STRUCTURAL MAPPING FROM MSS-LANDSAT IMAGERY: A PROPOSED METHODOLOGY FOR INTERNATIONAL GEOLOGICAL CORRELATION STUDIES

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ABSTRACT

A methodology is proposed for international geological correlation stu based on LANDSAT-MSS imagery, Bullard's et al. model of continental fit and compatible structural trends between Northeast Brazil and the West African c terpart. Six extensive lineaments in the Brazilian study area are mapped and discussed according to their regional behavior and relation to the adjacent tinental margin. Among the first conclusions, correlations were found betwee Sobral Pedro II Lineament and the megafaults that surround the West African craton; and the Pernambuco Lineament with the Ngaurandere Lineament in Camer Ongoing research to complete the methodological stages will include the mapp of the West African structural framework, reconstruction of the pre-drift pu and an analysis of the counterpart correlations.

1. INTRODUCTION

Since 1972, the LANDSAT Multispectral Scanner System has been collecti repetitive data over global regions in the visible and near infrared spectra regions.

Global tectonics has shown that the geological evolution of distant re of the world can be markedly similar. Since the general acceptance of contin drift by the scientific community, geological correlations have been made be selective drifted areas. Studies of this type can be supplemented by global LANDSAT scanning and image interpretation.

The Brazil-Africa Geological Correlation Project (Condwana Project) dev oped by the Brazilian Institute for Space Research (INPE) intends to test th application of LANDSAT imagery for international correlation studies based or theory of Continental Drift.

This paper presents the methodological approach that has been followed well as some results already obtained and some preliminary conclusions.

2. DISCUSSION OF METHODOLOGY

The proposed methodology was based essentially on modern means of globa data acquisition, as in the application of satellite technology to the study c continental drift and tectonics.

Orbital platforms of the LANDSAT type permit the collection of multispe data of the most extreme areas of the planet. Geometric resolution is constan while radiometric resolution can suffer variations, such as solar inclination with the latitude of the imaged area. In that sense, the study considered are along roughly the same latitude, we assumed (from a radiometric point of view the basic data for correlation to be equivalent; providing for spectral respo related only to natural targets, independent of atmospheric effects and diffe latitudes.

The areas studied are in regions classically correlated by researchers involved in continental drift. The physiography of the Atlantic Equatorial continental margin appears as pieces of a "jig-saw" puzzle, lending a natural tendency for reconstructing the ancient continent. The similarity between the continental margins of Africa and Brazil was the initial point of Wagner's hypothesis (Voisey, 1958). Bullard, Everett and Smith (1964) proposed a fitting of the two continents based on mean depths of the continental edge, considering it as the actual margin of the two continents. The scheme proposed by these authors will be the model used in this study, together with LANDSAT mosaics to discriminate the structural frameworks of the Brazilian northeast and African northwest. The model has been applied to Precambrian geological correlations (Almeida, 1966) as well as to tectonic fabric correlations of the continental margins (Gorini and Bryan, 1975).

The continental margins adjacent to the South Atlantic are commonly classified as Atlantic type (Heezen, 1974) as opposed to the Pacific type. While the first type adjoins deep oceanic zones of expansion, the margins of the Pacifi type are adjacent to zones of coalescence and thrusting plates, as on the weste margin of the South American continent. For the method proposed, it is fundamenta that the continental margins be of the Atlantic type, whose tectonic processes were less intense than the Pacific type and did not evolve to disfigure the adjoining landward structures.

Following the criteria that the continental margin be of the Atlantic typ that a model for connecting the continents be applicable and that LANDSAT data available, the visual interpretation of imagery and integration of tectonic and structural data could be pursued.

Preceding the actual research stage, the larger lineaments, principal structural tendencies and different geological sequences of the Brazilian North east were mapped. To support the visual interpretation, three geological profil were developed; the first,EW, from Natal to Currais Novos (Rio Grande do Norte) the second, NS, from Serra Talhada (Pernambuco) to Orós (Ceará) and, the third, from Orós to Cratus (Ceará), in a NW direction to Santa Quitéria (Ceará) in a N direction. The profiles permitted the lithological and structural characterization of the principal tectonic groups of the Brazilian Northeast.

The stage to follow would be the development of the same interpretative work for the African areas, the aim being to restructure the Gondwana segment, using, preferentially, the geometry of the structural map of the Brazilian-Afri counterparts.

