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THE PERNAMBUCO-ALAGOAS MASSIF, NORTHEAST BRAZIL

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ABSTRACT The Pernambuco-Alagoas median massif which runs E-W in the states of Pernambuco and Alagoas, Northeast Brazil, constitutes a large segment of Archean to Early Proterozoic rocks, surrounded by younger fold systems of Middle to Late Proterozoic age. Its litho-structural context is rather complex, comprising several gneiss-migmatitic suites associated with mafic to ultramafic rocks, and large gneiss-granitic batholiths. Granitic to syenitic stocks of Brasiliano age pierced locally the ancient rocks of the massif.

Apparently, the structural trends of the São Francisco craton, to the south, continue pervasively in this median massif. The schistosity of the surrounding fold systems typically verges onto this unit. A late phase of local deformation is represented by granitic masses which overthrust the southern and northern borders and partially masked the original limits of the massif.

Geophysical surveys helped to precise its limits. Important gravimetric and magnetometric anomalies shed some light on the geodynamic evolution of the massif plus its surrounding systems.

INTRODUCTION In this work, geophysical approaches have been used to analyze the behavior of some geotectonic units of the Precambrian basement, in Northeast Brazil. As yet, these units have been proposed on a theoretical basis only, on the grounds of regional geologic mapping, lacking an insight of the deep structures in the crust.

The success in analysing the Sergipean fold system with the aid of gravimetric and magnetometric data (Rand *et al.*, 1980) has encouraged these authors to go farther north, extending this geophysical survey onto the so-called Pernambuco-Alagoas massif (Brito Neves, 1975).

First, one aims to study the structural behavior of the massif in relation to the surrounding fold belts to allow a better assessment of its behavior as an independent unit and propose a better classification for it. Secondly, geophysical models which better fit the geological and geophysical data will be discussed.

The choice of this area in the present study is due to several geographical and geological facts and mainly because of the general thought that it played an important role in the evolution of the Borborema province (Almeida *et al.*, 1981).

PREVIOUS WORK AND CONCEPT Ebert (1962) was the first one to call attention to the fact that the area occupied by the Pernambuco-Alagoas massif was a site of very ancient rocks, basement for metamorphic rocks to the north. Richter and Ponte (1964) gave to the massif the name of Pernambuco-Alagoas batholith; Dantas *et al.* (1970) preferred to name it Itaíba massif; Brito Neves and Cordani (1973) baptized it as Pernambuco-Alagoas tectonic high. Brito Neves (1973, 1975) finally regarded it as a massif. Other contributions are due to the German Geological Mission (1973), Santos and Silva Filho (1975), Costa *et al.* (1977), Mello *et al.* (1977) who referred to this unit as the Pernambuco-Alagoas cratogenic area; and Silva Filho *et al.* (1977), gradually consolidated the present knowledge of this geotectonic unit.

At small areas within the massif, other contributions are of Sial and Menor (1969), Farina (1966, 1970), Santos (1977) and Albuquerque (1977)

Almost all of the massif has been covered by geologic mapping at the scale of 1:250,000.

The literature on the fold belts around the massif is extensive and mostly referred to or included by the authors of the above mentioned set of papers.

Brito Neves (1975) reviewed the geochronological data on the massif classifying this as a massif of the first type, according to Khain and Sheynman's (1962) views. Likewise, Mello *et al.* (1977) applied to this unit the term cratogenic area of Pernambuco-Alagoas, surrounded by mobile belts.

In fact, to the north of the massif, one finds the Pajeú-Paraíba fold belt or mobile belt, of the vestigial facet type. To the south of the massif, with well-preserved supra-structure, one can find the south Alagoan metamorphic belt of the Sergipean fold system. In both cases, there is evidence of a complex tectonic behavior of the massif, starting as a kind of foreland but facing lately several tectono-magmatic mobilizations.

LITHOLOGICAL ASSEMBLAGES With an area of about 70,000 km^2, the lithological constitution of the massif shows a variety of rock types. According to the order of importance, one can mention:

(*a*) Migmatite-gneissic terrains, associated to subordinate occurrences of metamorphosed mafic and ultramafic rocks. Metamorphism of the amphibolite facies, locally reaching the granulite PT conditions, seen very often.

(*b*) Granite-granodioritic terrains that constitute large polydiapiric batholiths.

(*c*) Metasedimentary, supracrustal terrains, representing folded covering.

(*d*) Calc-alkalic intrusives, from small batholiths to stratoid bodies, probably formed at the end of the Proterozoic.

(*e*) Several types of tectonites generated from the above mentioned terrains, through special structural circumstances.

(*f*) Volcano-plutonic association, south of Recife.

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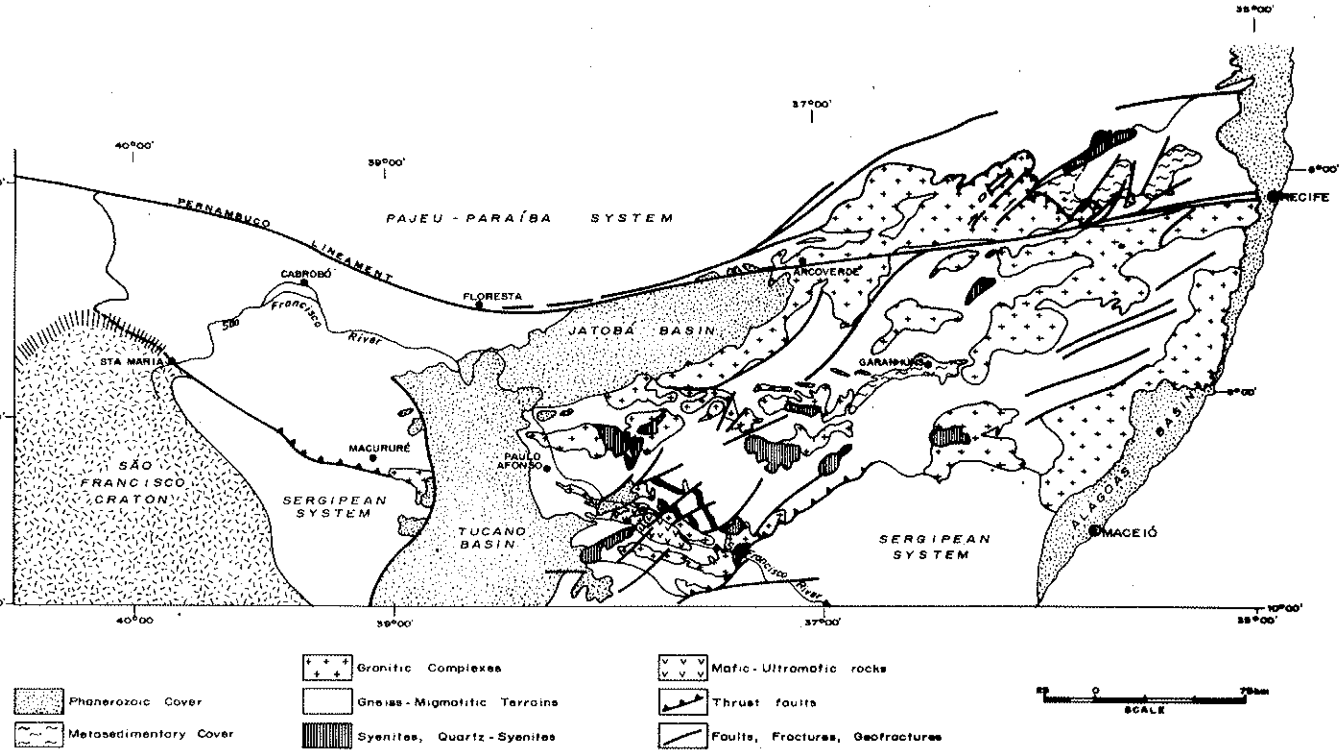
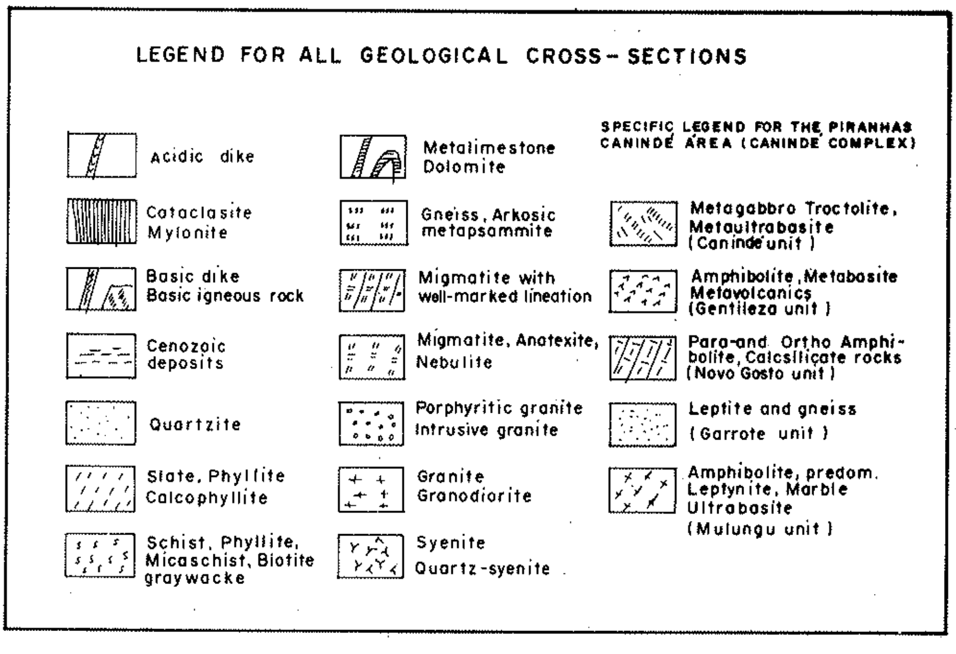


