MAGNETIC STUDIES ON MESOZOIC DIKE SWARMS FROM UBATUBA AREA, NE SÃO PAULO STATE, BRAZIL.

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Abstract (Resumo)

Foram estudados 20 diques (18 diabásios e 8 lamprófiros) que afloram nas praias de Ubatuba (NE do estado de São Paulo). Os diques intrudem rochas metamórficas, apresentam espessuras que variam de poucos centímetros até 2 m para os lamprófiros e até > 10 m para os diabásios, possuem direção predominante N40^o-50^{o}E com mergulho vertical. As tramas magnéticas foram determinas através da anisotropia de suscetibilidade magnética (AMS) e da anisotropia da magnetização anisterética (AARM). As propriedades magnéticas, obtidas através de vários experimentos, indicam que o mineral magnético responsável pelas anisotropias e remanência é a magnetita com grãos pseudo-domínio-simples. Entretanto todos os diques de lamprófiros mostram um comportamento magnético anômalo provavelmente devido à presença de siderita como indicado pela desmagnetização a baixa temperatura e espectroscopia Mössbauer. A trama magnética dominante para os dois enxames é a que é esperada para diques e corresponde ao fluxo magmático. A análise da inclinação de K_{max} permitiu inferir que os diques foram alimentados por fluxos horizontais (K_{max}<30°, a maioria) e inclinados (K_{max}>30°). Os dados paleomagnéticos indicam dois eventos intrusivos para os diabásios e lamprófiros evidenciados pela polaridade normal e reversa do campo geomagnético. Esses dados indicam que as fontes geoquimicamente diferentes estiveram simultaneamente ativas.

Introduction

The Mesozoic magmatism in Southern Brazil is represented mainly by the basaltic flows of the Serra Geral Formation, the tholeiitic dikes swarms from the Ponta Grossa Arch, Florianópolis, and along the coast between São Paulo and Rio de Janeiro, and several alkaline complexes that lie along tectonic features associated with the evolution of the Paraná Basin. The emplacement of the dike swarms and the alkaline complexes is related to the processes of separation between South America and Africa and, consequently, with the opening of Atlantic Ocean.

We are performing an intensive magnetic study (magnetic fabrics, paleomagnetism and rock-magnetism) in all dike swarms from the coastline of São Paulo state, in which the dikes with different chemical composition (tholeiitic, lamprophyre and alkaline) are widespread along the Serra do Mar between São Paulo and Rio de Janeiro then the swarms are known as Santos-Rio de Janeiro swarm. The principal purpose of this study is to apply both AMS and AMR techniques to investigate the magma flow, to provide information on its mode of emplacement, and to investigate the relative position of magma sources and fractures, and to determine the paleomagnetic pole(s) of the dike swarms to compare it with available poles from Ponta Grossa (Raposo and Ernesto, 1995a, b) and Florianópolis (Raposo et al., 1998) to verify whether they can be the same age since it is believed that the tholeiitic activity occurred during the Early Cretaceous and was then partly coeval with Ponta Grossa and Florianópolis dikes (e.g. Almeida, 1986); the other dikes are, however, younger than the diabases (Almeida, 1986). To have a good control of the magnetic carriers we also are performing an extensive rock magnetism study. In this paper we show results from the Ubatuba dikes.

The studied swarms (Fig.1) occur along the coast in the city of Ubatuba (NE of São Paulo State), and crosscut Archean and Proterozoic polymetamorphosed rocks of the Costeiro Complex. The dikes are

diabases and lamprophyres, and they crop out side by side in the beaches. They range from a few centimeters up to 2 m wide for the lamprophyres, and up to > 10 m for the diabase. Their trend is predominately N40^{o}-50^{o}E with vertical dips.

Magnetic Measurements

Magnetic studies were performed on oriented samples collected symmetrically (whenever possible) from both margins of the dikes together with the center. At least 15 and up to 20 cores, using a gasoline-powered rock drill, were collected from each dike for which the strike and thickness could be determined. A total of 26 dikes (18 diabases and 8 lamprophyres) were studied in this paper. Magnetic fabrics were determined by applying both anisotropy of low-field magnetic susceptibility (AMS) and anisotropy of anhysteretic remanent magnetization (AARM). Rock-magnetism was obtained from several diagnostic experiments including low temperature demagnetization (zero field cooled (ZFC) and field cooled (FC) curves), room temperature saturation isothermal magnetization (RTSIRM), frequency dependency of susceptibility (in the range 1-1000 Hz) from 10 to 300 K, and room temperature Mössbauer spectroscopy. Paleomagnetism was determined by both thermal and AF demagnetizations.

