Pliocene-Quaternary fault control of sedimentation and coastal plain morphology in NE Brazil

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Abstract

Although the last major tectonic event in the Brazilian passive margin was the South America–Africa breakup during the Mesozoic, there is pervasive evidence in northeastern Brazil for pronounced faulting since the late Tertiary. The faulting was partitioned between strike-slip and normal-slip and it reactivated Precambrian shear zones as well as generating new structures. A 040°–060°-trending fault set and a 300°–320°-trending set have strongly influenced both the deposition of alluvial and aeolian sediments and coastal evolution. Vertical throws have attained 260 m since the Pliocene, and topographic breaks resulting from cumulative late Tertiary to Quaternary slip have attained 30–40 m. Fault control of sediment deposition and coastal morphology may have affected the entire South American passive margin. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

In eastern South America and West Africa the last major tectonic event took place during plate separation in the Mesozoic. Several studies (e.g. Popoff, 1988; Chang et al., 1992; Matos, 1992) have shown that the Gondwana breakup reworked continental shear zones under a transtensional regime, leading to the formation of passive margin basins in both Africa and South America. Since then, both continents have enjoyed relative tectonic quiescence. Nevertheless, recent studies in South America that have focused on fission track data (e.g. Harman et al., 1998), intraplate volcanism (e.g. Almeida et al., 1988), the uplift of coastal deposits (Martin et al., 1986; Bezerra et al., 1998), paleodrainage patterns (Potter, 1997), and the instrumental seismological record (Assumpção, 1992; Ferreira et al., 1998) have shown that Precambrian shear zones and major faults were reactivated and new faults generated long after the breakup. Even so, it is not clear whether northeastern Brazil (Fig. 1), the last part of the South American plate to be separated from the African plate (Françoilin and Szatmari, 1987; Szatmari et al., 1987), underwent a clearly defined, widespread tectonic event in the Cenozoic. The role of faults in the deposition of Cenozoic sedimentary units in the region and in shaping the low-elevation coastal plain is also unclear. We addressed the question by analyzing the littoral zone between Natal and João Pessoa (Fig. 1) in an attempt to trace fault evolution since the Pliocene in this part of the South American passive margin. The evidence comes from remote sensing, borehole logs, and field mapping of geological and geomorphological features.

2. Tectonic setting and lithostratigraphic units

The coastal plain is composed of Precambrian crystalline basement overlain by Cretaceous basins and a Cenozoic sedimentary cover (Fig. 1). The basement consists of Archean and Proterozoic fold belts composed mainly of volcanic-sedimentary terrains and granite plutons deformed by one or more orogenic cycles dating from 2.3–2.15 Ga, 1.90–1.95 Ga, and 650–550 Ma (Jardim-de-Sá, 1994). The basement orogenies indicate strain partitioning between domains of folding and strike-slip or oblique-slip mylonitic belts. The last of these cycles (Brasiliano/Panfrican orogeny) strongly deformed and overprinted older structures throughout the area (Jardim-de-Sá, 1994; Amaro, 1998). The shear zones are generally marked by strong, pervasive foliation; present sigmoidal shapes (Fig. 1), and their deep roots are indicated by strong gravity anomalies (Jardim-de-Sá, 1994; Amaro, 1998).

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The historical and instrumental seismic record indicates an important level of seismicity in the region when compared with other areas in Brazil (Fig. 2). It occurs within the first 1–12 km of the upper crust (Ferreira et al., 1998) and has been known since 1808, when an earthquake of estimated magnitude $m_b = 4.0$ and intensity MM > VI occurred near Açu (Ferreira and Assumpção, 1983). Many earthquake swarms, lasting for at least six months, have been described (e.g. Ferreira et al., 1998). The most important of them was the João Câmara earthquake swarm from 1986 to 1989, when nearly 4,000 building were damaged and more than 40,000 events were recorded. Two main events of 5.0 $m_b$ and 5.1 $m_b$ and their aftershocks were concentrated along the 30 km long, 040°-trending Samambaia fault (Takeya et al., 1989), but no surface offset has been detected so far.

