Bio and magnetostratigraphy of two Lower Miocene sections, Tagus basin (Portugal)

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RESUMO

Palavras-chave: Miocénico inferior — magnetostratigrafia — Foraminíferos — Lisboa — Bacia do Tejo — Portugal.

Apresentam-se os resultados do estudo da magnetostratigrafia de dois cortes no Miocénico inferior da bacia do Tejo. Foi utilizada a desmagnetização térmica para isolar a componente primária de magnetização de 45 amostras recolhidas no corte de Foz da Fonte e 74 no de Trafaria. A sucessão de zonas de polaridade magnética reconhecidas foi correlacionada com a "geomagnetic polarity time scale"(GPTS) com base em dados biostratigráficos fornecidos pelos foraminíferos planctónicos.

As zonas de foraminíferos planctónicos e as de polaridade magnética reconhecidas nestes cortes podem ser correlacionadas adequadamente com a parte da GPTS [tabela calibrada por BERGGREN *et al.* (1985)] correspondente às anomalias 6 e 5E (Foz da Fonte) e 5D (Trafaria). Estas correlações sugerem idades entre 19,35 a 18,14 Ma para o corte de Foz da Fonte e de 17,9 a 16,98 Ma para o de Trafaria.

RÉSUMÉ

Mots-clés: Miocène inférieur — Magnetostratigraphie — Foraminifères — Lisboa — Bassin du Tage — Portugal.

On présente les résultats de l'étude magnetostratigraphique de deux coupes concernant le Miocène inférieur du bassin du Tage. La désaimantation thermique a été employée pour isoler la composante primaire d'aimantation chez 45 échantillons prélevés dans la coupe de Foz da Fonte et chez 74 en provenance de la coupe de Trafaria. La succession des zones de polarité magnétique reconnues a été corrélée avec la "Geomagnetic polarity time scale" (GPTS) en tenant compte des données biostratigraphiques fournies par l'étude des foraminifères planctoniques.

Les zones de foraminifères planctoniques et celles de polarité magnétique reconnues dans les coupes en question peuvent être corrélées d'une façon satisfaisante avec la partie de la GTPS [tabelle calibrée par BERGGREN *et al.* (1985)] correspondant aux anomalies 6 et 5E (Foz da Fonte) et 5D (Trafaria). Ces corrélations suggèrent des âges entre 19,35 et 18,14 Ma pour la coupe de Foz da Fonte et de 17,90 à 16,98 Ma pour celle de Trafaria.

ABSTRACT

Key-words: Lower Miocene — Magnetostratigraphy — Foraminifera — Lisboa — Tagus Basin — Portugal.

The magnetostratigraphy of two sections in early Miocene marine deposits of the Tagus Basin is studied. Thermal demagnetization was used to isolate the primary component of magnetization for 45 samples from the Foz da Fonte section, and for 74 others from Trafaria section. The succession of the polarity zones found in these sections is tentatively correlated with the geomagnetic polarity time scale (GPTS) on the basis of the biostratigraphic data yielded by planktic Foraminifera. The planktic zones and magnetic polarities recognized in these sections can be adequately correlated with the part of the GPTS [table calibrated by BERGGREN *et al.* (1985)] corresponding to the Anomalies 6 and 5E (Foz da Fonte) and 5D (Trafaria). This correlations suggests ages between 19,35 and 18,14 Ma for Foz da Fonte section, and 17,90 to 16,98 Ma for Trafaria.

INTRODUCTION

The Lower Tagus basin near Lisbon is well known for its Miocene infilling, which comprises a broad variety of lithotypes corresponding to six major transgressive events alternating with regressions. Except for the upper Tortonian and the Messinian (which are not so well characterized), stages from the Aquitanian to the Tortonian are represented by lithostratigraphical units that yielded much palaeontological and sedimentological information in addition to other data.

Furthermore, it must be stressed that the geographic position is specially interesting as this basin offers an unique occasion to establish correlations between the remaining Atlantic basins from western Europe (Aquitaine in France) and the Mediterranean basins, as well as between the North Atlantic continental margins (Europe plus western Africa-North and central America).

Much work has been done in the Tagus basin since the first known geological observations of T. D'ALMEIDA (1762). The first sections at Fonte da Telha were described by the remarkable mineralogist (and later politician, one of those who masterminded Brazil's Independence), José Bonifácio de ANDRADA E SILVA (1817), then occupied in the reactivation of Mediaeval and Arab times gold mines in these region.

Early palaeontologic and geologic work was done by Daniel SHARPE (1834, 1842), WILHELM-LUDWIG, Baron VON ESCHWEGE and Alexandre VANDELLI (both 1831).

