# Paleomagnetism of the post-Paleozoic alkaline magmatism in the Brazilian Platform: discussing ages and plate displacements

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## Abstract

A review of the available paleomagnetic data on the post-Paleozoic alkaline rocks in the Brazilian Platform in combination with other South American poles of same age allow the proposition of a new apparent polar wander path (APWP) revealing rotations of the plate associated with the emplacement of alkaline provinces. By means of an analysis of the magnetization polarity of the rocks some inferences of the relative ages of the igneous complexes were possible, as the investigated time interval comprises the long normal polarity interval of the Cretaceous (Cretaceous Normal Superchron). Absolute reconstructions of the drift movement of South America was achieved by means of paleomagnetic rotations and longitude control through the sea floor magnetic anomalies.

## Introduction

There are few paleomagnetic poles for the post-Paleozoic alkaline rocks in the Brazilian Platform Most of them refers to the alkaline provinces surrounding the Paraná (Brazil) and the Chaco-Paraná (Paraguay) basins (Ernesto et al., 1996), where an intense activity took place since the Triassic, and most concentrated from Campanian to Eocene (87-42 Ma; Almeida et al., 2000). The available paleomagnetic data from southeastern Brazil belongs to the Alto Paranaíba (Tapira and Salitre complexes; Montes-Lauar, 1993) and Serra do Mar (Poços de Caldas, Itatiaia and Passa Quatro complexes, Santos-Rio de Janeiro dyke swarm, and the São Sebastão necks; Montes-Lauar et al., 1995; unpublished data).

In Northeastern Brazil the Borborema Province (Almeida et al., 2000; Ulbrich & Gomes, 1981) was also affected by an alkaline magmatic activity ranging from Early Cretaceous to Tertiary (Fodor et al., 1998; Almeida et al., 2000). The older rocks are best represented by the Cabo Magmatic Province (CMP) in Pernambuco State (Nascimento, 2003), whereas the Tertiary activity, more abundant, occurs inside (Macau Formation; Mizusaki, 1989) or to the south of the Potiguar Basin (Cabugi Magmatism) as well as surrounding the Fortaleza city (Macciotta et al., 1990). Paleomagnetic data are only available from CMP (Schult and Guerreiro, 1980), and from the Fortaleza Province (Schult et al., 1986).

The restricted number of poles that are useful to trace the apparent polar wander path (APWP) for South America does not allow a rigorous selection, but poles based on less than five sites were discarded. Exception was made for the Fortaleza Province (only four sites) originally with seven sites (Schult et al. 1986), but recalculated here to lessen scattering. Some other reference poles of ages of interest in this paper were included. Poles from the alkaline provinces in Paraguay are considered along with the Brazilian alkaline magmatism, due to the intrinsic geodynamic relationship of these provinces.

## The APWP for South America

The Mesozoic-Cenozoic apparent polar wander path (APWP) for South America is displayed on Figure 1. It is noticeable the divergence of the APWP proposed by Randall (1998) combining paleomagnetic poles from South America and Africa, with the path proposed here. His curve does not fit the most reliable poles, mainly for the Paleocene-Eocene epochs.

Although much uncertainties still persists regarding the displacement of the South American plate from ~120 Ma to present due to the scarcity of reference poles (those satisfying the acceptable confidence criteria; e.g., Beck, 1988), and lack of precise radiometric dating in some cases, the available data is sufficient to calculate the amount of drift and rotations the SA plate underwent during that time interval. It its also possible to draw some inferences about the Brazilian alkaline magmatism ages through a comparative analysis.

The Early Cretaceous segment of the APWP is well established based on high quality paleomagnetic poles satisfying rigorous confidence criteria. Of particular interest in this paper are the poles for the PMP, including the tholeiitic extrusive rocks of the Serra Geral Formation (SG: 133-132 Ma; Ernesto et al., 1999), and the Ponta Grossa dolerites (PG: 129-131 Ma; Renne et al., 1996), which are represented in Fig. 3. The paleomagnetic pole for the Central Alkaline Province (CAP) in Paraguay is in well agreement with the Ponta Grossa pole, and K-Ar ages (127-130 Ma; Velázquez et al., 1992) also indicate that the alkaline activity on the western side of the PMP was taking place at the same time as the tholeiitic activity (Ponta Grossa dykes) on the eastern side. The record of the youngest activity in PMP is given by the Florianópolis dykes (FL pole), with Ar-Ar ages ranging from ~119 to 128 Ma (preferred age <127 Ma; Raposo et al., 1998) although Deckart et al. (1998) assigned age of 129±0.3 Ma for those dykes. However the FL pole is significantly different from CAP and PG poles, leading to the conclusion that CAP rocks really concentrate on the older ages of ~130 Ma. To the north, the Cabo Magmatic Province represented by trachytes, rhyolites, ignimbrites, basalts/trachy-andesites, monzonites and alkali-feldspar granite with radiometric age of 102±1 Ma (Nascimento, 2003) was emplaced during the Cretaceous Normal Superchron (CNS of ~121-84 Ma; Gradstein et al., 1994) of normal geomagnetic polarity, as also indicated by the normal polarity magnetizations of those rocks.