AMS Fabric

The dominant AMS fabric in both swarms is that one which is expected for dikes, and is called as *Normal* fabric (Rochette et al., 1992). It is characterized by having the AMS foliation (K_{max}-K_{int} plane) nearly parallel to the dike plane whereas the AMS foliation pole (K_{min}) is nearly perpendicular to it (Fig. 2). The anomalous AMS fabric known as *Inverse* fabric was found in only three dikes (2 diabases and 1 lamprophyre) is defined by K_{int} and K_{min} axes clustering close to dike plane and K_{max} axes nearly perpendicular to this plane. The AARM fabric is either coaxial or better defined than AMS fabric. The AARM fabric is coaxial for all dikes inclusively for those with *Inverse* AMS fabric.

Rock Magnetism Properties.

Rock magnetism properties indicate that pseudo-single-domain grains of almost pure magnetite carry the magnetic fabrics. However, all lamprophyre dikes show an unusual magnetic behavior mainly for low *KxT* curves (Fig. 3). The magnetic susceptibility of these dikes is dependent of field intensity (Fig. 4) while in the basic dikes K is field-independent. The K variation with field intensity suggests that titanomagnetite (Hrouda, 2009) could be present in the lamprophyre dikes, which is corroborated with high *KxT* curves. Low temperature magnetic measurements down to 10 K (Fig.5) for these dikes suggest the presence of the iron carbonate siderite. Maybe this mineral could explain the anomalous behavior for low *KxT* curves (?).

Paleomagnetism

Paleomagnetic studies show that both swarms register normal and reverse polarity (Fig. 6). The mean remanent magnetization direction from both swarms suggests that the sources which give arise lamprophyre and diabase dikes were active at the same time when the geomagnetic field was normal and reverse polarity.

Discussion

Normal AMS fabric is interpreted as due to magma flow in both swarms. The analysis of the K_{max} inclination permitted to infer that the majority of dikes from both swarms were fed by horizontal flow

(K_{max} < 30°, Fig. 7), suggesting that they were far from the magma source. On the other hand, five diabase and two lamprophyres dikes were fed by inclined (K_{max}>30°) flows (Fig.7), suggesting that they were close to the magma source. Horizontal and inclined flows in dikes in both swarms can indicate either some movement of South American plate or more than one magma source for diabases and lamprophyres as well.

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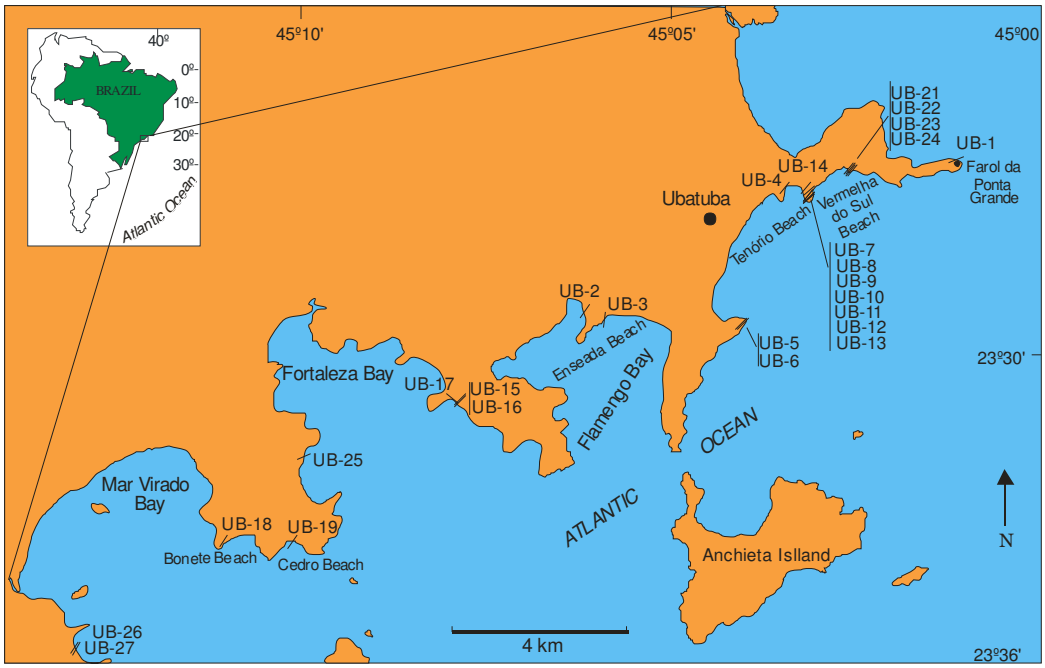

Figure 1 – Map with the localization of the sampled dikes.