Several basins that formed during the South Atlantic opening overlie the Precambrian basement. To the north of the study area, the Potiguar basin, whose age ranges from Early to Late Cretaceous, lies along the east-trending coast. Its structural framework comprises half-grabens separated by intrabasinal highs related to the Early Cretaceous riftting episode of the Brazilian marginal basins (Araripe and Feijó, 1994) (Fig. 1). The stratigraphic column of the Potiguar basin consists of continental rift sediments and marine post-rift sediments. Deposition was controlled by NE-trending structures during the rift phase in the mid-and Late Cretaceous (Matos, 1992). To the south of the study area, the Pernambuco-Paraiba basin is divided into several faulted blocks (Rand and Manso, 1990). It occupies a narrow zone along the coastal plain, which crops out to the south of João Pessoa and near Recife (Fig. 1); it also occurs offshore (Fig. 1).
Fig. 2. Historic and instrumental seismicity and secondary ground failure (liquefaction and landslide) in northeastern Brazil (modified from Ferreira, 1983; Ferreira et al., 1998; Bezerra, 1998).

Stratigraphic studies based mainly on outcrop data indicate that it includes a rift clastic sequence capped by marine post-rift sediments (Feijó, 1994).

Eocene–Oligocene magmatic activity is represented by the Macau volcanism (Fig. 1) of 44.6 ± 6.6–29.0 ± 0.9 Ma (Mizusaki, 1989) and consists of mafic volcanic rocks such as basalt, basanite, and ankararite that occur as plugs, dikes and necks (Sial, 1976; Almeida et al., 1988). The Macau Formation is also encountered in boreholes and is indicated by geophysical studies (e.g. Salim et al., 1975).

The late Tertiary sedimentary rocks of northeastern Brazil formed late in the history of Atlantic opening and are represented mostly by a sedimentary sequence called the Barreiras Formation, which crops out along more than 4,000 km of the Brazilian littoral zone from the Amazon delta to the Rio de Janeiro coast (Mabesoone et al., 1972).

The age of the Barreiras Formation has long been a source of debate. Relative dating by palaeomagnetism and micro-pollen indicates that it dates from Miocene to Pliocene times. A peat layer found in the Barreiras Formation at Natal, described by Salim et al. (1975), yielded angiosperm pollen of Zonocostites ramonae. Although this species ranges from the Eocene to the Holocene, it is abundant in late Miocene sedimentary rocks. More recently, a palynological study of the upper Barreiras Formation in the Potiguar basin yielded Retisteplanocolpites gracilis, indicative of a Pliocene age (Lima et al., 1990). In Bahia state, 1000 km to the south of the study area, a Pliocene age was proposed for the base of the Barreiras Formation by Suguio et al. (1986) on the basis of palaeomagnetic dating. The dates they obtained range from 4.5 to 5.0 Ma (early to middle Pliocene) near the base of the deposit to 3.0–3.4 Ma (late Pliocene) near the top. For the purpose of the present study, the age of the top of the local Barreiras Formation is therefore taken to be Pliocene.
Quaternary sedimentary rocks overlie the Barreiras Formation and are composed of alluvial and aeolian sediments and beachrock. The deposits range in age from Pleistocene to Holocene (e.g., Mabesoone and Campos-e-Silva, 1972). Silva (1991) obtained an age of 30,190 ± 370 yr for post-Barreiras Formation deposits ~200 km northwest of the study area, but this must be considered a minimum value. The alluvial deposits include sediments deposited in fluvial channels, deltas, and estuaries (Fig. 3). They are usually oxidized owing to dry conditions during deposition, and therefore contain little or no organic matter outside the deltas and estuaries.