Later on, excellent palaeontologic research on mollusks was carried on by F. Pereira da COSTA (1866-1867) during the period of the (2d) Comissão Geológica.

Field work was carried out, mostly by Carlos Ribeiro, who presented a paper on the Tertiary formations of Portugal to the International Geological Congress, in Paris (1878).

Characterization of lithostratigraphic units was firstly attempted by SHARPE (1842) who included Miocene beds in a single unit that he named "Almada beds". A detailed study was conducted much later by J. C. Berkeley Cotter, which was best presented as a stratigraphic introduction to the study by Dollfus on miocene mollusks (DOLLFUS, COTTER & GOMES, 1903-1904).The units defined by Cotter ("divisions", as he called them) are still in use, although a thorough revision is needed.

Despite some contributions by P. Choffat, research nearly stopped until 1937 with G.Zbyszewski.

New investigation was carried on and promoted by M.T.Antunes since 1959, either directly or in collaboration with other researchers.

PALAEOMAGNETIC STUDY

Sampling

During a field trip in April 1989, sections were sampled for magnetostratigraphical study. The results concerning two sections, Foz da Fonte and Trafaria, are presented. For the situation of these sections and their geologic and palaeogeographic context see figure 1.

Oriented blocks, with azimuth and dip measured, were collected at 15 horizons in the Foz da Fonte section (thickness 29.7m) and 22 horizons in Trafaria (thickness 21.5 m). The continuity of the outcrops allows good stratigraphic control and the determination of vertical distances between sites with an accuracy of 10 cm. In the Trafaria section, the sediments are quite homogeneous, consisting of silts and silty clays. The Foz da Fonte section presents a more diversified lithology including clays, sandstones and limestones.

Blocks were drilled in the laboratory in order to obtain 22 mm long cylindrical samples of a standard volume. Compressed air was used to cool the corer and to remove the dust. Measurements were performed with a CTF three axes cryogenic magnetometer at the IPG Paleomagnetic Laboratory in Paris.

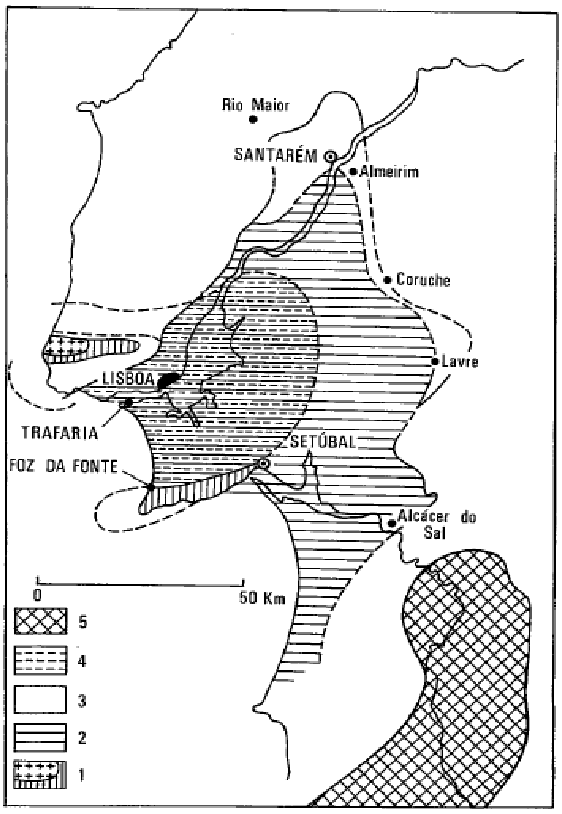

Fig. 1 — Geologic and palaeogeographic sketch map of Tagus Basin, with the situation of the Foz da Fonte and Trafaria sections. 1 - Sintra subvolcanic massif and mesozoic sedimentary formations from Sintra-Caneças and Arrábida Chain. 2- Uppermost Burdigalian transgression. 3 - Upper Langhian and Serravalian transgression. 4 - Tortonian transgression. 5 - Messinian trangression only at the Alvalade basin.

Paleomagnetic data

74 samples from the Trafaria section and 45 from Foz da Fonte were stepwise demagnetized up to 600°C. Some preliminary testing of alternating field demagnetization did not give conclusive results; therefore, all samples were demagnetized by heating, with their magnetic susceptibility controlled at each step. The IRM test was performed on five samples from each section up to 1.25 T (Fig.2); the shape of the IRM curves shows clearly that magnetite should be the main magnetic carrier in these sediments.

