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# Release fault: A variety of cross fault in linked extensional fault systems, in the Sergipe–Alagoas Basin, NE Brazil

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**Abstract**—Two types of cross faults are herein recognized: transfer faults and the newly termed release faults. Transfer faults form where cross faults connect distinct normal faults and horizontal displacements predominate over vertical ones. In contrast, release faults form where cross faults associated with individual normal faults die out within the hangingwall before connecting to other normal faults, and have predominantly vertical displacements. Release faults are geometrically required to accommodate variable displacements along the strike of a normal fault. Thus, they form to release the bending stresses in the hangingwall, and do not cut normal fault planes nor detachment surfaces at depth. Release faults have maximum throws adjacent to normal faults, and may be nearly perpendicular or obliquely oriented to the strike of the latter. Such geometry appears not to depend upon pre-existing weaknesses, but such variable orientation to normal faults is an inherent property of release faults. Release faults commonly appear as simple normal faults in seismic sections, without implying extension along the strike of rift and basins. Three-dimensional strain deformation occurs in the hangingwall only between the terminations of an individual normal fault, but regionally, release faulting is associated with plane strain deformation in linked extensional fault systems.

## INTRODUCTION

The purpose of this paper is to describe the geometric characteristics of the principal types of cross faults that may occur in linked extensional fault systems, and, by doing so, illustrate and clarify the current problem with the terminology of cross faults. There are important implications for the evolution of extensional fault systems as well as for hydrocarbon exploration associated with linked fault systems.

Cross faults, dominantly perpendicular but also highly oblique, have been widely quoted and invoked in recent extensional tectonics literature (transfer fault, Gibbs 1984; transverse fault, Letouzey 1986, Colletta *et al.* 1988; cross fault, Morley *et al.* 1990). The current interest stems largely from the genetic role they play in the architecture of rifts and extensional basins (e.g. Harding & Lowell 1979, Bally 1981, Gibbs 1983, 1984, 1987, 1990, Letouzey 1986, Rosendahl *et al.* 1986, Etheridge *et al.* 1987, 1988, McClay & Ellis 1987, Colletta *et al.* 1988, Milani & Davison 1988, Morley *et al.* 1990). Others have emphasized that cross faults are scarce or absent in some extensional settings (Rosendahl *et al.* 1986, Scott & Rosendahl 1989, Morley *et al.* 1990), but those authors do not consider that cross fault inferences are necessarily incorrect. Rather, they lack definitive documentation (Morley *et al.* 1990) or they probably relate to the ways in which we derive rift morphology from the various modes of linking of half-graben (Rosendahl *et al.* 1986). Gibbs (1990) suggests that there are two end-members for extensional fault systems, those which are dominated by fault systems linked to cross faults named transfer faults (Gibbs 1984) and those where displacement is transferred by other compatible deformation mechanisms between the terminations of major faults, resulting in accommodation zones (Rosendahl *et al.* 1986, Scott & Rosendahl 1989) or transfer zones (Morley *et al.* 1990). Gibbs (1990) also suggests that both end-members could coexist in a balanced map or section.

In this paper, a third origin is proposed for cross faults, that is, a type of cross fault described and named release faults ('falhas de alívio' in Destro *et al.* 1990, Destro & Masiero 1992, 1993). The interpretation of release faults is based mainly on field data, and supported by about 7500 km of a 1980/90's vintage seismic data of the Sergipe–Alagoas Basin. A release fault forms as a result of varying throws along the strike of a listric normal fault (Fig. 1). As a result of differential vertical displacements, the hangingwall bends, and as the normal faults terminate laterally, some kind of cross faults and/or fractures are geometrically necessary to accommodate the increase of length along strike in the hangingwall. The release fault forms to accomplish this increase, since faulting is the most active deformation mechanism in the brittle upper crust (Kuznir & Park 1987, Morley *et al.* 1990), although ductile deformation may also occur (Larsen 1988).