3. Materials and methods

The images used in the current study were X-band airborne SAR and digital SPOT images (path/row 731–362 of 06 August 1994) which were normalized for haze removal according to the method of Chavez (1988). The digital images were processed on ER-Mapper 5.5 run on a UNIX workstation. Digital manipulation included principal component 1 (PCI), using a high-pass filter for edge enhancement after Schowengerdt (1983). Equalizing transforms were also applied to the above image in order to increase contrast between stratigraphic units. Further information was extracted from the topographic maps of SUDENE (scale 1:100,000) and aerial photos (1979, scale 1:70,000).

Borehole logs were supplied by the Water Resources Department of the State of Rio Grande do Norte and the state Water and Sewage Company (CAERN); reinterpreted geoelectric soundings were derived from Queiroz et al. (1985) and the Instituto de Pesquisas Tecnológicas of State of São Paulo (IPT, 1982). The available boreholes and geoelectric soundings refer mainly to the area from Natal to Canguaretama (Fig. 3) and were
used to map subsurface faults. Most of the data are concentrated in the Cenozoic units and the top of the Cretaceous stratigraphic units, but a few bear on the crystalline basement.

4. General features of the Cenozoic faults

Two sets of shear zones occur in the area. The NE-trending set and the NW-trending set display right-lateral and
left-lateral slip (Fig. 3) related to tectonic extensional and transtensional deformation, respectively (Amaro, 1998). Mylonitic foliation dips are mainly subvertical and mylonitic zones display evidence of brittle reactivation provided by fault breccia, cataclasite, and pseudotachylite veins, and they form the basement framework where Cenozoic reactivation has taken place.

In the interior of the continent, part of this brittle reactivation may predate the Cenozoic sedimentary cover, as this is confined to patches bounded by remobilized shear zones. Along the coastal plain, however, pronounced faulting post-dates or is coeval with Cenozoic deposition. Three main fault sets can be recognized: a 040–060° (NE) trending set; a 300–320° (NW) trending set; and a 350–010° (N)
trending set (Figs. 3 and 4). The NE- and the NW-trending faults are dominant. The amount of strike-slip offset was difficult to assess owing to the lack of markers and the flat-lying nature of the sedimentary layers. Vertical offsets were easy to estimate in cross sections. NE- and NW-trending faults display systematic cross-cutting relationships, suggesting they are contemporaneous and have acted as conjugate faults. Fault planes are relatively smooth polished surfaces but sometimes also irregular or listric. They often display dips of more than 80°. The faults provide the main boundary between the Pliocene Barreiras Formation and Quaternary alluvial sediments and are buried in places by Quaternary aeolian sediments (Figs. 3–5).

The faulting processes that have affected Cenozoic stratigraphic units occurred at very shallow depths, as indicated by fault zones marked by non-cohesive fault breccia and clay gouge as well as clear evidence of surface rupture, probably coseismic, such as soil disruption. Most of the mesoscopic faults in outcrops of the Barreiras Formation cut across layers previously affected by the products of weathering that took place mainly during the Pliocene and again in the Pleistocene–Holocene (Mabesoone and Lobo, 1980).

Syndepositional faulting is indicated in Barreiras cliffs near Baía Formosa, where layers of faulted sandstone and conglomerate underlie and overlie undeformed layers. Liquefaction features such as sand dikes and pillar structures, which point to coseismic faulting, are also associated with the faults in places (Figs. 6 and 15). In addition, repeated changes in sediment package thickness across fault zones suggest synsedimentary faulting (see Fig. 5).

5. The Graben-Horst structure of the coastal plain

Along the coastal plain, several faults form the boundary between the graben and horst that are responsible for the coastal structural framework. The Canguaretama graben is bounded by two 060°-trending faults which display strike-slip and normal movement. Strike-slip movement is suggested by the linear geometry of faults, and normal movement is indicated by the high concentration of striae at a high pitch to the fault plane (Fig. 4, stereonets f, k, l, m, n, and o) and by cross-section A–A’ (Fig. 5) (see also Bezerra and Vita-Finzi, 2000). Translational structures related to the normal and strike-slip component of movement are common (Figs. 6–8). The vertical offsets of the two faults that bound the Canguaretama valley range from ~60 m in the southern part of the valley to ~15 m in the northern part (Fig. 5).