Figure 1 – Geographical and geological location of the Pernambuco-Alagoas massif, Northeast Brazil. Gneiss-migmatitic complexs, polidiapiric batholiths, granitic bodies and metasedimentary covers are also shown

1. *Migmatite-gneissic terrains.* Many lithological types are seen though migmatization masked the multiple lithotypes (sedimentary metamorphic and igneous rocks).

These terrains represent the oldest rocks of the massif, as will be discussed later and are the main point of support of the structural framework of this geotectonic unit under consideration. Most of the other above mentioned lithological components have been generated from this one, and/or are in conspicuous unconformity with these fundamental complexes. At the better known Cabrobó and Chorrochó areas one can recognize two lithotypes of these terrains, both grading very often into diatexitic facies. The first one, a widespread lithotype is constituted by several lithological assemblages, metasedimentary ones (quartz-schists, two-mica schists, metarkoses, quartzites, calc-silicate rocks, paramphibolites and, less frequently, limestones), acidic meta-igneous rocks (orthogneisses), intermediate to basic (orthoamphibolites, metagabbros), and locally meta-ultrabasic rocks (metapyroxenite, metahornblendite, etc). These metamorphic rocks constitute an association where banding



is common, caused by transposition, besides a common evolution to metatexitic units, where stromatitic structures predominate. Where the migmatization reached its utmost point, diatexites with many resisters and restites are found, mainly from the ultramafic and mafic lithologies.

As a faciologic variation of this authentic suite (in Henderson *et al.* sense, 1980), one can observe the presence of a metasedimentary set of high-grade, composed of gneisses and dark schists, with sillimanite, biotite, muscovite and garnet. In this context the presence of interleaved quartzite and calc-silicate rocks has been noted, indicating a predominantly sedimentary origin. Locally, the presence of ortho-derivate rocks, such as talc-schists and orthoamphibolites, have been recorded.

Aplitic and pegmatitic veins, of a premetamorphic phase (before the development of the main schistosity) are abundant and typical. These veins have been metamorphosed, with schistosity planes conforming to their host rock schistosity.

The structural history of these units is very intricate, for a preliminary analysis one could indicate that five or six deformational events took place, giving rise to different types of interference patterns. The degree of metamorphism, as already mentioned, is of high amphibolite facies, with common migmatization.

This complex pattern of composition, structure and metamorphism is widespread within the massif, as may be understood by analysing the corresponding literature. In addition, the incidence of late tectonic events (lineaments and allochthonism of the borders of the massif) have generated new petrotectonic fabrics in these rocks. Multiple granitic activity has also contributed to the general picture of the area. Due to these processes, developed in different stages, practically all contacts between the gneissic-migmatitic terrains and the granitic-granodioritic ones are only inferred, even at the scale of semi-detail.

Within these terrains, rocks of the granulite facies of metamorphism have been recorded. Among these, one includes leptynites, kinzigites, charnockites, enderbites, hypersthene-gneisses, etc, from Palmeira dos Índios to the south (Alagoas), up to Nazaré da Mata (Pernambuco). All these occurrences still lack a careful petrographic study and a definition of their true extent in the field.

With respect to the mafic and ultramafic rocks, besides several occurrences, more or less isolated (resisters and restites), the best exposures are recorded at the low course of the São Francisco River and at Passira, Pernambuco. In the low course of the São Francisco River, between Pão de Açúcar and Canindé (Alagoas-Sergipe), Silva Filho *et al.* (1977, 1981) identified and mapped a large sequence of metavolcanic-metasedimentary rocks, including acidic, basic and ultrabasic rocks which alternate with clastic (leptynites, quartzites, schists) and chemical sediments (limestones and itabirites). This sequence is overlain by the Canindé complex, made up predominantly of metagabbros. All this context, folded and metamorphosed (see geological section) has been pierced by late granites and syenites.

At Passira, Pernambuco, not far from the northern border of the massif, Sial and Menor (1973), Silva Filho and Guimarães (1979) and Farina *et al.* (1981) recorded occurrences of anorthositic rocks within basic rocks (diorite, gabbros and ultramafics) partially migmatized, within which several occurrences of Fe-Ti-oxides have been found. These are andesine-rich, massive bodies which may represent exposures of the lower continental crust.

2. *Granite-granodiorite terrains.* The granite-granodiorite complexes constitute large batholiths or granitoid belts in the chinese-soviet sense, for they can be found for thousands of square kilometers, although with compositional, textural and structural variations.

From the petrographic viewpoint, diorites to K_2O-enriched granites have been identified. The granodiorites tonalites and monzonites predominate volumetrically. Texturally, they range from fine-grained rocks up to porphyritic types. Structurally, they are not well defined and can be emplaced along the regional trend of the massif or assume diagonal positions.

Among these polydiapiric/polycyclic massifs, it is worth while mentioning those of Jaboatão-Bonito (Pernambuco), Ipojuca-Messias (Pernambuco-Alagoas), Manari-Arcoverde-Brejo (Pernambuco), and Paulo Afonso-Cacimbinhas (Bahia-Alagoas). Remnants of different kinds, metamorphic rocks, basic to ultrabasic, calc-silicate rocks and limestones, of modest size are sometimes seen within them. Transitions to gneissic-migmatitic terrains are common.