The last stage would be an analysis of continental correlation. Several types of correlations to support the theory of continental drift could be teste based on LANDSAT mosaics, and reconstruction maps.

In summary, the various stages of the proposed methodology can be itemize as follows:

1 - selection of LANDSAT-MSS imagery, channels 5 and 7 at the 1:1,000,000 scale,
2 - collection of available regional geological papers and regional maps from both sides of the Atlantic,
3 - definition of a dependable model for recomposition of the continents,
4 - recognition of the types of adjacent continental margins,
5 - outline and elaboration of structural and tectonic frameworks of the correlation areas,
6 - juxtaposition of the areas following the reconstruction model and principal lineaments (pre-drift puzzle),
7 - juxtaposition of the LANDSAT mosaics, and,
8 - analysis of correlation.

3. STRUCTURAL FRAMEWORK OF THE BRAZILIAN NORTHEAST

Visual interpretation of MSS imagery has allowed the mapping of 6 major lineaments striking regionally for hundreds of kilometers (Figure 1). There are other fracture lines not so apparent as the Cabugi lineament and Santa Quitéria lineament. For each extensive lineament the regional tectonic behavior concerning the precambrian geological scheme and the physiography of the adjoining continenta margin will be described. These major lineaments are often strike-slip in nature but sometimes multiple slips are present (Mello et al., 1978).

Some lineaments are policyclic and therefore older than 1,800 m.y. as are th Pernambuco and Patos Lineaments. Cabuji Lineament otherwise seems to be younger, its vulcanism being 20-30 m.y. old,(Santos, 1968; Ponte and Asmus, 1978).

3.1 SOBRAL-PEDRO II LINEAMENT

This lineament extends northeastward over 300 kilometers from the Parnaíba Paleozoic Basin to the Barreirinha Cenozoic Basin close to the Atlantic margin. In the Parnaíba Basin, it appears as a normal faulting system following the Upper Valley of Pote River. Inside the precambrian area, there are post-tectonic granitoids (450 m.y.) intruded along the lineament strike and some alignments of grabens. The enclosed vulcanics of these grabens are 430 m.y. or cambro-ardonician age (Almeida et al., 1967).

At the immerged continental margin, this lineament bounds two different basin architectures. In the west, the basement is deep and dips landward. In the east, the basement is shallow and dips seaward (Ponte and Asmus, 1978). Thus, the lineament shows some reactivation in Upper Cretaceous. Upper Cretaceous marks the beginning of Wealdenian reactivation of Brazilian Platform (Almeida, 1969).

3.2 NOVA RUSSAS (TAUÁ) LINEAMENT

This lineament is a strike-slip fault extending over 300 kilometers, in a precambrian domain. The predominant trend is NNW with a final NE inflection following the trend of the Sobral-Pedro II Lineament (Figure 1). The south segment is aligned with the Senador Pompeu Lineament and controls the Coccoci Graben filled with clastics of Cambro-Ordonician age (Almeida et al., 1967). The Northern segment confines locally, the eastern border of Parnaíba Basin separating the Paleozoic basin from the granitic zone of Santa Quitéria (Santa Quitéria Median Massive). The structural trends of Curu-Independência Folded Belt (Brito Neves, 1975) are clearly aligned with the Nova Russas Lineament.

3.3 SENADOR POMPEU LINEAMENT

This Lineament comprises several dextral transcurrent faults trending NE along 300 kilometers, from Coccoci, at Parnaíba Basin border, to the Potiguar Cretaceous Basin in the coast. Several granitoids and metabasics are present along this fault system. Granitoids are elongated to the NE following the lineament trending. Almeida (1967) suggests that granitoids are post-tectonic according to the radiometric ages (430 m.y.), supposing otherwise an older age for the metabasic (diorite) bodies. The southwestern segment of the lineament controls the southern fault of the Coccoci Graben.

3.4 JAGUARIBE LINEAMENT

This structural feature extends over 400 kilometers from the Parnaíba Basin border to the Potiguar Basin on the coast line.