Sediments from both sections are initially characterized by weak NRM intensities, generally less than 1 mA/m. However, during subsequent demagnetization steps, the magnetic behaviour of sediments from the two sections differs. In samples from Trafaria section, about 50% of the NRM is destroyed in the first steps of demagnetization (100 or 150° C); this indicates the presence of a large viscous component. Moreover, from the temperature of 380 or 400° C, in almost 80% of samples, there is a continuous increase in the intensity of magnetization, along with an increase in the magnetic susceptibility (Fig.3). Following this remagnetization, declinations and inclinations become random. Therefore, the magnetic polarity of each sample was determined from

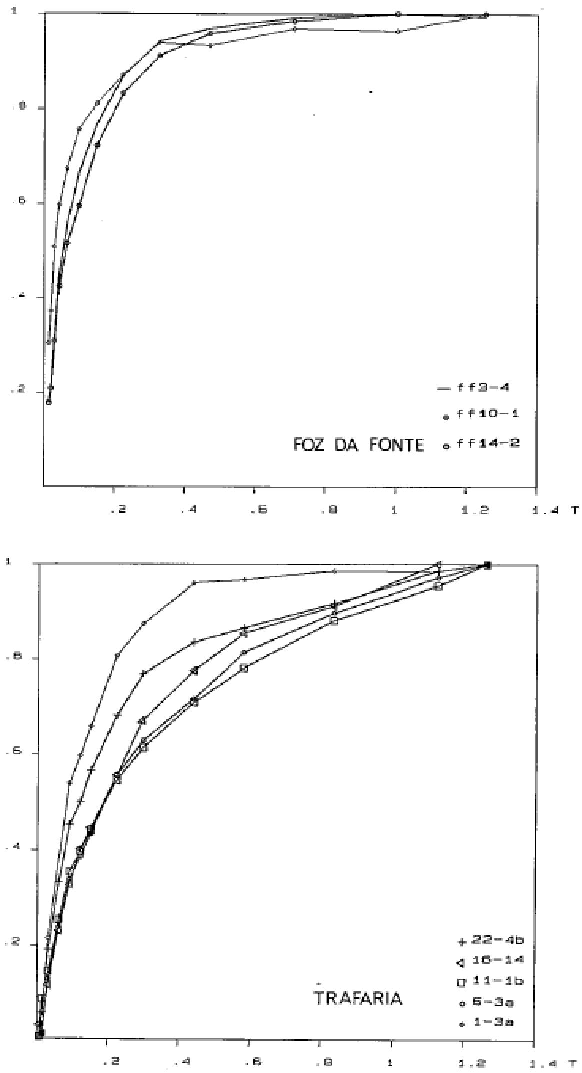

Fig. 2 — IRM acquisition curves for samples from the Foz da Fonte and Trafaria sections.

the directions which occur after the cleaning of the viscous component, but before the remagnetization. For a large number of samples, it was not possible to identify clearly the directions of the primary component, probably due to the effect of the large viscous magnetization and/or the weak intensities. In these cases, the more coherent values are taken as declinations and inclinations, and the polarity was deduced from the magnetic behaviour of samples during the successive steps of demagnetization. At least three samples from each site were demagnetized to determine its polarity with accuracy.

The magnetic behaviour, during demagnetization, of the sediments from the Foz da Fonte section is quite variable; this is probably a consequence of the more diversified lithology found in this section. In the two sites, the intensity of magnetization decreases sharply (more than 50%) below the temperature of 150°C; it is then gradually cleaned up to a temperature of 500°C, showing almost stable directions. In the other sites, the cleaning of the remanence is more regular up to temperature of 380°C or 450°C.