Although, there is evidence of a polycyclic development which may go far back at least to the Neo-Proterozoic, the geochronological data point to the culmination of development, during the Brasiliano cycle.

3. *Metasedimentary, supracrustal terrains, representing folded covering.* The best exposures of supracrustal rocks are in form of an elongate band, trending ENE-WSW, in the central area of the massif, in Garanhuns and surroundings. These are metasedimentary rocks, essentially quartzite with subordinate participation of feldspar and muscovite, and xenoblastic texture, overlying unconformably gneissic and migmatitic terrains. The Garanhuns Formation, according to Cardoso and Castro (1979) has undergone essentially disruptive tectonics and was cut by many granitic and pegmatitic veins.

In the northern border of the massif in elongate NNE-SSW depressions (Riacho das Almas, Apoti-Feira Nova), in the gneissic-migmatitic basement, metasediments such as mica schists, metagraywackes, quartzites, limestone intercalations, of the greenschist facies and amphibolite are present. These lithologies are intensively tectonized along their basement, in such a way that it is difficult to establish precisely the limit of these supracrustal rocks in relation to the Pajeú-Paraíba fold belt metasediments farther north. Thence the northern limit of the Pernambuco-Alagoas massif is only conventional.

4. *Calc-alkalic intrusives* Calc-alkalic igneous rocks are better represented in the massif between Macururé (Bahia), and Santana do Mundaú (Alagoas), south of the parallel 9°00′ S, comprising fissural intrusives stocks, and small batholiths. These rocks have been generated at different events, but within the Brasiliano cycle. They are two-mica granites (Ouro Branco-Cariba), equigranular and porphyritic granites and granodiorites (Glória), hornblende granites, quartz-syenites and syenites (Água Belas), leucogranites and adamellites with many xenoliths (Mata Grande), etc., all of which still remain to be studied in detail.

5. *Tectonites.* The most important belt of tectonites follows the geofracture known as the Pernambuco lineament, which accompanies the northern border of the massif from Recife westward, to Arcoverde, from where the lineament itself represents the northern border of the massif.

This lineament, multiply reactivated, has generated a tectonite belt whose width varies from 1 to 5 km, including cataclasite, mylonites, pseudotachylytes, ultramylonites, etc. Textures of the flaser type (besides the cataclasites) are generated in the massif next to its borders due to tangential movements of granitic and gneissic-migmatitic masses over the fold systems, surrounding the massif.

6. *Volcano-plutonic association, south of Recife* It is worth while mentioning also that to the eastern border of the massif, a few volcanics of the Pernambuco Group (Amaral and Menor, 1979) and the peralkalic granite of the Santo Agostinho Cape (Sial, 1973) can be found. This magmatic activity, Cretaceous in age, is associated with the process of formation and evolution of the eastern continental margin of south America.

REGIONAL STRUCTURAL BEHAVIOR A – general features As a whole, the Pernambuco-Alagoas massif shows its main axis, about 520 km long, trending W-E (WNW-ESE and WSW-ENE), separating divergent structural trends of the fold systems adjacent to the massif.

A preliminary analysis of the inner structural features of the massif point to a polyphasic evolution, with a heterogeneous outline, with a complex style, from the eastern to the western extremity. The sudden interruption of structural lines, mainly to the western portion of the massif seems to indicate that the massif is really a fraction of a larger unit, isolated by disruptive processes.

At the western extremity there is a continuity of the structural lines and main rock types of the São Francisco craton into the Pernambuco-Alagoas massif, where these lines undergo a remarkable change of their trend from N-S to WNW-ESE. Farther east, the tectogenic participation of the borders of the massif in the evolution of the surrounding fold systems seems clear.

In examining the traces of foliation of the gneissic-migmatitic complexes, several structural interference patterns were verified, resembling many times the patterns observed in ancient platforms. Only seldom does the dominating structural trend seem to follow the E-W trending axis of the massif. In many places, the traces of foliation are disposed diagonally to the axis of the massif. Likewise, in the granite-granodiorite terrains the foliation can follow the trend of this axis (*e.g.*, Jaboatão-Jurema, Manari-Brejo da Madre de Deus, Pernambuco), but can also be at variance with it (*e.g.*, Ipojuca-Messias).

The massif has behaved as a foreland for the surrounding fold systems. Later, small portions of this massif have been thrust over these fold systems. The strike-slip movements along the Pernambuco lineament, have been considered as late events in relation to the above mentioned ones (Santos, 1971, 1977) and will not be discussed here.

B – The foreland of the surrounding foldbelts In the geological sections (Figs. 2 to 12) the vergence of the schistosity in the surrounding fold belts toward the massif is clear attesting to that the massif has acted as the foreland during one stage of the evolution of these foldbelts. Figs. 2 to 8 refer to the northern flank while Figs. 9 to 12 to the southern flank of the massif.

The folding has generated isoclinal tight folds conspicuous in the supracrustals, and extending down to the basement of the foldbelts, next to the borders of the massif.

Of course, in order to unravel the history of deformation of this phase and previous ones, a careful structural analysis must be done in the two fold bands which bound the massif. Anyway, the mechanism of folding of the schistosity, verging to the massif, is a notorious fact. In the segment to the north of the massif, this has been known for a long time (Santos, 1971, Brito Neves and Albuquerque, 1978; Mello and Siqueira, 1971). In the segment to the south of the massif, the analysis and interpretation given by Jardim de Sá *et al.* (1981), although without a careful mapping, at-

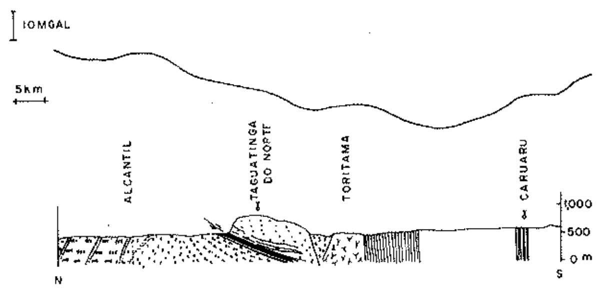


Figure 2 – Geological section between Caruaru and Alcantil, Pernambuco, showing the overthrust of Taquaritinga do Norte. The gravimetric Bouguer anomaly is also shown, and shows a gradual increase Northward

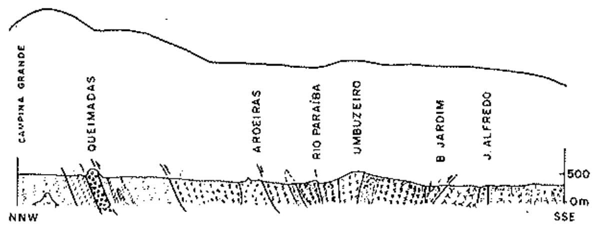


Figure 3 – Geological profile between João Alfredo and Campina Grande, Paraiba. Opposite vergences are shown in this section, with an axial zone of divergence around Umbuzeiro. The gravimetric anomaly is also shown gradually increasing Northward

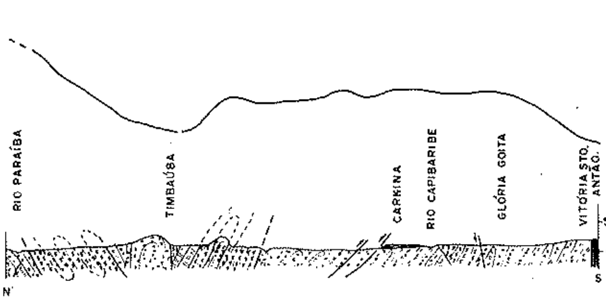


Figure 4 – Section between Vitória de Santo Antão, Pernambuco, and Paraiba River. A double vergence is clear in this profile with the axial zone of divergence located around Timbaúba, in Pernambuco. The Bouguer gravimetric curve indicates a small negative anomaly on the Timbaúba granitic body