Three extensive faults conform to this lineament between Fronteiras (Piauí State) and Orós (Ceará State),(Figure 1). These faults trend ENE. From Orós to the coastline, the lineament is formed by two faults: one is the Orós fault that trends NS, the other is the Jaguaribe fault that trends NNE. These several faults show multiple slips: strike slipping and thrust slipping. The prominent deflection

of this lineament, which abruptly changes the trend from ENE to NNE, is followe by all structural alignments between Patos Lineament and Jaguaribe Lineament. This deflection can be seen in the elongated forms of the granitoid, in contor grabens, in the migmatite foliation and in the metasedimentary bending. The lin ment was reactivated in Upper Cretaceous although confined to the western bord of the Araripe Cretaceous Basin - a relevant feature related to the Northern Brazilian Continental Margin. Ponte and Asmus (1978) described some horizontal displacement in the block faulted system of the continental shelves caused by the reactivation of the Jaguaribe Lineament.

3.5 PATOS LINEAMENT AND PERNAMBUCO LINEAMENT

These lineaments are the most remarkable elements from the northeastern structural framework. They are confined to a wide zone of EW structural trendi known as the transversal belt of the Brazilian Platform. These broad lineament can be drawn out over much of 500 kilometers from the Parnaíba Basin to the con tinental border.

The Patos Lineament has a final deflection to NE while the Pernambuco Lineament follows a straight EW trend. Both lineaments bound relevant tectonic elements of the Brazilian Northeastern. The Patos Lineament limits the Rio Pira Median Massif (older than 1,800 m.y.) from the Pianco Alto Brígida folded belt (younger than 1,000 m.y.).

The Pernambuco Lineament bounds partially to the Pernambuco-Alagoas Media Massif from the adjoining Upper Proterozoic folded belt (Brito Neves, 1975).

Both lineaments were reactivated in the Early Cretaceous as can be drawn from the images. Patos Lineament confines the northern border of Araripe Basin while Pernambuco Lineament confines the northern border of Jatobá Basin.

Some offshore features are aligned with these lineaments. The Paraíba escarpments are aligned along the 6°40'S parallel, the same latitude as the Pato onshore lineament (Ponte and Asmus, 1978). No significant magnetic anomalies we drawn by Fainstein et al. (1975) offshore of Paraíba. The Pernambuco Seamounts and the Pernambuco Plateau are aligned with the Pernambuco Lineament. Fainstain et al. (1974) link significant magnetic anomalies with the Pernambuco Plateau. For a time, the alignment of these features were considered only coincidental b Ponte and Asmus (1978). The Cabo Magmatic Province (Cobra, 1967) is emplaced closely with the Pernambuco Lineament near Recife. Both basic vulcanics and alkaline granites are the predominant rocks. According to Vandoros (Almeida et al. 1967) age determinations of Cabo Granite reveal values of 90 m.y. for the event. This suggests that Cabo Granite may be the youngest of the Brazilian Platform. Gorini and Bryan (1975), among other authors, suggest a genetic relati ship between Cabo Province and Pernambuco Lineament.

4. FIRST CONCLUSIONS

Although the interpretation of LANDSAT images over Africa has not been developed, some preliminar conclusions can be made based on the reported result and available bibliography of Africa:

1 - The structural frameworks displayed by the Pan-African Cycle in Weste Africa (Torquato, 1976) and by the synchronous event of the Brazilian Cycle in northeastern Brazil, are the most secure parameters in the reconstruction of a paleo-continent, since they were not affected by younger orogenic cycles.

2 - Four extensive fault zones can be correlated according to the propose model. The Sobral-Pedro II Lineament can be correlated with the NS transcurrent faults that separate the metasediments of the West-Afric Craton (Almeida, 1966; Bertrand and Gaby, 1978). Both lineaments limi cratonic areas partially, conditions post-tectonic granites and asso- ciated Cambro-Ordovician grabens. The Pernambuco Lineament can be

correlated with the volcanic line of cameroon and the Ngaurandere Lineament. The Pernambuco Lineament has a transcurrent character and conditions Cretaceous grabens, recent volcanism and young granites (Cabo Granite). According to Almeida (1966), Gorine and Bryan (1975), the Ngaurandere Lineament is also transcurrent, has reactivated during the Cretaceous conditions grabens and is associated with young volcanis (Cameroon volcanism).

3 - The extensive oceanic transforming faults are not secure structural elements for correlations since their tectonic conditioning elements are different on both sides of the Atlantic. Ponte and Asmus (1978) point out that the Atlantic fractured zones are tangent to the Brazilia coast and do not affect significantly the physiographic character of th continental margin. In equatorial Africa, on the other hand, they condition the limits of several Cretaceous basins (Togo-Dahoney, Abidza and the Benne Trough) without affecting significantly the extensive African lineaments (Delteil et al., 1976; Gorini and Bryan, 1975).