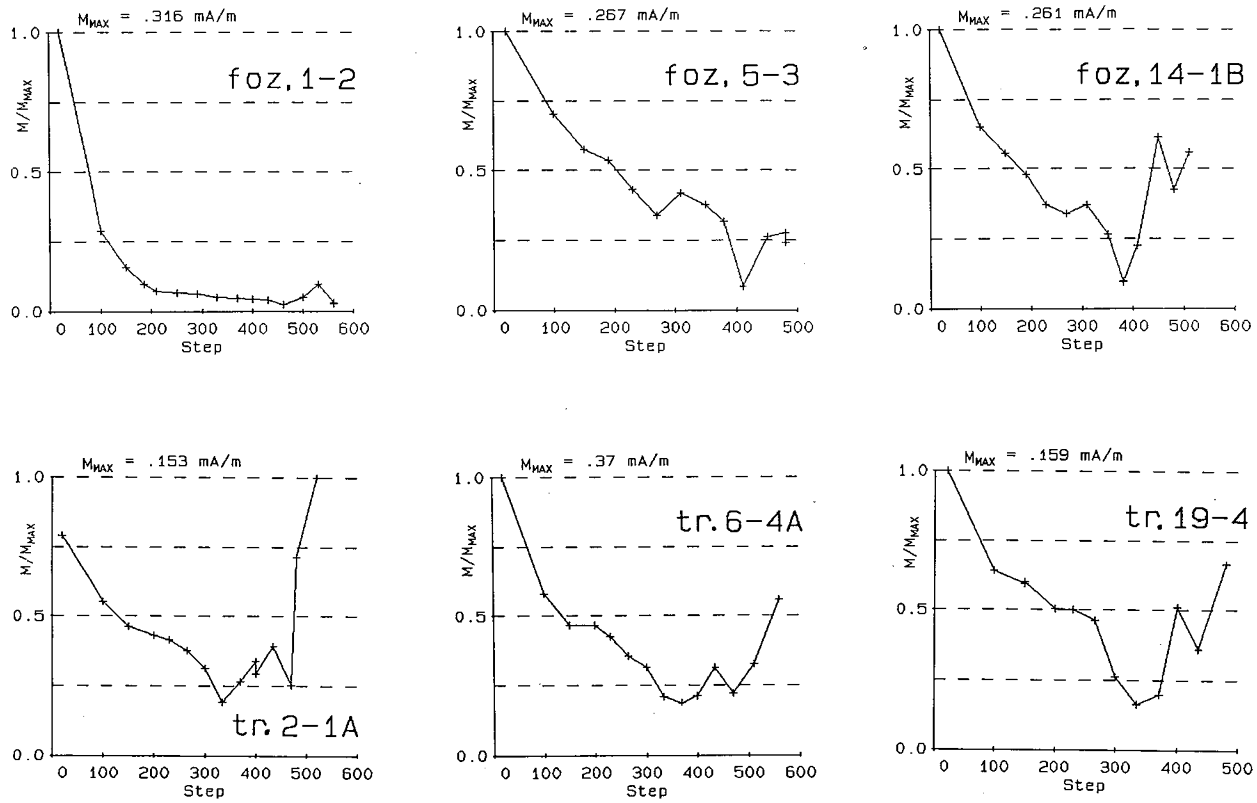

Fig. 3 — Decay curves of the intensity of magnetization during the thermal demagnetization for six samples from the Foz da Fonte and Trafaria sections.

As in the Trafaria samples, the remagnetization, along with an increase of the magnetic susceptibility, is observed in seven sites up to 380°C and in six others up to 450°C. Therefore, the directions of the primary component are presumably determined after the cleaning of the viscous component and/or the secondary component and prior to the occurrence of the intensity increase (Fig.4).

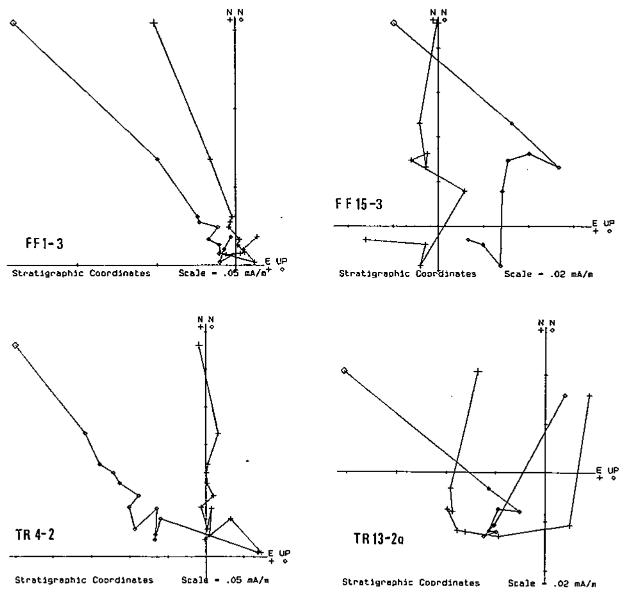

Fig. 4 — Zijderveld diagrams for four samples from the Foz da Fonte and Trafaria sections.

Polarities

Declinations and inclinations of the presumed primary component of magnetization are shown in figures 5 and 6 for each sample. Altough we observe some clustering of the declinations around 0°C or 180°C, the inclinations are not always as would be expected for the latitude of this region. A large number of samples having southerly declinations show positive or very low negative inclinations. However, for both declinations and inclinations, we can observe some pattern in their gathering in the specific parts of the sections. In all cases, the polarity of each site is inferred not only from the average directions of the presumable primary component, but, more importantly, from the magnetic behaviour of each sample during demagnetization. Moreover, in both sections, each polarity zone includes several successive horizons because of the regular sampling and the small distances between the horizons.