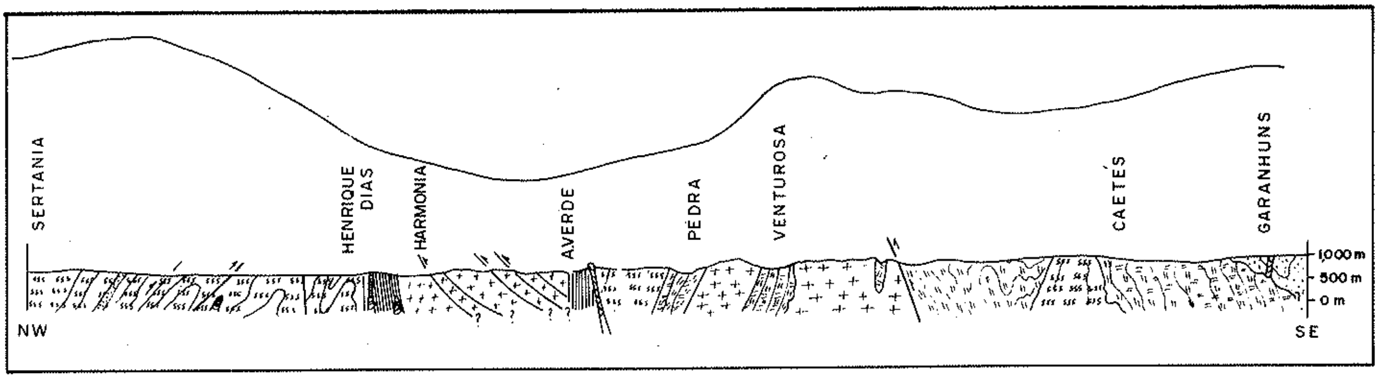


Figure 5 — Geological section between Garanhus and Sertania, Pernambuco. Opposite vergences are seen around Henrique Dias. Two important shear zones are seen at Arcoverde and Henrique Dias. The gravimetric Bouguer curve shows a negative anomaly between Pedra and Henrique Dias

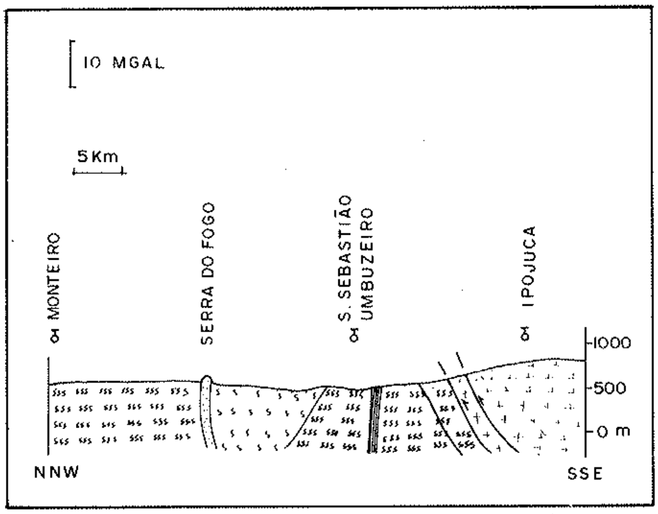


Figure 6 — Geological profile between the Ipojuca River, Pernambuco, and Monteiro, Paraiba, Reverse faults are seen at the southern end of this section

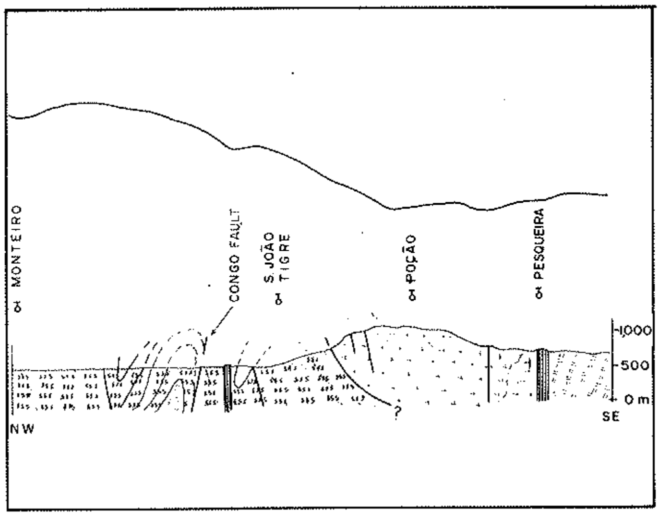


Figure 7 — Geological section between Monteiro (Paraiba) and Pesqueira (Pernambuco). The Congo fault divides structures which apparently show axial planes of folds dipping in opposite directions. At Pesqueira, a shear zone, vertically dipping, is present. The Bouguer gravimetric curve increases Northward.

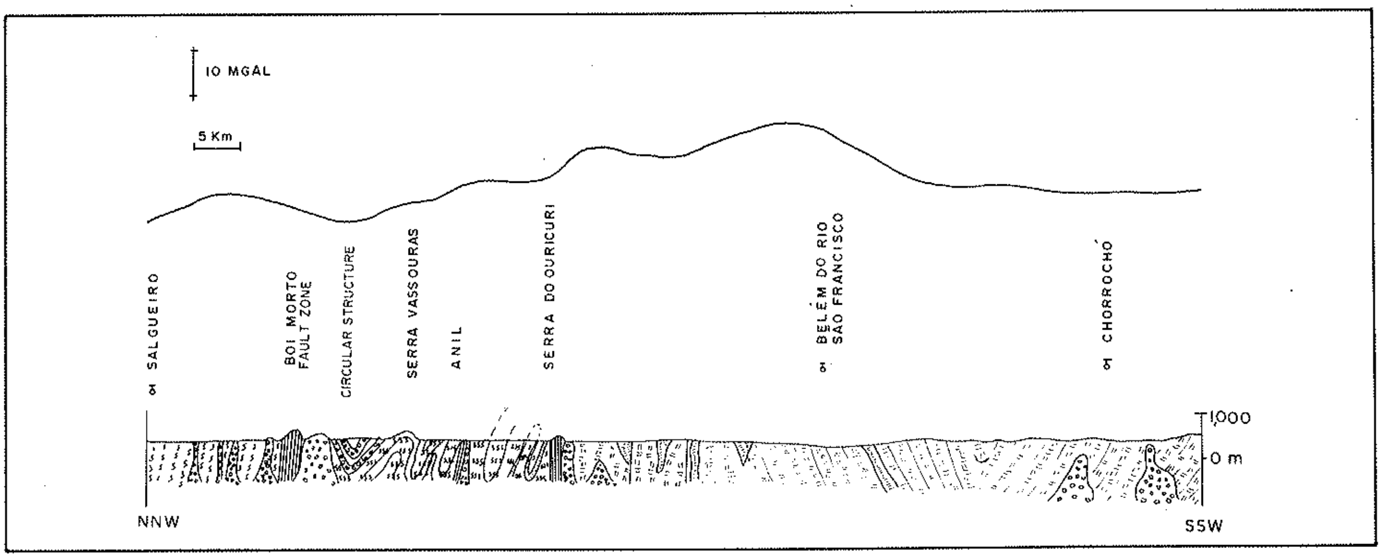


Figure 8 — Geological section between Salgueiro (Pernambuco), and Chorrochó (Bahia). The Pernambuco-Alagoas massif is located between Serra do Ouricuri, where the Pernambuco lineament is represented by a shear zone, and Chorrochó, in this section, Several basic intrusives bodies are present, besides a few granite bodies, Between Serra do Ouricuri and Salgueiro (Pernambuco) metasediments of the Piancó-Alto Brigida are tightly folded and pierced by numerous granite intrusions. The Bouguer gravimetric curve shows a slight increase on the massif, where basic intrusives are present