The Jacuí river and Guarára lagoon form the Guarára valley, which is bounded by two 050°-trending faults (Figs. 3 and 4). These faults show a vertical offset of more than 40 m in the Barreiras Formation (cross section B–B’ in Fig. 5). There is a scattered pattern of mesoscopic faults owing to the occurrence of NE-, NW-, and N-trending faults, but there is a clear dominance of the normal component in all three sets (Fig. 4, stereonets i and h; see also Fig. 5). As in the Canguaretama graben, faults in the Guarára graben are the result of right-lateral and normal late Tertiary to Quaternary reactivation of NE-trending Precambrian shear zones which occur underneath these valleys and crop out to the west in the crystalline basement (Fig. 3).

The Trairi valley occupies a NW-trending fault-bounden graben limited by two 345°-striking normal faults. The faults are parallel to NW-trending Precambrian shear zones to the west (Fig. 3). The Barreiras Formation has a thickness of up to 80 m in the downfaulted block and 20–30 m in the uplifted blocks, probably owing to synsedimentary faulting and erosion; its base is offset by up to 40 m in one of the faults (cross section C–C’ in Fig. 5). In the Bonfim lake area, both NE- and NW-trending sets of faults with a normal component were mapped. The latter set is more pervasive (Fig. 4, stereonets e and f). A similar pattern occurs around Nísia Floresta lake, where there is a relatively high concentration of NW-trending faults mainly with 320° strike (Fig. 4, stereonet g).
A NW-trending graben is found to the north of Trairí. It is bounded by two 320°-striking faults truncated, in places, by NE-trending faults. The 320°-striking faults display vertical offsets that range from 30 m (cross section D–D', Figs. 3 and 5) to 35 m (cross section F–F' in Fig. 5). Quaternary to Holocene aeolian sediments cap part of the downfaulted and uplifted blocks, including fault scarps (Figs. 3 and 5). Another small downfaulted block, where the base of the Barreiras Formation is offset by 20 m, also occurs to the northeast of Parnamirim (Fig. 3, and cross sections E–E' and F–F' in Fig. 5).

The Jundiaí half-graben extends for at least 20 km from the shoreline to Macaíba and is bounded by the 060°-trending Jundiaí fault located on the right margin of the Jundiaí river (Fig. 3). This fault, which is truncated in places by N-trending faults, cuts across the Barreiras Formation, a limestone and a lower sandstone of Cretaceous age, and the crystalline basement. The main topographic expression of the Jundiaí fault is a topographic break about 40–60 m high, which is frequently covered by Quaternary alluvial sediments.

As can be seen from cross sections G–G' and H–H' (Fig. 5), up to 350 m of sedimentary rocks cap the crystalline basement and fill the Jundiaí half-graben, showing sharp changes across the Jundiaí fault. The thickness of the Barreiras Formation changes from an average of 100 m in the uplifted block to more than 250 m in the downfaulted block (cross-section H–H'), and its base displays a vertical offset of about 250 m. A less abrupt change in thickness is seen upstream, where the Barreiras formation is 75 m thick in the uplifted block and 80–85 m in

Fig. 7. Negative flower structure indicating transtensional slip affecting the Barreiras Formation. Sea cliff 1 km north of Baía Formosa.

Fig. 8. Pervasive conjugate joint system related to transtensional structures. Sea cliff 1 km north of Baía Formosa.
brecciation of sediment and soil from an early phase of filling. Normal reactivation is also indicated by R and T (tension) fractures affecting the sediment-filled faults themselves, the granite, and its weathered layers. On the other hand, the N-trending faults moved as right-lateral strike-slip structures only, as revealed by R fractures on fault zones, although a pull-apart effect allowed sediment and soil filling here, too. Away from the Jundiaí master fault, this pattern of dominant NE-trending faults changes completely in the Jundiaí half-graben footwall, as indicated by a dominant normal N-trending set which shapes the present shoreline and affects the Barreiras Formation (Fig. 4, stereonet d).