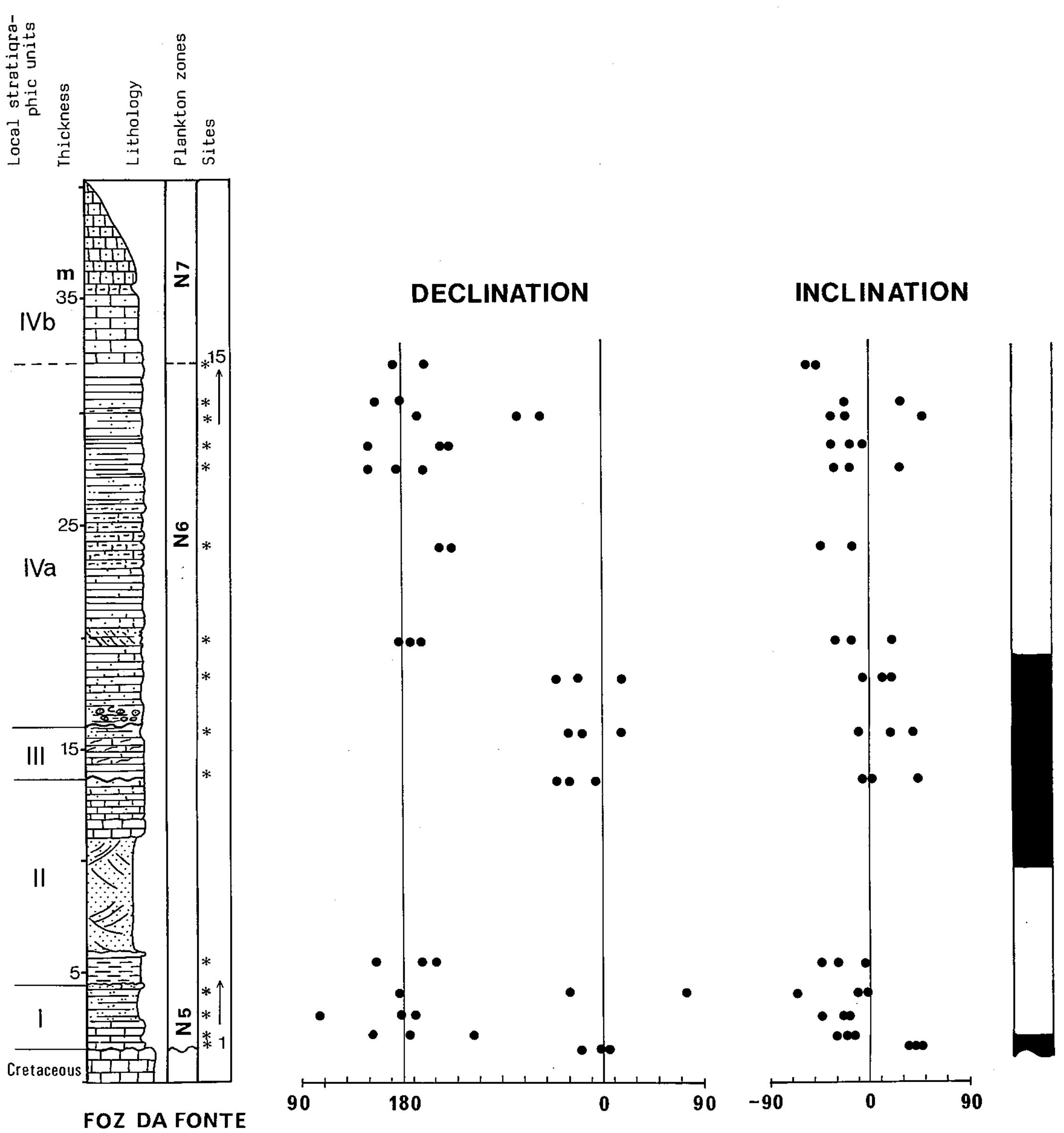

Fig. 5 — Declination and inclination of the caracteristic magnetization component in the Foz da Fonte section. The left part of the figure concerns stratigraphic data from this section.

From these results, the following sequence of polarities has been observed in the Foz da Fonte section (from the bottom to the top): one normal horizon, four reversed horizons, four more normal horizons and six more reversed horizons. The boundary between the first reversed and the second normal zones is approximate because of a gap in the sampling (about 8 m) between the sites FF5 and FF6. This part of the section is mainly composed of unconsolidated sands.

