	α_{95} (°)
RSF-R	11	166.3	35.0	60.5	5.9
RSF-N	4	358.9	-43.1	76.0	10.6

N, number of site; D, declination; I, inclination; k, Fisher concentration parameter; α_{95}, radii of 95% confidence circle.

Table 2. Compilation of some Mean Apparent Polar Wander Path (APWP) and paleomagnetic reference pole of South America for the Middle and late Triassic (Trm-Tru), Middle; late Jurassic (Jm, Jl) and Early Cretaceous (Ku) together with the RSF pole before and after rotation (clock-wise by 14°).

Interval	Lat	Long	α_{95}

	(°S)	(°E)	(°)	Ref
Trm-Tru	80.4	259.2	8.4	Rapalini et al.,1993
Jm	85.0	197.0	6.0	Vilas, 1974
Jl	74.0	132.0	5.0	Vizán et al., 1990
Ku	84.3	90.1	1.2	Raposo & Ernesto, 95
RSF-N	85.7	92.2	6.5	This- study
RSF-R	74.0	71.0	3.9	This- study
RSF-R*	79.9	127.1	3.9	This- study

CONCLUSIONS

The ChRM directions resolved with detailed thermal and AF demagnetization from the RSF are of dual polarity but fail the fold test. Some of the normal polarity directions are apparently contaminated by an uncleanned secondary magnetization of the underlying Serra Geral flood basalt and believed to be post depositional. Therefore, we suggest that the normal polarity directions observed at RSF are remagnetized and only the reversed ones should be considered as primary. This primary reversed polarity is consists of the lower 17m of the section and defines a single reversed polarity magnetostratigraphy for RSF. The mean VGP of the reversed polarity sites yields 74.5°S, 71°E with an angle of 95% confidence of 3.9° and comparable with Middle and Late-Jurassic APWP of South America after making a rotation of about 14°. More sections need to be investigated in the future to see if the observed local block rotation indeed exists or remagnetization plays still a great role in the ChRM of the RSF. If similar magnetic polarity can be found in other sedimentary sections of the same age group in the region, it will be possible to carry out correlation and then magnetostratigraphy could be established on multiple sections across the Paraná Basin.

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