4 - The structural directions of Seridó fold belt (NE) (Brito Neves,1975) and of Dahoney fold belt (NS) (Cahen, 1961) are compatible when the continents are fitted.

5 - Geochronological data compiled from bibliographical sources show correl tions that certify the continuity of the tectonic events between both continents. The Pan-African tectogenesis is correlatable with the Braziliano and the Eburnean tectogenesis with transamazonian (Cahen and Snelling, 1966; Clifford, 1970; Almeida et al. 1973). Two tectonic cycles affected the precambrian rocks between Recife and Fortaleza, likewise, two cycles affected the precambrian rocks between Cameroon and Ghana. The synchronism between events as well as the similarities between the structural tendencies when the pre-drift scheme is sketched indicate that the pre-drift hypothesis is a perfectly verifiable fact.

In that, continental drift is a verifiable fact, and the continental margin is of the Atlantic type, it appears to be feasible to develop studies of international geological correlations with LANDSAT images.

5. ONGOING RESEARCH

Ongoing research will complete the final stages proposed by the methodology They can be drawn as follows:

1 - To map the structural framework of Western African between Cameroon and Ghana using MSS imagery, channel 5 and 7, 1:1,000,000 scale.
2 - To fit the counterparts based on their structural framework and on Bullard's fitting model.
3 - To fit the LANDSAT mosaics from the continental counterparts.
4 - To analyze the correlation supported by tectonic and lithological data.

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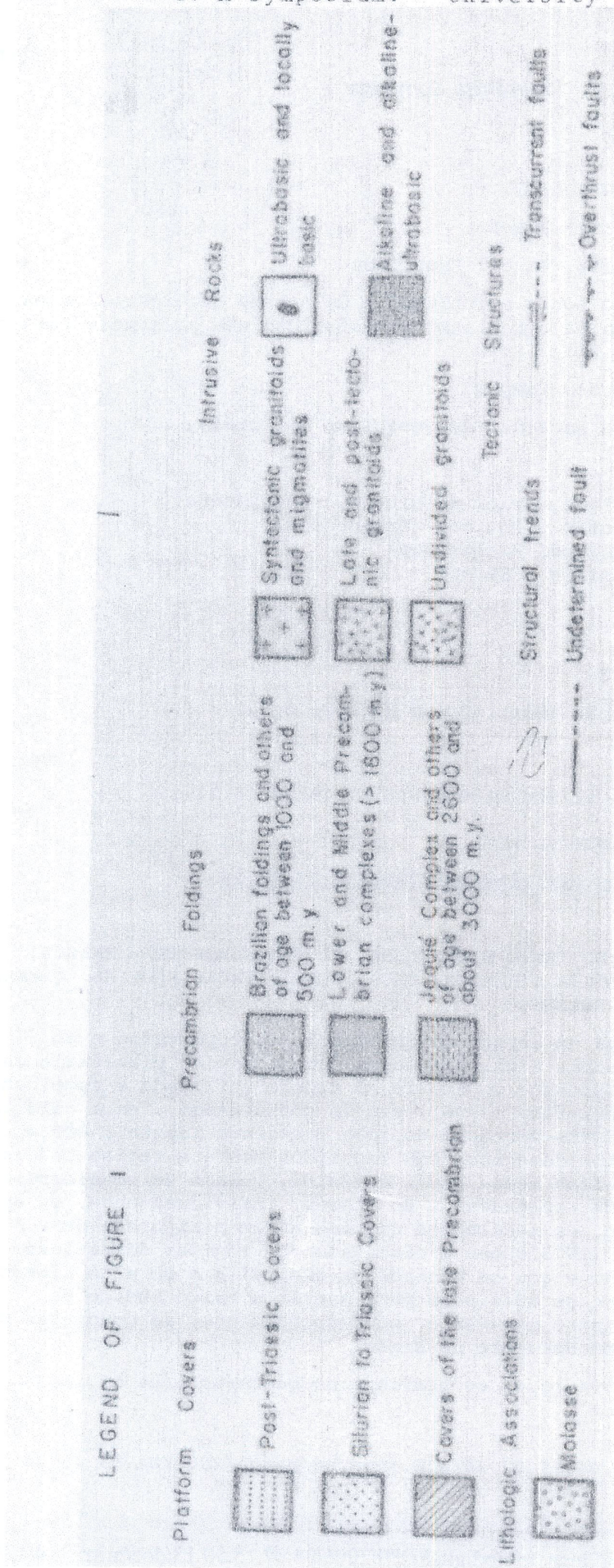