Release faults do not connect distinct normal faults but die out within an individual hangingwall (Fig. 1). Although release faults form to accommodate differential vertical descending movements of the hangingwall, they do not cut the normal fault planes nor detachment surfaces at depth (Fig. 1). Generally release faults do not reveal strike-slip movements in seismic sections and in structural contour maps (e.g. flower structures, en échelon folds and Riedel-type geometries).

It is important for paleogeographic and paleotectonic

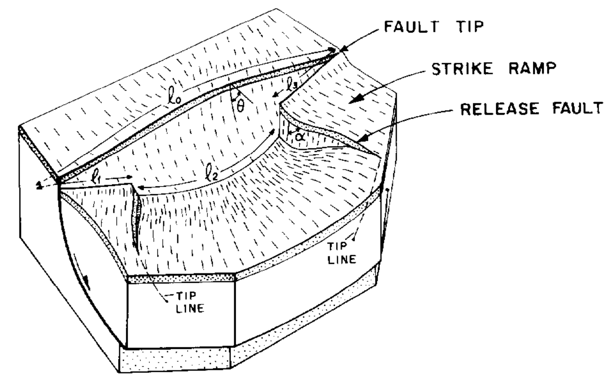


Fig. 1. Block diagram showing the displacements variation along the strike of a normal fault. The release faults form in order to conserve the relation $l_0 = l_1 + l_2 + l_3$. The pitch of slickenside lineations (angle $\alpha$) along the release fault is in the same range as the dip (angle $\theta$) of the normal fault.

evaluations to distinguish release faults from transfer faults. Both may be important in hydrocarbon exploration, as they exert strong control over the sediment input within the basins and may be responsible for the formation of structural and stratigraphic traps.

## GEOMETRY AND KINEMATICS OF RELEASE FAULTS

The geometric and kinematic properties of release faults were based on the analysis of an exposed release fault which occurs in the Sergipe–Alagoas Basin (Fig. 2). The fault is shown in the geologic map of the Malhada dos Bois area (locality 1 in Fig. 3) and Fig. 4(b). It is formed to accomplish the increase in length of the hangingwall along the strike of the Fazenda Pedra da Onça Fault (Fig. 3). The varying displacement along this fault is apparent in the occurrence of older lithologies near its extremities and younger carbonates of the Morro do Chaves Member at its center (Fig. 3), corresponding to a doubly plunging syncline. The concavity of the bedding traces towards the Fazenda Pedra da Onça Fault is also a result of the variation in the throw along that fault. The release fault shown in locality 1 (Fig. 3) is slightly oblique rather than perpendicular to the strike of the Fazenda Pedra da Onça Fault, and such orientation will be discussed later. In the same locality, the attitudes show that the strike of the release fault is almost perpendicular to the strike of the bedding (Figs. 3 and 5b).

In the northwest–southeast extensional regime of the Malhada dos Bois area (Destro *et al.* 1990), the pitches of the slickenside lineations on the normal fault planes are high (greater than 80°) (Figs. 3, 4a and 5a). Smaller pitches are found in the release faults (locality 1 in Figs. 3 and 5), indicating oblique displacement along them (Fig. 4b). The dips of the normal faults are in the same range as the pitch across the release faults (Fig. 5), suggesting that the motion along the release faults is guided by the dip of the normal faults. Thus, it is not necessary to invoke strike-slip faulting and horizontal compressive stress to explain the small pitches of slickenside lineations on the release fault planes. One outcome of the complexity of the kinematic interactions between nor-