6. Fault control of alluvial and coastal morphology

The widespread faulting events that have taken place in the region since the Pliocene are responsible for the current configuration of the coastal plain. The alternation of graben and horst produces plateaus as high as 200 m composed of Barreiras material. The Barreiras Formation has been dissected in the uplifted blocks and capped by alluvial terraces, sand dunes, or both along the downfaulted blocks, as already indicated by Lima et al. (1990). The Barreiras Formation forms cliffs up to 15 m high which rise abruptly from the foreshore zone where the horst meets the ocean (Fig. 9). One of the best examples of these plateaux is depicted in cross sections A–A’', B–B’ (Fig. 5) and in 3D view (Fig. 10), where the central blocks, which range in altitude between 2 m and 30 m asl, were downfaulted along NE-striking faults, whereas the upper blocks (footwall) have altitudes of up to 70 m asl. Furthermore, another visible effect of the graben-horst structure is the retreat of shoreline along downfaulted blocks (Bezerra et al., 1999) (Fig. 5).

Scars are also associated with the uplifted and downfaulted blocks. Several of the faults display evidence of surface rupture such as normal fault scars marked by steep slopes and abrupt topographic breaks and, in places, by triangular facets. Most of them are degraded and capped by debris slopes, vegetation, and soil, indicating that they have not been active recently despite their late Tertiary to Quaternary age. Free faces are relatively uncommon, and the shape of fault scarp as well as fault plane dips depicted in cross section give a rough representation of the general topography. The best examples of such topographic breaks are seen in the Canguaretama and Guaraira valleys, where faults cut across the flat-lying beds of the Barreiras formation plateau (Fig. 10).

The drainage pattern and alluvial morphology are also strongly controlled by faults. The relatively dissected and rough surface of the crystalline basement displays a high-density, dendritic stream pattern, which in places is deflected along Precambrian shear zones. On the sedimentary terrain, which is characterized by a smooth
Fig. 10. Block diagram showing the topography of the Guaraíra and Canguaretama graben, including plateaux (horsts) and faulted-controlled valleys (graben). The area displayed is 30 km wide.

Fig. 11. Block diagram showing the topography of the Bomfim lake area. Arrows indicate main faulting directions. The area displayed is 24 km wide.
surface, NE- and NW-trending faults form a rectangular drainage pattern associated with right-angle shaped lagoons and lakes. The margins of the Nisia Floresta lake, for example, the northern part of the Guaraíra lagoon, as well as the river channels in the downfaulted block of several grabens, are oriented parallel to the faults and suggest active tectonic control (Figs. 11 and 12). A further cluster of lakes in the northern uplifted block display 060°- and 320°-oriented margins, especially Bonfim lake (Figs. 3, 11 and 12), also indicative of tectonic control of the morphology. In addition, the cross-sectional geometry and surface characteristics of alluvial sediments to some extent indicate that sedimentation in the Jundiaí half-graben is controlled by a master fault (Fig. 13): while they occupy a zone less than
1 km wide on the right margin of the Jundiaí river, they are at least 5 km wide on the left margin where the presence of palaeomeander loops (Fig. 14) may reflect tilting and lateral migration of the river channels towards the Jundiaí fault.

7. Secondary ground failure

There is evidence for secondary ground failure from both the historical and the geological record of northeastern Brazil. A few valuable reports of earthquake-induced liquefaction and landslides have been recognized in the catalogue of historical seismicity by Ferreira (1983). Liquefaction occurred during the Araticum earthquake swarm in March and April 1969, which caused soil collapse and disrupted soil that silted up minor streams (Ferreira, 1983). Landslides were observed during at least three events: (a) the Araticum earthquake; (b) the Pereiro earthquake of 2 January 1968, after which boulder falls were reported in local and national newspapers; and (c) the Senador Pompeu earthquake of 23 February 1968 (MMI VII and $m_b = 4.6$), during which blocks of crystalline rocks were dislodged from steep slopes in the epicentral area (Ferreira, 1983) (Fig. 2).