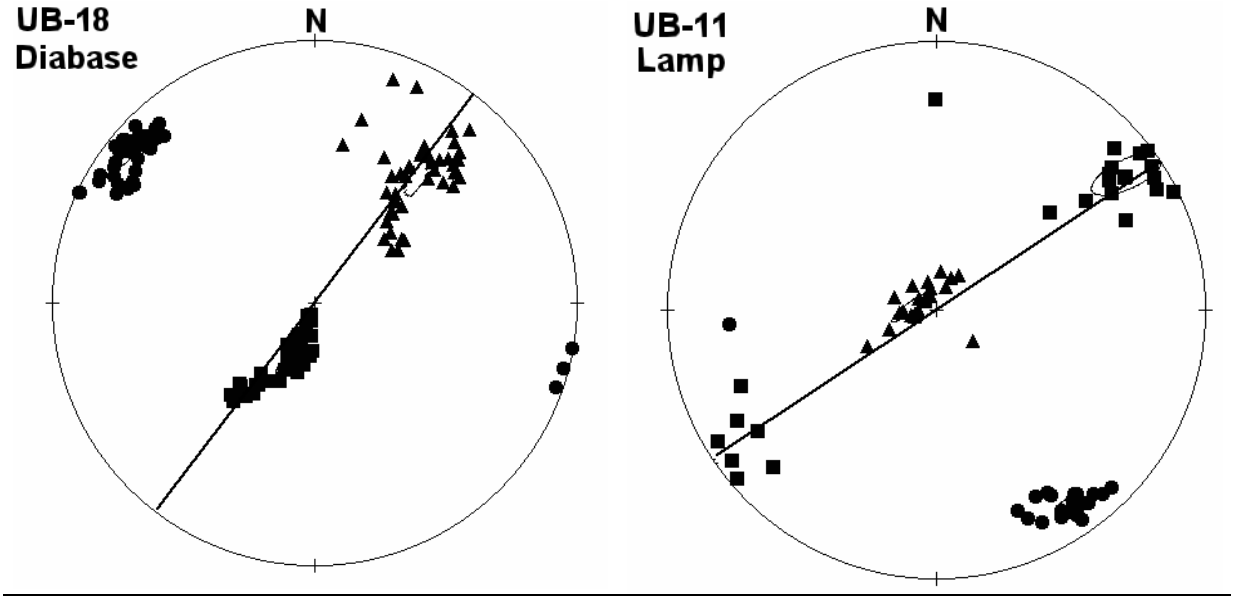

Figure 2 – Examples of AMS fabric for both swarms. Squares are maximum susceptibility (K_{max}) triangles are intermediate susceptibility (K_{int}) and circles are minimum susceptibility (K_{min}). Dashed line ellipses = 95% confidence ellipses. The full line represents the dike plane with vertical dip. Data plotted in the lower hemisphere stereonets. Lamp means lamprophyre.