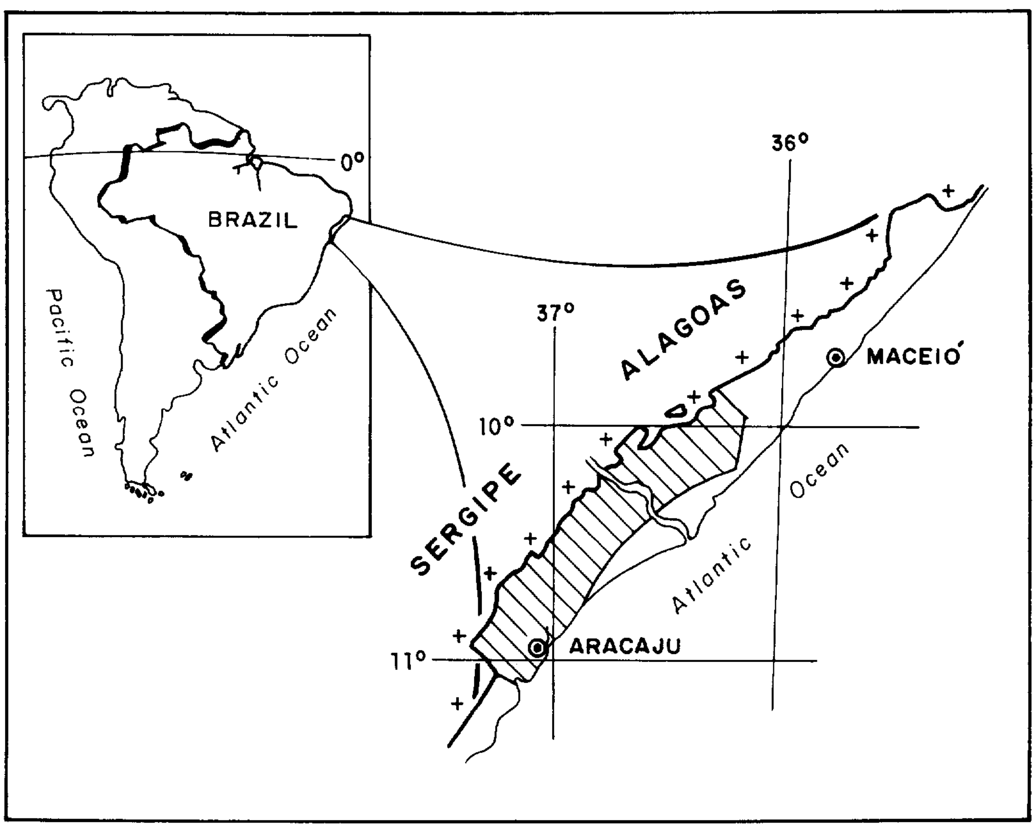


Fig. 2. Location map of the Sergipe–Alagoas Basin and the study area (shaded).