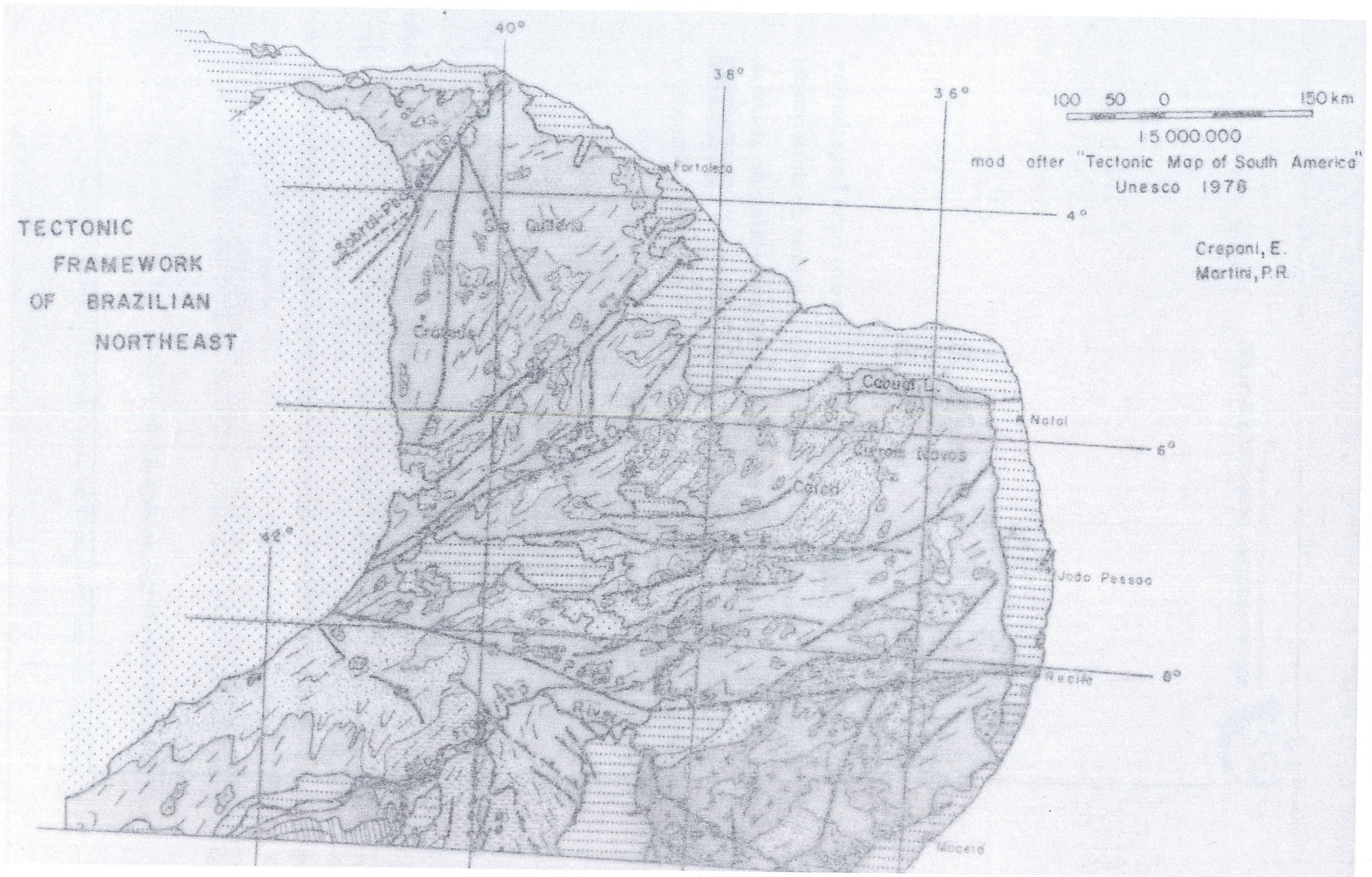
TECTONIC
FRAMEWORK
OF BRAZILIAN
NORTHEAST
40°
38°
36°
100 50 0 150 km
1:5.000.000
mod after "Tectonic Map of South America"
Unesco 1976
Crepani, E.
Martini, P.R.
Fortaleza
4°
Natal
6°
João Pessoa
8°
Recife
Maceió
42°