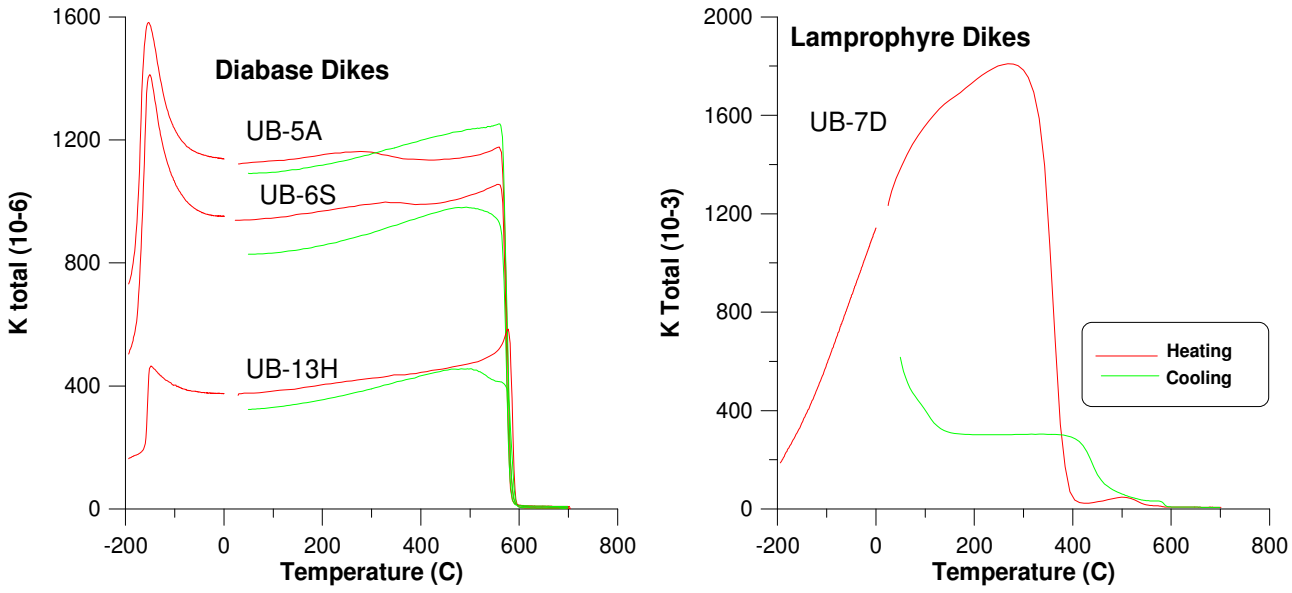

Figure 3 – Representative K-T curves (susceptibility versus temperature), obtained in argon atmosphere for samples from both swarms.

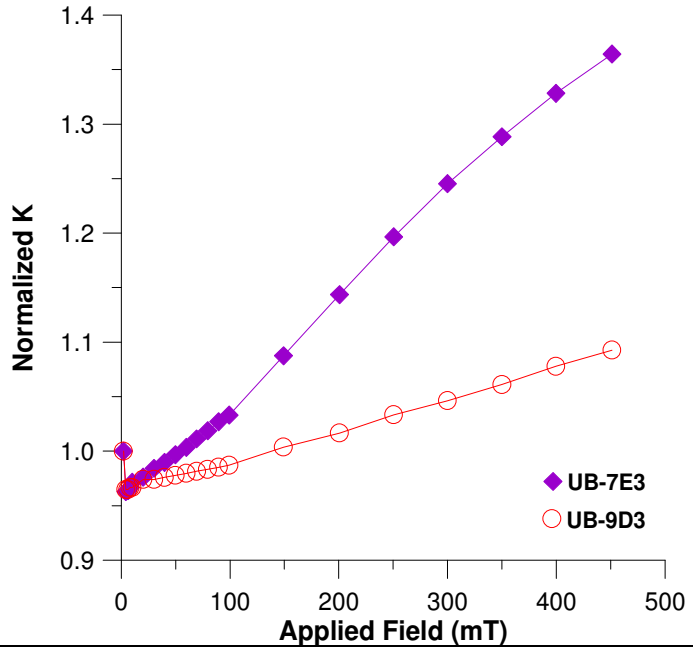

Figure 4 – Variation of K with field for lamprophyre dikes.

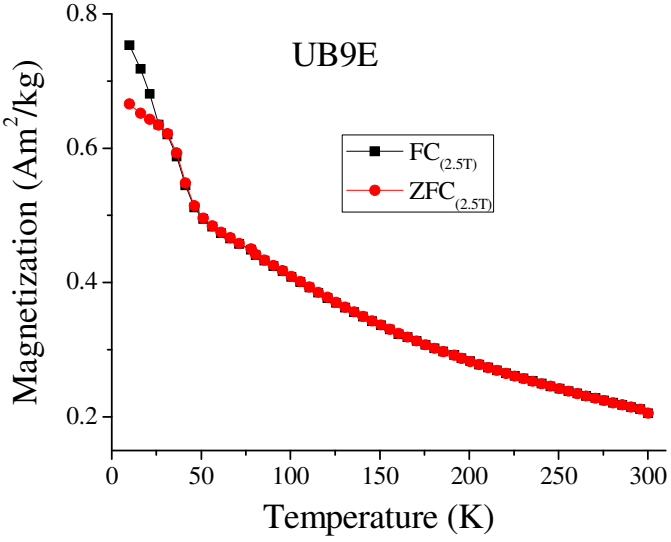

Figure 5 – Low temperature remanent magnetization. The main feature of ZFC and FC curves is a remarkable drop in magnetization around 38 K that indicates the presence of siderite. Its presence was also confirmed by Mossbauer spectroscopy.