In the Trafaria section, three polarity zones are apparent: a normal zone 5 meters thick between two reversed zones. The first reversed zone is represented by two horizons in the silty clays. At these sites, the weak magnetization of sediments and the presence of a hard secondary component did not allow a primary direction to be clearly determined. Therefore, more samples (five from each horizon) were examined. In most of the samples, the behaviour of the remanent magnetization during the successive steps of heating leave no doubt about the reverse polarity of these two horizons. In the other horizons, the directions of the characteristic remanent magnetization are reasonably well grouped and allow the determination of normal and reverse polarity zones.

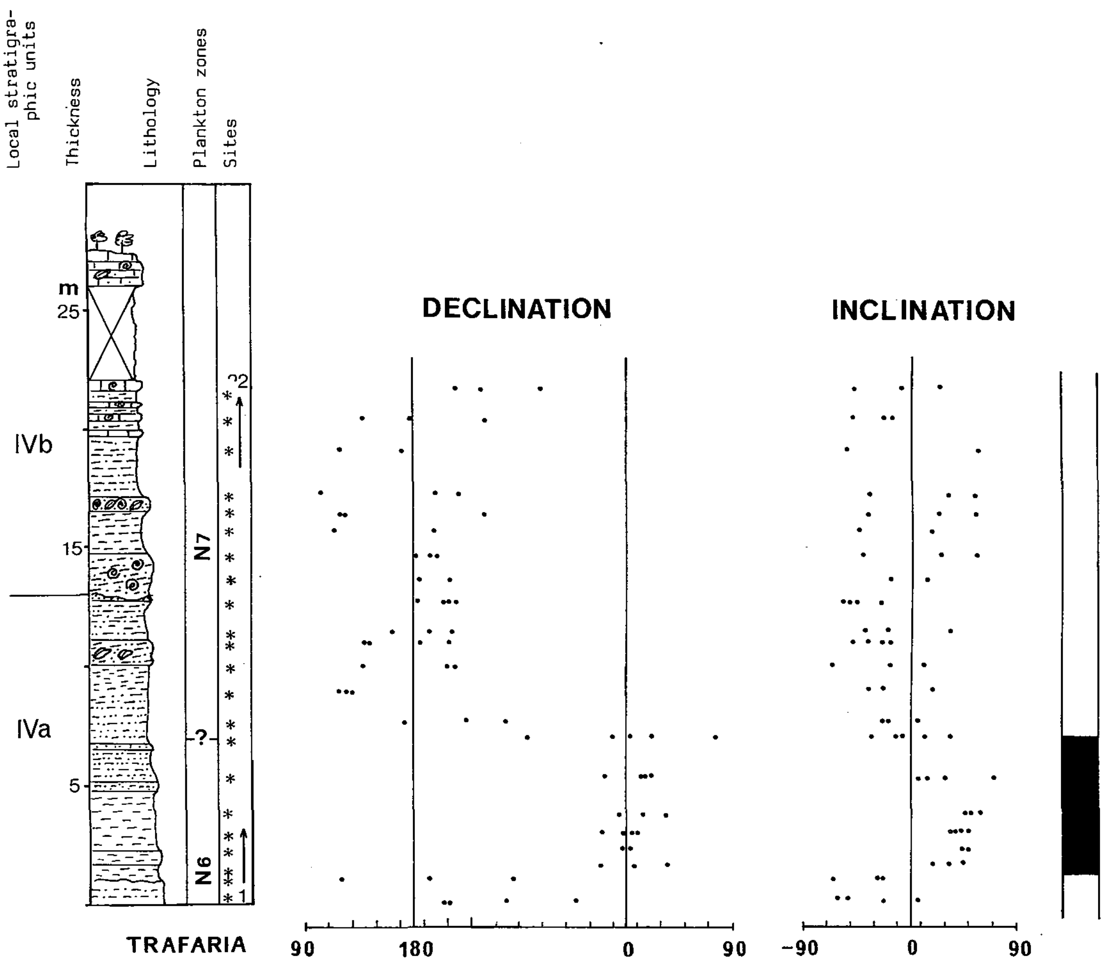

Fig. 6 — Declination and inclination of the characteristic magnetization component in the Trafaria section. The left part of the figure concerns stratigraphic data from this section.

BIOSTRATIGRAPHY

Both Foz da Fonte and Trafaria sections, already sampled for magnetostratigraphy, were also studied under a biostratigraphic viewpoint, specially as far as planktic Foraminifera are concerned.