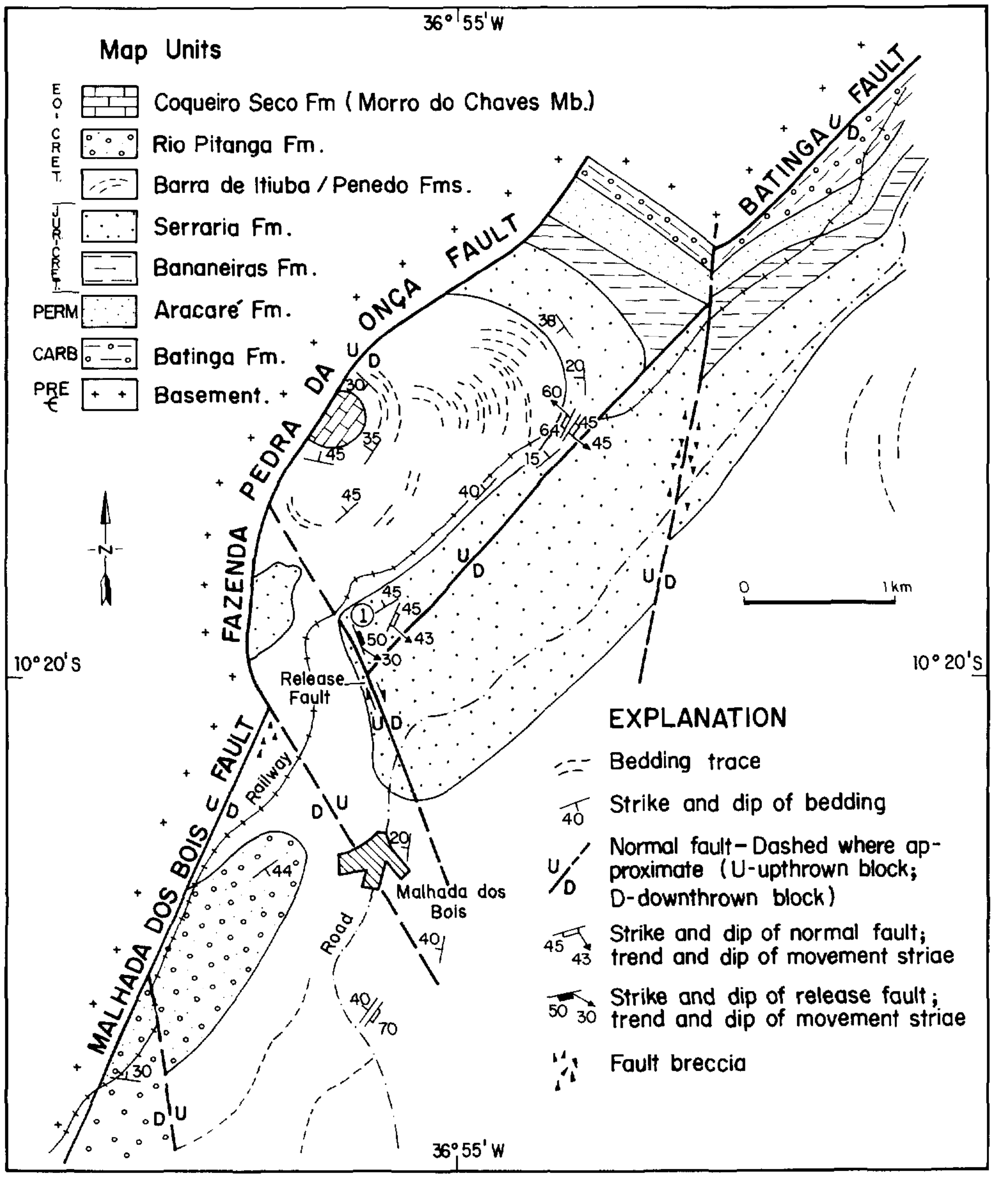


Fig. 3. Geologic map of the Malhada dos Bois area (modified from Perrela *et al.* 1963) (see Fig. 8 for location). The bedding traces are concave toward the Fazenda Pedra da Onça Fault, reflecting the variation in its throw. The release fault shown tends to be perpendicular to the bedding and not to the strike of the major normal faults.

mal faults and release faults is that subhorizontal slickenside lineations may be occasionally found on both normal and release faults.

The most common positions of release faults with respect to the strike of normal faults are shown in Fig. 6. Release faults may form over strike ramps (Figs. 6a & b), or at normal fault terminations (Fig. 6c). Morley *et al.* (1990) consider strike ramps as situated between two overlapping synthetic faults. Similarly, Larsen (1988) describes relay ramps as situated between the tip lines of two offset faults. In this paper, strike ramps are also considered to occur associated with an individual normal fault (Figs. 1, 6 and 7), thus independent of the interaction between two normal faults. In the case where release faults form over the strike ramps (Figs. 6a & b) both dextral and sinistral senses of apparent horizontal displacement are expected along the strike of normal faults. If only one release fault forms, one sense of movement will predominate (Fig. 6a). If two release faults form, both dextral and sinistral senses of displacement may be important (Fig. 6b). In this case, there is a line of neutral strike-slip movement due to the opposite senses of displacements along the normal faults. When release faults are positioned at the terminations of normal faults (Fig. 6c), there is only one sense of displacement.