Although no landslides have been identified in the local geological record so far, there is widespread evidence for earthquake-induced liquefaction both in the Barreiras Formation and in Quaternary alluvial deposits. The earthquake-induced features include water-escape structures such as pillars, dikes, and pockets. Liquefaction pillars (Lowe and LoPiccolo, 1974) are the most common type. They are generally marked by elongated vertical columns of pebbles which die out upwards or are slightly inclined towards the horizontal near the top. One example occurs at the contact between the Barreiras Formation and overlying alluvial terraces and resulted from liquefaction of both units (Fig. 15). Similar structures were described by Fonseca (1996) about 200 km to the west of the study area but in the same stratigraphic and tectonic setting.

Some of these features, such as flame structures, load casts associated with passively deformed beds, and gravity sliding, may be interpreted as sedimentary features in the area; however, coseismic surface faulting is the most probable cause for water-escape features. The vast majority of cases occur in gravelly sediments underlain and overlain by undeformed beds. The collective occurrence of liquefaction structures in a variety of lithological, sedimentological, and topographic conditions strongly suggests a paleoseismic origin. In addition, structures such as sand dikes have been interpreted elsewhere as unequivocal proof of seismically induced features (Obermeier 1996), and their spatial and stratigraphic
association with other soft-sediment structures indicates that they were generated by earthquakes.

8. Discussion

Several studies have already revealed Late Cretaceous to early Tertiary tectonism in the area associated with some kind of tectonic uplift and faulting. Cremonini (1995), for example, described two major tectonic events that affected the Potiguar basin and were caused by heat from the oceanic plate during the Late Cretaceous (Mesocanopian) after the formation of the Potiguar rift. The first and stronger event was responsible for regional erosion during the Mesocanopian as well as extensive uplift and reverse faulting. The second event, during the Tertiary, resulted in E–W folding.

In the Potiguar basin, Oliveira et al. (1993) described the NW-trending Afonso Bezerra fault, which affected the Cretaceous Jandaíra Formation, and they concluded that early Tertiary movement occurred along the fault because of N–S subhorizontal compression. They suggested that the tectonism was related either to Campanian erosion or to the magmatism that generated the Macau Formation during the Eocene–Oligocene. Oliveira et al. (1996) have since described two tectonic events that affected the Jandaíra Formation immediately northwest of the study area, the first one of ESE–WNW extension and the second a phase of NNW–SSE compression.

Evidence of late to post-Cretaceous deformation leading to uplift and reverse faulting has also been observed offshore. Gomes (1997) found evidence in seismic surveys for inversion tectonics on the east coast of Brazil which affected the oceanic crust and overlying Cretaceous to post-Cretaceous sediments but not pre-Miocene age volcanic rocks (12.3 my) in oceanic islands at low latitudes.

Despite all this evidence of Late Cretaceous to early-middle Tertiary deformation, there is no consensus on how many tectonic events took place and what caused them. But it was only after the Pliocene that widespread faulting showed association with sediment deposition and coastal plain morphology and can thus be traced more easily. Several tectonic pulses favored the development of strike-slip and normal faulting, but no subsequent great kinematic or geometric change in the fault pattern has been observed. The continuity is consistent with the E–W-oriented maximum compression and N–S-oriented extension (Assumpção, 1992; Lima et al., 1997; Ferreira et al., 1998) that are implicit in the shape and direction of movement of the South American plate since the Pliocene.

The difference in altitude between the base of the Barreiras Formation in several plateaux inland (up to 650 m) and in the study area (from 50 m asl to ~250 m bsl) may also indicate further faulting in the crystalline basement and thus displacement of crustal blocks.

The tectonic evolution of the area since the Holocene can now be described with more precision, thanks to the radiocarbon ages obtained by Bezerra (1998), and Bezerra et al. (1998). Although there is clear continuity with earlier events, the record is detailed enough to reveal the interplay between sea-level change, coastal sedimentation, and faulting. The influence of sea-level changes, as we have seen, can be divided into two major phases.