Foz da Fonte section

A sample collected 2.5m from the bottom of this section yielded the first *Globigerinoides altiaperturus*. The first appearence of this species is a datum that has been used as marker for the lower boundary of *Globigerinoides altiaperturus* — *Catapsydrax dissimilis* subzone from the *Globoquadrina dehiscens dehiscens* — *Catapsydrax dissimilis* zone (IACCARINO, 1985). The same datum is also employed to recognize the Aquitanian-Burdigalian boundary (BIZON & BIZON, 1972; DEMARCQ *et al.*, 1974; BIZON, 1984; IACCARINO & SALVATORINI, 1982; IACCARINO, 1985).

IACCARINO (1985) correlates the *Globigerinoides altiaperturus - Catapsydrax dissimilis* zone with Blow's N5 and N6 zones.

No *Catapsydrax dissimilis* forms have been found at Foz da Fonte. This makes it difficult to correlate the upper part of the section to any biozones. The last occurrence of this species is an useful datum to characterize the passage from *Globigerinoides altiaperturus* — *Catapsydrax dissimilis* subzone to *Globigerinoides trilobus* zone (IACCARINO, 1985), which corresponds to Blow's N7 zone.

Otherwise *Praeorbulina glomerosa* s. l. seems entirely absent. This excludes ascribing the Foz da Fonte Foraminifera associations to the *Praeorbulina glomerosa* s. l. zone (IACCARINO, 1985), which may be correlated to Blow's N8 zone.

Summing up, Foz da Fonte section corresponds essentially to BLOW's N5-N7 zones, even if its upper levels may be correlated to the lower part of Blow's N7 zone.

Trafaria section

All the samples studied are enriched in *Globigerinoides trilobus* and *Globigerinoides immaturus*. Other species — *Globigerinoides* *obliquus*, *Globigerinoides altiapertурus* and *Globorotalia obesa* are common. All samples yield some forms ascribed to *Globigerinoides bisphericus*.

This association allow a rather satisfactory correlation of Trafaria section to *Globigerinoides trilobus* zone (IACCARINO 1985) or to its equivalent N7 zone from BLOW (1969).

Calcareous nannoplankton from Palença section (about 6 kilometers East from Trafaria's) allowed FONSECA (1977) to ascribe the higher levels from IVa division — corresponding to those of Trafaria section — to MARTINI's NN4 zone. According to BERGGREN *et al.* (1985), this zone begins at the lower part of N7 and ends in the midlle part of N8 zone (Blow); however, the viewpoints of STEININGER *et al.* (1990) are not identical as to its upper boundary, which they regard as ending just after the beginning of N8.

Another upper boundary for IV-a unit is given by the mammalian fauna from overlying IV-b unit (Lisboa, Cristo-Rei), characterized by the first appearance of mastodonts and the last of anthracotherids (*Brachyodus*); this fauna is quite close in age to that from Artenay, France; that may be ascribed to Mein's mammal Neogene unit MN4a, which corresponds to the N6 and the main part of N7 Blow's zones (STEININGER *et al.* 1990), Upper Burdigalian (part) or to the late Orleanian Faunal unit (also in part), or to the early Aragonian continental stage.

CORRELATION

Based primarily on planktic Foraminifera, some biostratigraphic zones have been identified for both the Foz da Fonte and the Trafaria sections.

According to these data, the first section includes the planktic zones lying between the top of N5 and, may be, the base of N7. In the Trafaria section, N7 zone is well characterized for almost all the section. The central column of figure 7 compares the ranges of the early Miocene planktic zones as proposed by BERGGREN *et al.* (1985) and by STEININGER *et al.* (1990), along with their correlations to the geomagnetic polarity time scale (GPTS)