The hangingwall bends as a result of the varying throws along the strike of the normal faults. Bending is greater above the strike ramps (see curvature of contour lines in Figs. 6 and 7). This explains why the release faults are more common over strike ramps. Thus, the position of the release fault shown in Fig. 6(c) may be due to pre-existing weak zones, and another example is given later. Field evidence, as in the Malhada dos Bois

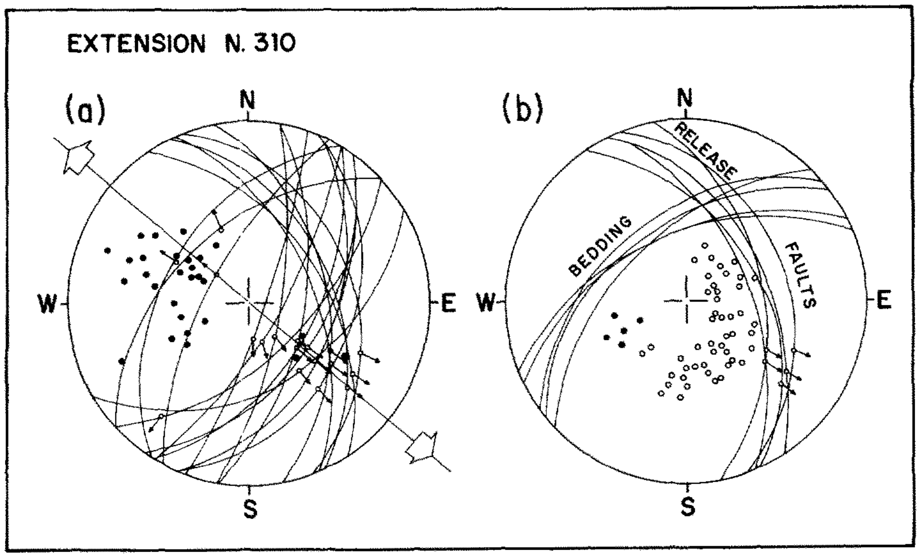


Fig. 5. Wulf stereogram with lower hemisphere projection of structures in the Malhada dos Bois area. (a) Normal faults (NE–SW) and release faults (NNW–SSE). (b) Release faults and bedding (great circles) for locality 1 in Fig. 3. Note also the curved pattern in the distribution of poles to bedding (open circles) for the Malhada dos Bois area, as a result of the curvature, in map view, and the varying throw of the Fazenda Pedra da Onça Fault (Fig. 3). Dots: poles to fault planes. Arrows: slickensides on the fault planes.