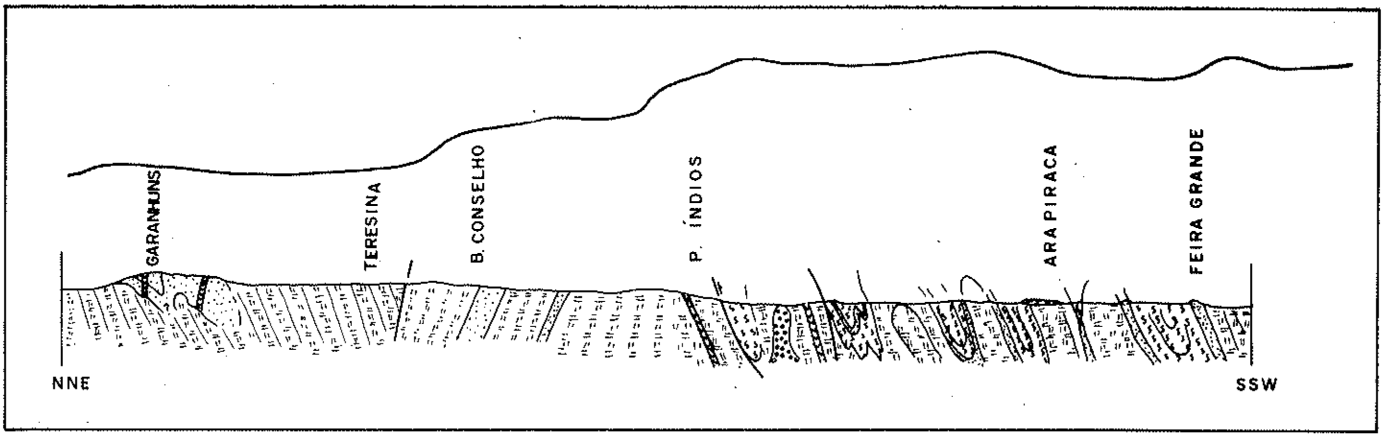


Figure 9 – Section between Feira Grande (Alagoas), and Garanhuns (Pernambuco). The area between Feira Grande and Palmeira dos Índios is characterized by tight, isoclinal folds and, at Palmeira dos Índios, a reverse fault is observed. From Palmeira dos Índios to Bom Conselho, migmatites including nebulites are present, and from Bom Conselho to Garanhuns, migmatites and locally quartzites are well represented. The Bouguer gravimetric curve increases gradually Southward

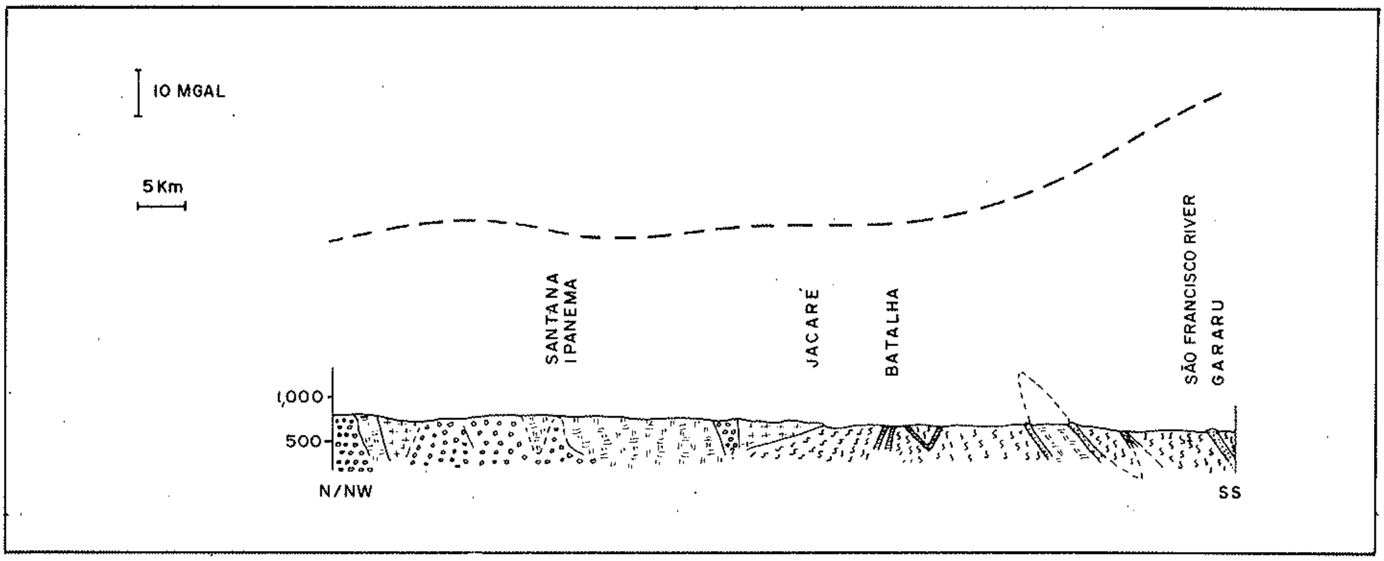


Figure 10 – Cross section between Ouro Branco, and Gararu (next to the São Francisco River). One can see the lithological and structural forms between the area of Jacaré dos Homens-Gararu and Jacaré dos Homens-Ouro Branco. At Jacaré dos Homens, granitic rocks overthrust the metamorphic rocks of the Alagoas foldbelt. The Bouguer gravimetric curve increases gradually Southward fold belt

tested to a verging of the schistosity of the foldbelt rocks towards the massif. In both cases, the intensity of folding becomes greater as one approaches the massif, involving thrust faults in a few cases.

The age of this fold phase is not well known being ascribed to the Brasiliano cycle (supported by geochronological data) or to the Eo-Proterozoic. In either case, only the Pre-Brasiliano age of the rocks which make up the massif is quite clear.

The tectonic phase described ahead is in contraposition, in its sense, to the scheme discussed here.

C – The late extension tectonics In the northeast and southwest borders of the massif a better preserved late phase of allochthonism is observed, resulting in overthrusting centrifugal structures.

The extent of such an event is so large that the original shape of the massif is masked. From Arcoverde to the west, to Riacho das Almas, in Pernambuco, one verifies the displacement of granitic and migmatitic masses onto the metamorphic rocks of the Pajeú-Paraíba system, with variable intensity from point to point, developing typical overthrusts. This overthrusting from southwest to northeast in a general way was greatly facilitated by a number of strike-slip faults trending NE-SW (or maybe a few of these faults resulted from overthrusting as has taken place nearby in Santa Cruz do Capibaribe (Pernambuco). Associated to the overthrusting are mylonites and flaser structures developed in granitic rocks and augen-gneisses.