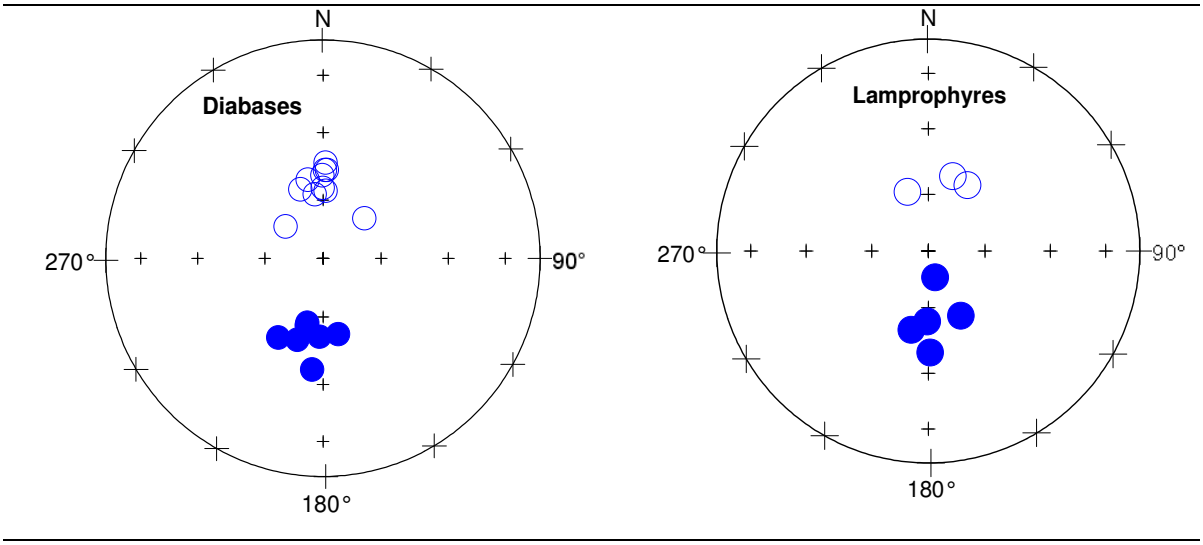

Figure 6 – Mean paleomagnetic direction for all studied dikes.

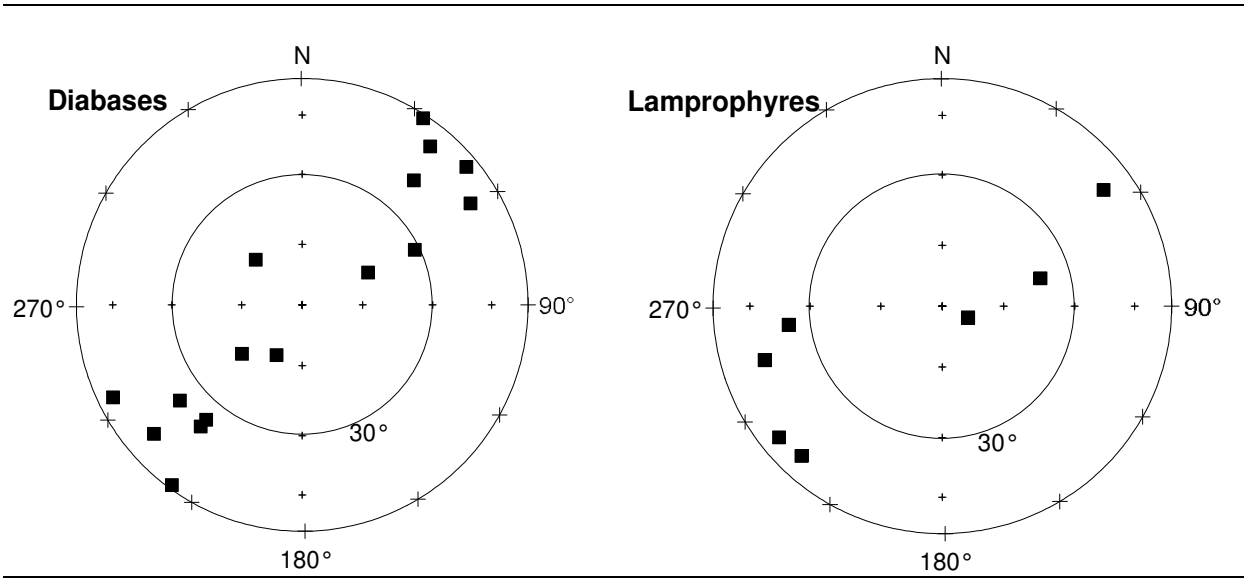

Figure 7 – Inclination of K_{max} for dikes with **normal** AMS fabric. Data plotted in the lower hemisphere stereonets.