The paleomagnetic poles with ages assigned to Late Cretaceous come from the southeastern region (Fig. 1), and form two age groups: Serra do Mar Province (SM2; Montes-Lauar et al., 1995, Marques et al., 1992; and unpublished data) which includes the stocks and dykes in the São Sebastião Island, and dykes along the coast between Santos and Rio de Janeiro cities, Poços de Caldas (Montes-Lauar et al., 1995) and Tapira (Montes-Lauar, 1993) complexes, with ages around 80 Ma. The Salitre Complex (Montes-Lauar, 1993) from the same region and also of ~80 Ma, did not gave a paleomagnetic pole because data was obtained from unoriented cores, but the mean magnetic inclination of 47° is in well accordance with those obtained for the other rocks of same age. Except for SM2 showing only normal polarity, all other poles of this group include reversed polarities. Although very short chrons of reversed polarity are found inside the CNS (Poornachandra Rao & Mallikharjuna Rao, 1996), they are often of ages greater than 95 Ma. Therefore the ages of the reversed polarity rocks may fall between 84 and 81 Ma (Campanian), approximately the limits of the first reversed chron after CNS, according to Gradstein et al. (1994), considering that the majority of the analyzed rocks displayed reversed polarities. The Tapira pole, however, is far from the other two poles, and will not be considered for further interpretations. In fact, as mentioned by Montes-Lauar (1993) this complex is composed by only one plug of 6 km in diameter and shows deep weathering.

In the city of Rio de Janeiro it is frequent to see the dykes of the Serra do Mar Province (normal polarity) being cut by a younger generation of alkaline dykes of reversed polarity. The latter are of more evolved lithotypes (Marques et al., 1992), and $^{40}Ar$-$^{39}Ar$ ages concentrate around 70 Ma (Deckart et al., 1998). Same magnetic and chemical characteristics are shown by other widespread dykes along the coast between Santos and Rio de Janeiro. These evidences are strong enough to allow the calculation of two distinct paleomagnetic poles for the Serra do Mar Province: SM1 and SM2 for the reversed and normal polarity rocks, respectively. However, these two poles do not differ significantly on statistical basis, in part due to the low number of sites (only 7) included in SM1. The younger pole SM1 should be closer to the combined Itatiaia-Passa Quatro pole (IP; Montes-Lauar et al., 1995) as the ages are also around 70 Ma, as well as to the pole based on the basaltic rocks from Patagonia (PB1; Butler et al., 1991) although in this case the available K-Ar ages are mores scattered (64-79 Ma). However, pole SM1 seems match better the pole group formed by the Asunción plugs (AP; Ernesto et al., 1996), the Patagonian basalts of younger ages (PB1; Butler et al., 1991), and the transitional basalts from Abrolhos Islands (AB; Montes-Lauar, 1993), all of them showing K-Ar data in the 39-56 Ma interval. Despite this observation pole SM1 will be considered along with IP and PB2 for the purpose of calculating a mean pole, as all three poles agree in radiometric ages (~70 Ma). To the other pole group (AP, AB and PB1) an mean age of ~50 Ma will be considered. The only Oligocene available pole for the Brazilian Platform is the one from the Fortaleza plugs in Ceará State (pole FP; Schult et al., 1986) with age of about 28 Ma.

## Discussion and Conclusions

Mean paleomagnetic poles for each age group were calculated. Except for Early Cretaceous the mean poles show large uncertainties, for they are based on few independent results. However, they give good indications of the paleolatitudes of South America, and the rotations this plate described since about 130 Ma. The paleomagnetic reconstructions of South America considered as a rigid plate are seen on Fig. 1. For reference, the Atlantic islands Fernando de Noronha (FN), Trindade (TR), and Tristan da Cunha (TC) are plotted in the same figure. From Early Cretaceous to Eocene, South-American plate was rotating clockwise and latitudes varied from slightly lower to slightly greater than the present latitudes. From Oligocene to Present the plate describes a counter clock rotation, and move northwards to recover the present position.

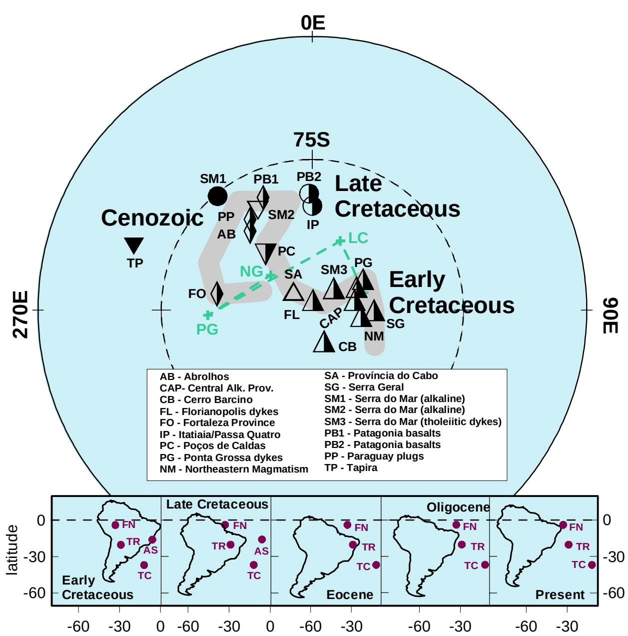


Figure 1. Paleomagntic poles and the APWP for South America since Early Cretaceous. The green curve represents the APWP proposed by Randall (1998).

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