Several papers deal with these structures (Santos, 1971; Sial and Menor, 1973; Costa *et al.*, 1977; Mello and Siqueira, 1971; Albuquerque, 1977; and so on) in their general descriptions but fail to analyse the causes of such an event,

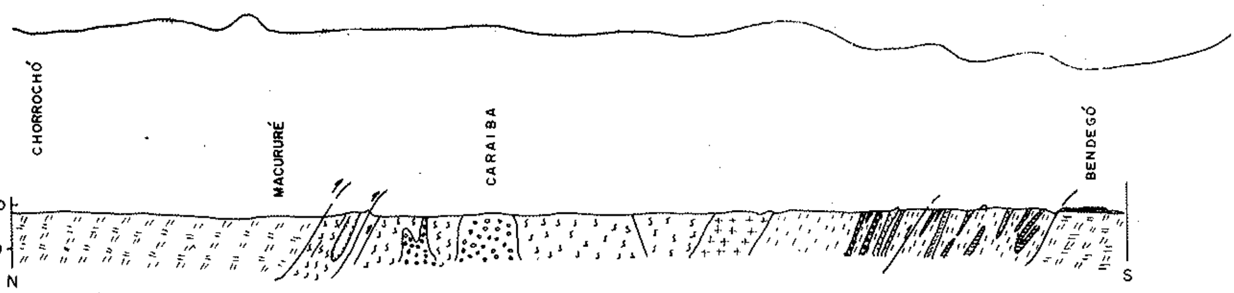


Figure 11 – Geological section between Chorrochó and Bendegó, Bahia. Next to Bendegó tight, isoclinal folds exhibit axial planes dipping north. At Bendegó and at Macururé, reverse faults are observed. The Bouguer gravimetric curve is rather flat, decreasing slightly around Bendegó

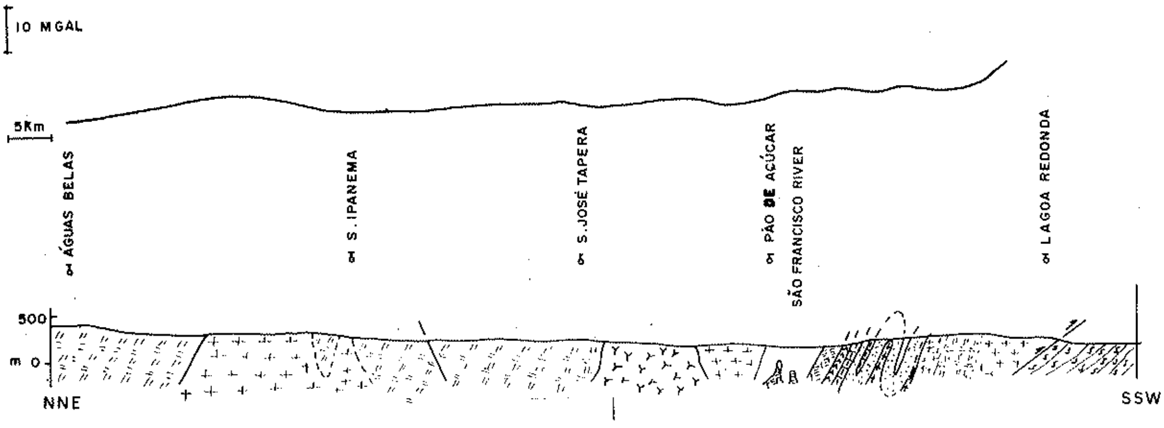


Figure 12 – Cross section between Águas Belas (Pernambuco) and Lagoa Redonda (Alagoas). From Mulungu to Canindé, tight isoclinal folds show axial planes dipping north. At Lagoa Redonda, this set seems to overthrust the biotite-schists of the Alagoas fold belt (Sergipean fold system). The Bouguer gravimetric curve is rather flat, except at Lagoa Redonda where it increases suddenly

practically opposite in drift (diagonal) to the movement of the Pajeú-Paraíba fold belt which overthrusts the massif. Although the movement under consideration was diagonal to the event responsible for the vergence, the new schistosity imprint is reduced to a band of a few kilometers to the north of the displacement front.

In the southern flank of the massif, from Minador do Negrão (30 km west of Palmeira dos Índios, State of Alagoas) to Santa Maria da Boa Vista, in Pernambuco, a late front of tectonic displacement is present. One has a series of reverse faults with granitic masses of the massif thrown on the metamorphic rocks of the Sergipean system.

This process has been as vigorous as the one responsible for the overthrusting in the northern flank of the massif, although faults with high angles predominate in this case. The same type of fault mechanism is repeated within the Sergipean fold system in the state of Bahia, and many times masks the observation of the vergence scheme of its folding. Only at Minador do Negrão to the south and to the east, away from this fault zone, is it possible to see the primary bipolar vergence pattern of this system (Brito Neves *et al.*, 1977).

The age of all these overthrustings cannot be determined with the desirable accuracy. As the Pajeú-Paraíba and the Sergipean fold systems are regarded as of Brasiliano age, this allochthonism must therefore be late Brasiliano.

The geochronological data A relatively good amount of K-Ar and Rb-Sr data is available in the specialized literature, usually resulting from reconnaissance work only. These data attest to a polycyclic evolution testifying the several thermal-tectonic events recorded in the South-American platform.

Since the first geochronological work in Northeast Brazil, in the 60's, indications of Archean and Eo-Proterozoic rocks have been revealed, confirming the preliminary ideas of Ebert (1962), on the grounds of field work.

With the growing amount of geochronological data, the idea of an Archean to Neo-Proterozoic evolution was solidified, for the gneissic-migmatitic complexes that make up most of this geotectonic unit. Likewise, it was also confirmed that after the Eo-Proterozoic, all processes represent overprinting and reworking of previously metamorphosed and deformed rocks.

Besides the geochronological data available for the massif, a number of datings carried out on the basement of the neighbouring/geotectonic units provide supporting information to these conclusions.

(*a*) Isotopic determinations older than 2.6 Ga are rare and are obtained only from relict patches in view of the overprinting by the late tectonic events. Among the accurate direct data, one can list the conventional ages obtained for rocks from Avencas (Limoeiro, State of Pernambuco;

K-Ar), Santa Maria da Boa Vista (Rb-Sr) and the area south of Veneza (Rb-Sr) in the western extremity of Pernambuco. It must be added that from the same areas above, other samples yielded isochrones equivalent to the Transamazonian, or conventional Post-Archean ages. As the quality of the data is regarded as good, the Post-Archean ages resulted from isotopic rejuvenation. In the area to west of Pernambuco, at the occidental extremity of the massif, a litho-structural connection occurs between the units which make up the massif and those at the São Francisco craton where Archean and Early Proterozoic ages have been recorded.

If these facts alone are not enough to prove the importance of the Archean lithogenesis in the massif, the description of these gneiss-migmatitic complexes and structural patterns attest to this contention. Descriptions of high-grade Archean terrains in other continents (Windley, 1978) are fully applicable to the lithological, and structural patterns observed in this massif which extends into the São Francisco craton.

(*b*) Regarding the Transamazonian cycle there is a huge amount of geochronological data, through conventional, reference and true isochrones. The amount of geochronological values in the range 1.8-2.0 Ga (south of Veneza, Nazaré da Mata, Vargem Grande, Limoeiro, Garanhuns, in Pernambuco; and Palmeira dos Índios, in Alagoas) obtained in gneissic and migmatitic terrains resembles the picture depicted from the eastern portion of the São Francisco province, to the south, where the presence of a mobile belt of this cycle is recognized. For the basement of the systems which surround the massif (Alagoas fold belt and Pajeú-Paraíba fold system), the number of Transamazônico ages is substantially increased in lithotypes which are the extension of those of the massif.