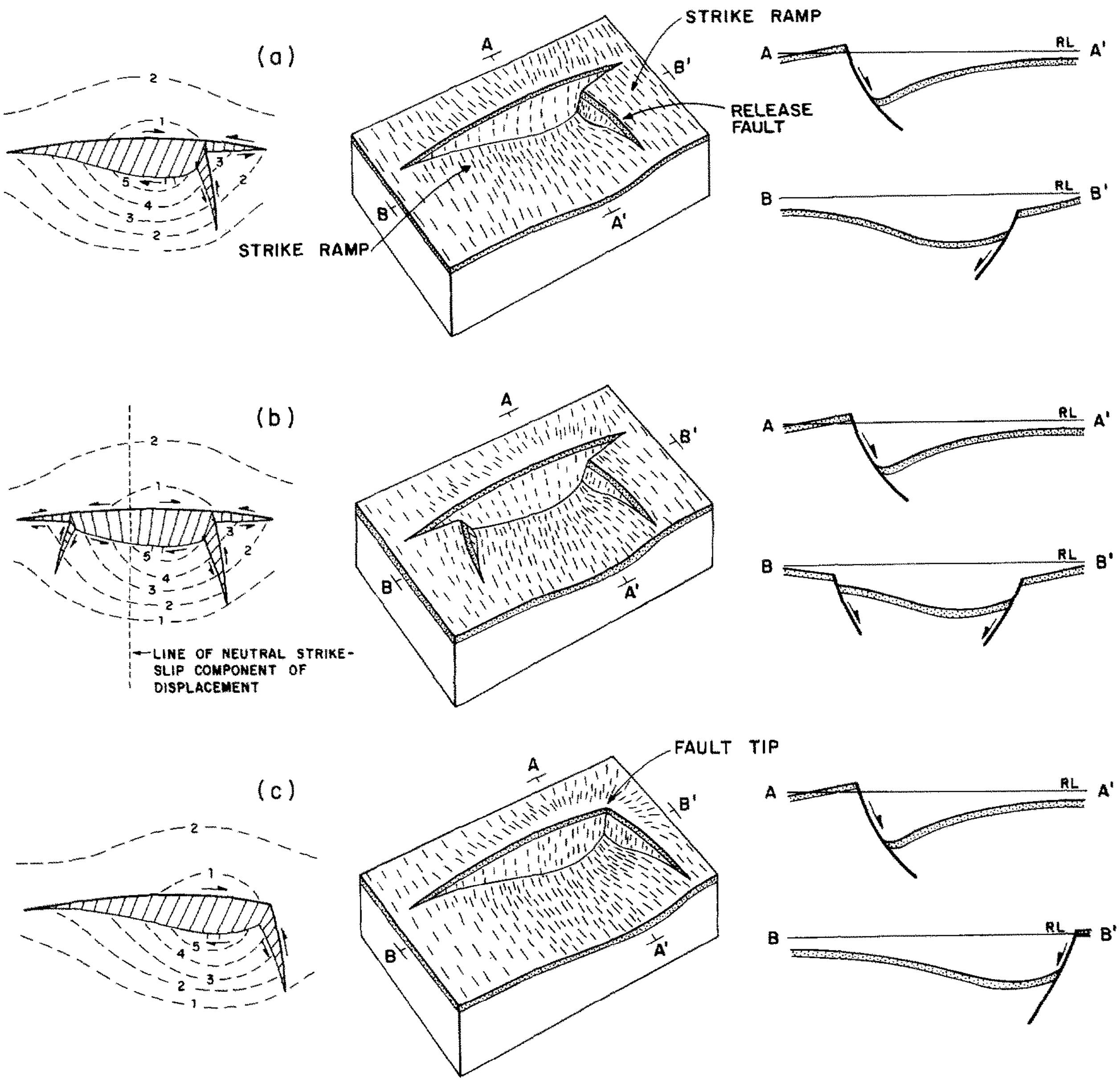


Fig. 6. Idealized structural contour maps, block diagrams and cross-sections of some basic types of release faults. They may form in the strike ramps (a,b) or at the normal fault tips (c). The cross-sections B–B′ show that release faults do not present footwall uplift. Structural contours indicated by numbers 1 (highest)–5 (lowest). Arrows in maps represent the apparent lateral movements originated by the release faults.