From 10,000 yr BP sea-level rose, passed its current position about 7,000 yr BP, and reached a 2 m highstand at 5,000–5,500 yr BP. The second phase is characterized by a steady fall (Bezerra et al., 1998). During the regressive phase, significant coastal sedimentation and faulting took place. Strong winds removed sediments from the exposed shelf, redepositing a large quantity of sand onshore; Holocene surface fault reactivation of several NE- and NW-trending faults, some of them probably associated with liquefaction features, trapped aeolian sediments in downfaulted blocks.

The pervasive faulting has controlled sedimentation and geomorphological features across the region. The Barreiras Formation usually occurs in troughs controlled by NE- and NW-trending faults. This pattern has been already observed in the Cenozoic record of southeastern Brazil, where sediments occur usually in small graben (e.g. Riccomini et al., 1989; Saadi, 1990,1993; Saadi and Pedrosa-Soares, 1990). Sediment deposition in fault-controlled troughs in northeastern Brazil is also consistent with post-breakup denudation rates for the Brazilian passive margin in the São Francisco Craton (~1,000 km south of the study area), which amounted to between 2 and 7 km of denudation (Harman et al., 1998).

Both the NE- and the NW-trending faults are compatible with ongoing E–W compression (Assumpção, 1992; Lima et al., 1997; Ferreira et al., 1998). But as some NW-trending faults depart by more than 45° from the optimum direction of fault reactivation (Bezerra, 1998), their reactivation may have been favored by high-fluid pressure and weak fault material (Bezerra and Vita-Finzi, 2000).

9. Conclusions

The background to Pliocene-Quaternary faulting in northeastern Brazil can be summed up as follows. Northeastern Brazil is located on the Brazilian passive margin within the intraplate part of South America. The region displays a Precambrian crystalline basement deformed mainly by shear zones, overlain by Cretaceous sedimentary basins which formed during the South America-Africa breakup and by Cenozoic stratigraphic units. Faulting started in the Pliocene, when, to judge from the geometry and orientation of the South American plate, the current stress field was established. Since then, the region has been under E–W-oriented compression and N–S-oriented extension.

There are three main sets of faults in the region, trending NE, NW, and N. The maximum horizontal compression
deduced from focal mechanisms is oblique to the NE- and the NW-trending faults in a compressive direction, which favors right-lateral and left-lateral strike-slip, respectively. This obliquity in most cases is about 30° for the majority of the fault planes.

Although strike-slip offsets could not be quantified, vertical offsets indicate significant movement along major faults since the Pliocene. The base of the Barreiras Formation was displaced by as much as 260 m in the Jundiaí half-graben since the Pliocene.

The geological record of northeastern Brazil is characterized by successive phases of fault reactivation. The vast majority of late Tertiary to Quaternary faults represents reactivation of preexisting zones of weakness in basement-controlled structures, which are in the range of optimum orientation for reactivation, suggesting this should be an important condition for deformation of previous structures in the region. But important exceptions have been found that cut across existing structures, notably the Jundial fault.

Geomorphological features of tectonic origin may be seen along the coastal plain. Valleys filled by alluvial and aeolian sediments overlie the Barreiras Formation, and dissection of the Barreiras plateaux has given rise to horsts. Extensive bodies of aeolian sediment that penetrate as far as 15 km inland are the combined product of downfaulting, sea-level fall, and wind directions favorable to deposition along the graben.

The methods used during this study, including remote sensing, borehole logging, and geophysical investigation, were useful for locating and determining the geometry of late Tertiary to Quaternary faults. Although some seismological studies indicate that the E–W coast in northeastern Brazil is more seismic than other coastal areas along the Brazilian passive margin (Assumpção, 1992; Ferreira et al., 1998), there is no reason to believe that the late Tertiary to Quaternary evolution and pervasive faulting observed here is not repeated in other coastal areas on the eastern part of the South American plate. But new paleoseismological analyses are required to address this point.

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