It is feasible to think that the majority of these units formed in the Archean and that the Transamazônico cycle is only a widespread overprinting phenomenon, of the geochronologic values, due to the migration of ^{87}Sr (high heat flow, migmatization, and so on).

(*c*) A relatively high proportion of conventional ages (Rb-Sr and K-Ar) is situated in the range of 0.9-1.4 Ga throughout the massif, sometimes including rocks which have also yielded conventional or isochronic Rb-Sr ages between 1.8 and 2.0 Ga as well as 2.7-2.8 Ga.

The Rb-Sr analytical values of some of these samples of gneisses and migmatites are enough to attest to a Pre-Brasiliano age. On the other hand, it cannot be assumed that only the partial isotopic rejuvenation of ancient rocks is responsible for the age pattern observed. The available data as yet does not enable us to assume the existence of an intermediate cycle between the Transamazonian and the Brasiliano.

Only with the accumulation of new data, and the beginning of a careful geochronological survey on a suitable scale, will assure the presence of the Uruçuano (= Espinhaço) event in this massif. It is worth while mentioning that granitic rocks of Rio Formoso (Pernambuco), and Serra Verde, (Alagoas) have yielded some age values within the range of this cycle.

(*d*) The widespread granitogenesis in the massif seems to be confined to the Brasiliano cycle, it is considered as Brasiliano due to the amount of geochronological data which definitely attest to this. Small intrusive bodies as well as larger polydiapiric batholiths yielded ages in the interval of the Brasiliano event. With only a few exceptions, Rb-Sr and K-Ar ages of the granitic rocks are between 0.5 and 0.65 Ga. Very often K-Ar ages of gneisses and migmatites and high-grade rocks lie in the Brasiliano interval of age, except for a few exceptions. These are evidences enough to indicate a generalized reworking of the massif during the Brasiliano tectonic cycle.

It seems to be beyond dispute that the present delimitation of structural patterns of the Pernambuco-Alagoas massif is mostly due to the Brasiliano cycle, as attested by several sources of information concerning regional geology. However, there is no doubt that geochronology and structural analysis have very much to add to our current knowledge of the massif.

GEOPHYSICAL SURVEYING The results of gravity and magnetic surveying here presented include data from several sources. Thus, the gravity anomalies of the sedimentary basins were already determined several decades ago (Petrobrás, 1957, 1963). More recently the whole coastal strip N of 9° latitude was mapped both by gravity and magnetic methods (Rand, 1978). With 900 stations per square degree on the coast, and 300 stations per square degree further inland, this mapping can be called detailed and semidetailed respectively. However, in the major part of the Pernambuco-Alagoas massif, the densities are only about 100 stations per square degree. Consequently, at present, this mapping has to be classified as a reconnaissance. Despite this shortcoming, the Bouguer gravity and vertical field magnetic maps bring interesting improvements to the existing geotectonic maps.

The Bouguer gravity anomaly map (Fig. 13) is apparently dominated by the large negative anomalies of the sedimentary basins. From our point of view, the anomalies within and along the borders of the massif are more interesting. First of all, there is the large and broad negative anomaly within the massif immediately N of the Pernambuco lineament. Comparison with theoretical curves enables us to locate the source of the anomaly – a graben or a down-folding of the crust – at the depth of Moho, provided the crust is not more than 30 km thick (Fig. 14). This thickness ought to be fairly correct, calculated by the Isostasists for the region in question (Sazhina and Grushinsky, 1971). Our illustration shows a traverse across the *E* portion of the anomaly. The two sizes shown for the graben depend on the density contrast that one assumes. One extreme is the "classical" case of geodesists, with the upper mantle of 3.27 and the crust of 2.67 (density contrast 0.6). The other extreme would be the lowest possible density for the uppermost mantle, with a "basaltic" rock of density 2.97 (density contrast 0.3). The truth probably lies between these two extreme. Even so, the same anomaly could be produced by a graben at any shallower depth. In that case it would be only necessary to modify the shape of the graben. However, such a graben at a shallower depth would give rise to insurmountable difficulties in finding a suitable low-density rock within the basement. Moreover, geological considerations favor the model here proposed. The situation is quite different W of the Jatobá basin. The region of the thickening of the crust there turns to NW, away from the massif. Instead of a negative anomaly, there appears a strip of positive anomalies immediately N of the Pernambuco lineament, turning to NE at one end and SW at the other. There the positive anomalies cross the W portion of the massif and become diffused. The short wave length of these anomalies does not enable us to localize the origin at the Moho, to

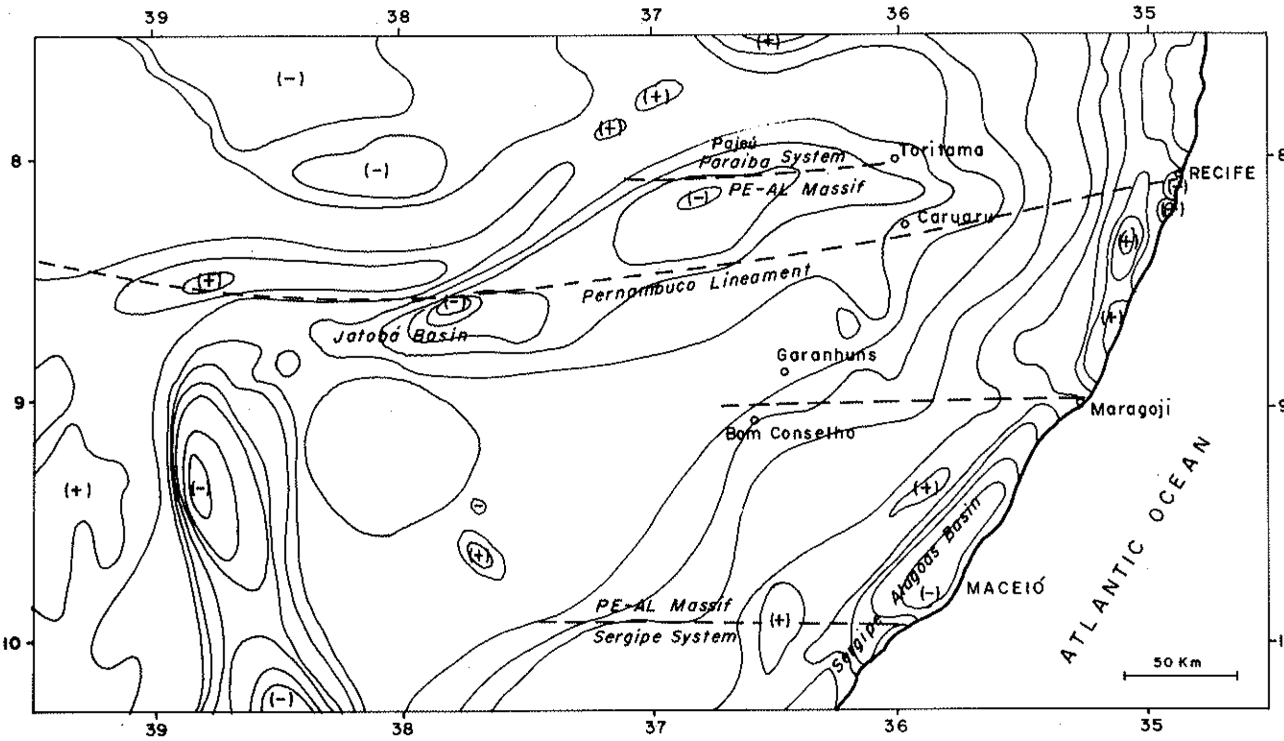


Figure 13 – Bouguer gravity anomaly of the Pernambuco-Alagoas massif. Contour interval 10 mgal. Lineations discussed in the text are shown by dashed lines, and anomalies by (+) and (–) signs