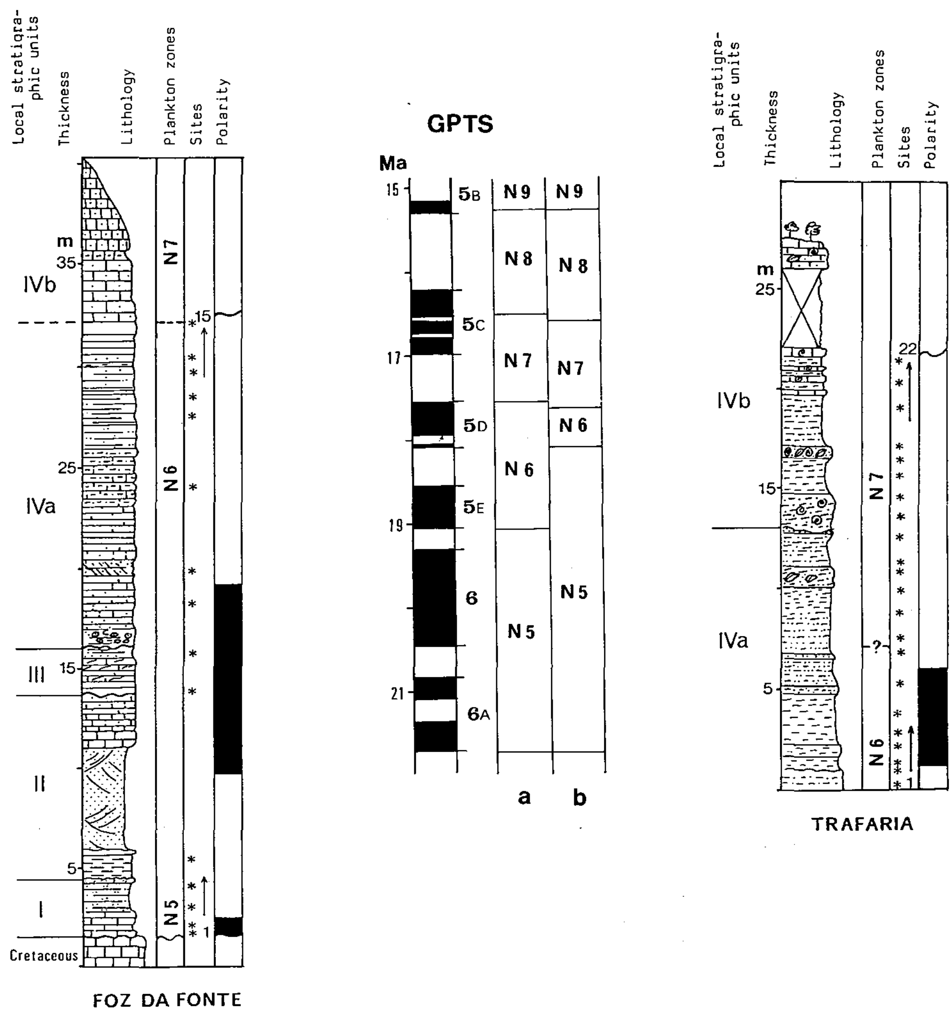

Fig. 7 — Stratigraphic and magnetostratigraphic data from the Foz da Fonte and Trafaria sections, and the calibration of the planktic Foraminifera chronology as proposed by BERGGREN *et al.*, 1985 (a) and STEININGER *et al.*, 1990 (b). Note the age difference for the N5-N6 boundary.

after BERGGREN *et al.* (1985). We must emphasize that the major difference between these two calibrations concerns the age of the N5 - N6 boundary: 19 Ma according to the first authors, but 18 Ma according to BERGGREN *et al.* (1985). In this last calibration, the span of the zone N6 is very brief, e.g. less than 0.5 Ma.

The range of the planktic zones after BERGGREN *et al.* (1985) implies that the Foz da Fonte section should include the polarity chrons from the top of the Anomaly 6 to the top of the Anomaly 5D. The four polarity zones found in this section are less than the number that would be required by this. Several hypothesis would explain this discrepancy: 1) insufficient sampling to record all polarity zones concerned by the interval of deposition; 2) occurrence of some unconformities and/or very low sedimentation rate; 3) the top of N6 and the N7 zones are not represented. In spite of these difficulties, the only possibility of correlation with the BERGGREN *et al.* (1985) calibration would be that the complete normal zone found in Foz da Fonte section corresponds to the Anomaly 5E. This correlation implies ages between 19.35 and 18.14 Ma for the Foz da Fonte section.

In the STEININGER *et al.* (1990) correlation table, the planktic zone N6 is very short and it is approximately time equivalent to the Anomaly 5D (fig.7). The polarity zones of the Foz da Fonte section fit worth with this calibration, since in the bottom of the section, the N5 zone is represented and, otherwise, the N7 zone should be represented from the middle of the section but this seems not to be supported by the Foraminifera data.

In the Trafaria section, the palaeontological data allows to correlate the palaeomagnetic anomalies with the reverse and upper normal periods of the Anomaly 5D and to the lower reverse anomaly of C5C. The correlation is better using BERGGREN et *al.* (1985) scale. This correlation implies ages between 17,90 and 16,98 Ma for the Trafaria section.

Taking into account this last correlation, a sedimentation rate of 2.1 cm/Ka can be estimated for the two complete polarity zones of the Foz da Fonte section. If we estimate the sedimentation rate by dividing the total thickness of the Foz da Fonte section (29.7m) by the suggested interval of time (19,35-18,14 Ma), this rate will be 2.7cm/ka. In any case, these are quite reasonable amounts often found in such marine deposits (SEN, 1988).

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