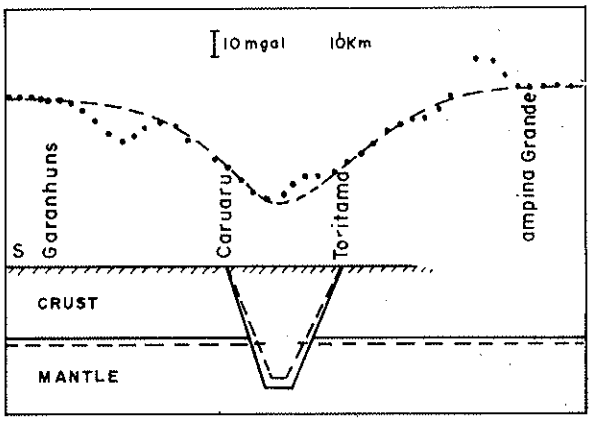


Figure 14 – Above: *N-S Bouguer anomaly across the hypothetical graben. Dashed line is the smoothed curve of the point anomalies.* Bellow: *Cross-section calculated from the anomaly. Full line corresponds to the assumed density contrast of 0.3, dashed line is for of 0.6 the density contrast*

suggest a chain of horsts of mantle material in the lower crust. Therefore, the basaltic rocks in the middle or upper part of the crust that cause these anomalies must have uprisen through narrow conduits not large enough to produce detectable anomalies.

Another strip of positive anomalies runs parallel to the coast from SW of Recife to SW of Maceió. Since the Moho is only 20 km deep on the coast (Sazhina and Grushinsky, 1971), some of the positive anomalies could correspond to intrusions of mantle material into the lower crust. SW of Recife, these intrusions locally reach the surface (Cabo volcanism).

The vertical field magnetic anomaly map (Fig. 15) has a number of features in common with the gravity map. One reason is that the obvious latitude effect in magnetics is oriented in the same direction as the thickness of the crust effect in gravity. An attempt to remove this latitude effect graphically resulted in a rather complicated and uncertain residual map. Evidently, the low density of the stations does not permit reliable residuals to be drawn. Nevertheless, even with the latitude effect, the vertical field magnetic anomaly is informative in the coastal and middle part of the massif. The positive gravity anomalies associated with known and supposed basaltic rocks have corresponding well-defined magnetic anomalies SW of Recife. By contrast, the strip of positive gravity anomalies N of the Pernambuco lineament does not fit very well with magnetic anomalies. Probably, magnetic anomalies there locate near-surface intrusions, whereas gravity anomalies are the product of weighted averages from all depths.

Most interesting is the complete agreement in the two maps regarding the four prominent E-W lineations. From N to S they are:

1) The N border of the Pernambuco-Alagoas massif with the Paraíba system. In the gravity interpretation, this coincides with the N border of the graben. However, on the geological maps it is identified as a thrust fault.

2) The Pernambuco lineament, well known for its large and obvious dextral off-sets on the geological and magnetic maps, and as the border of several anomalies on the gravity map.

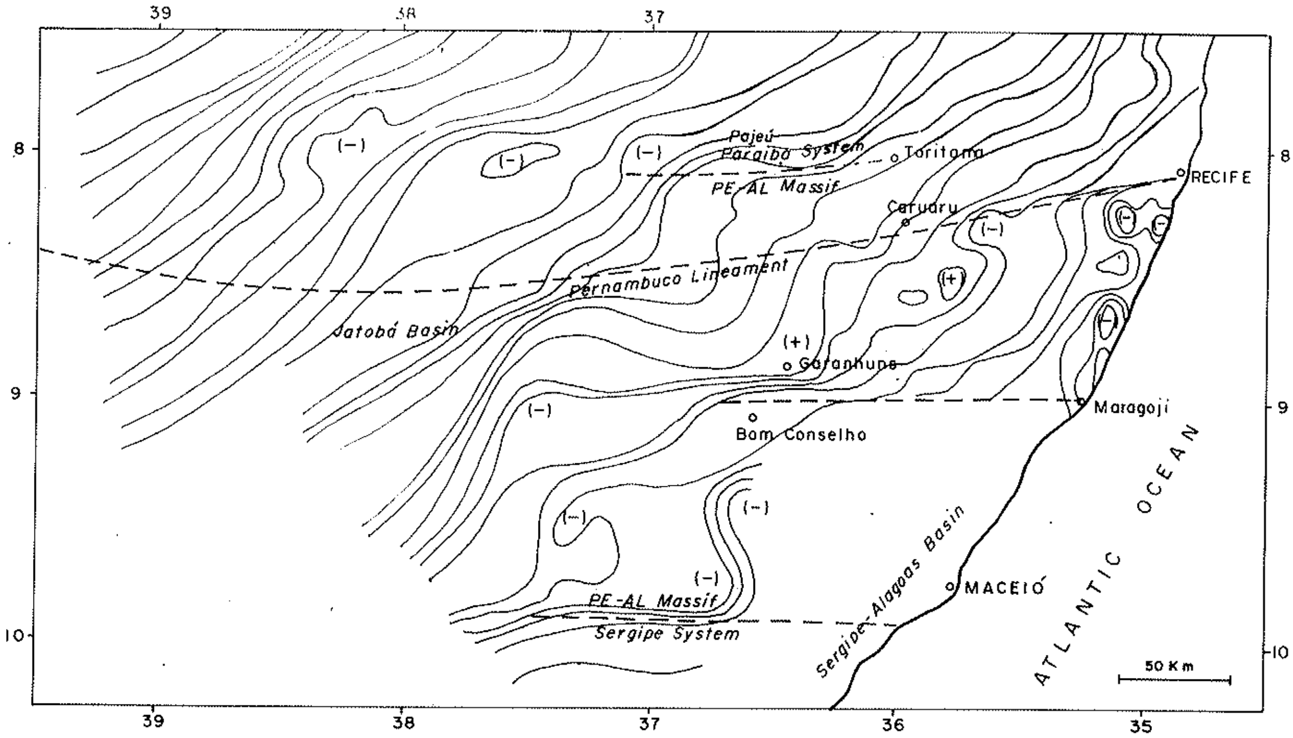


Figure 15 – Vertical field magnetic anomaly of the Pernambuco-Alagoas massif. Contour interval 100 grammas. Lineations discussed in the text are shown by dashed lines, and anomalies by (+) and (–) signs.

3) The Maragoji-Bom Conselho lineation. This lineation has the same dextral strike-slips on all three maps – geological (N border of the Sergipe-Alagoas basin), gravity (NE-SW step and NE-SW "basaltic" intrusions), and magnetic (exceptionally well-defined off-set of the NE-SW step).

4) The S border of the Pernambuco-Alagoas massif with the Sergipe system. Again, the dextral offset is well-developed on the magnetic map, and somewhat less so on the gravity map.

Looking at the two maps, gravity and magnetic, with all these E-W lineations and off-sets, one is left with the impression that the Pernambuco-Alagoas massif was thrust eastward in relation to the Sergipe system to the S. Moreover, the N portion of the massif was the one that was thrust farthest E. Our studies farther to the N seem to confirm this conclusion since all E-W lineations N of the Pernambuco-Alagoas massif show sinistral strike-slips, instead of dextral ones as in the massif.

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