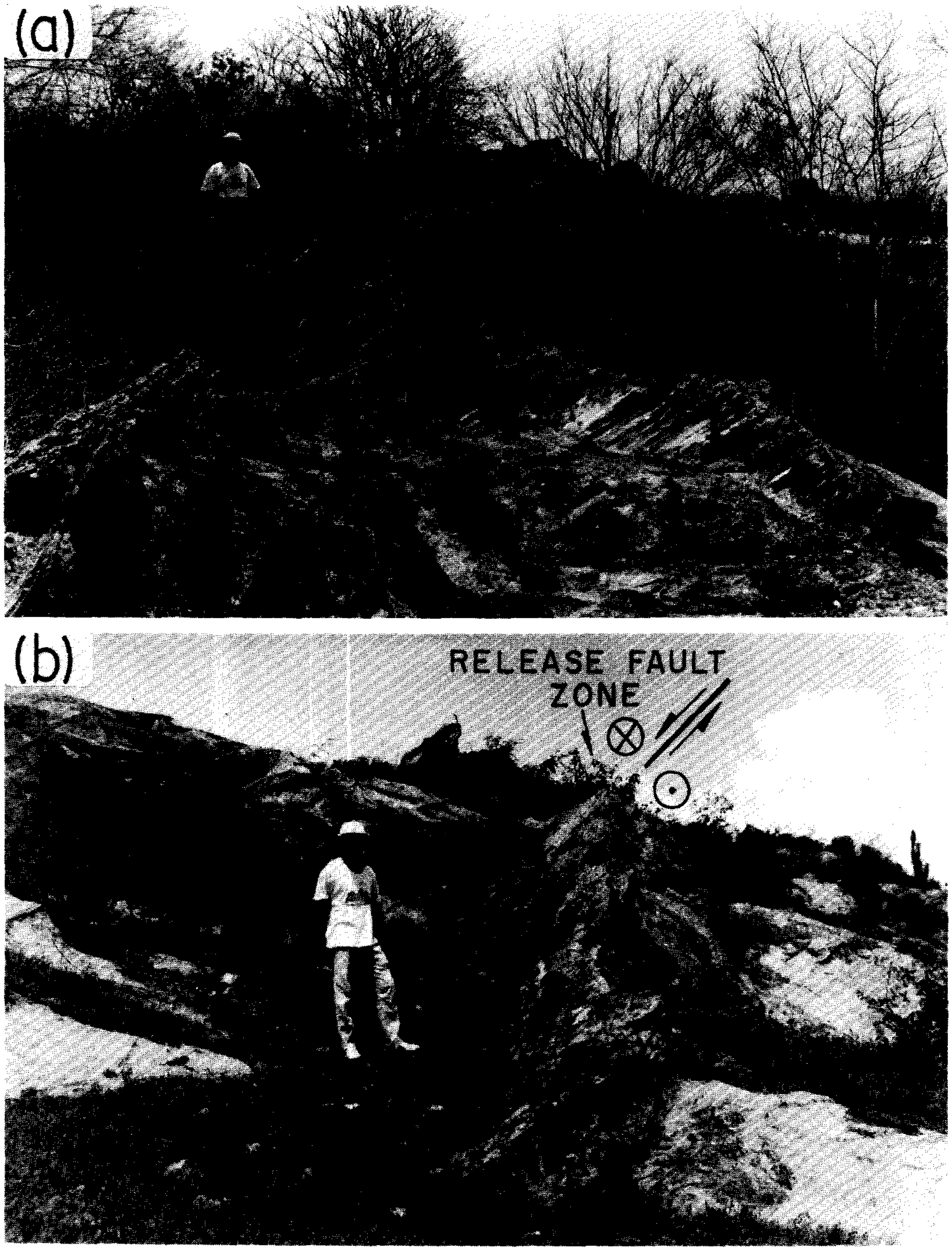


Fig. 4. (a) Fault zone dipping southeast within the Serraria Sandstone, Malhada dos Bois. The slickenside lineations, formed near the margin of a fault zone, show great pitches. (b) Well defined release fault zone viewed from northwest and striking-NW (locality 1 in Fig. 3) showing relatively small dip.

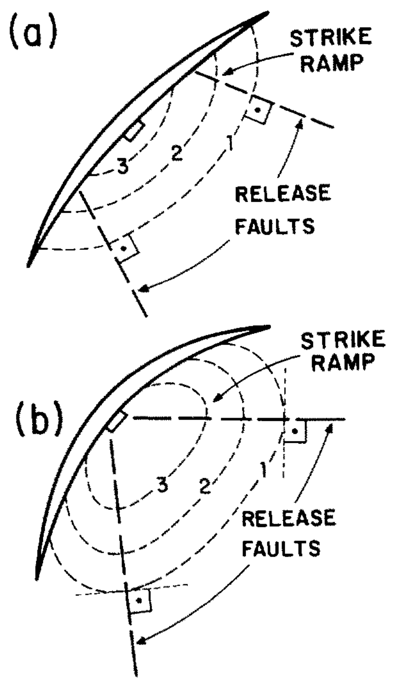


Fig. 7. Idealized structural contour maps in hangingwall showing (a) high angle release faults, and (b) oblique release faults. Structural contours indicated by numbers 1 (highest)–3 (lowest). Note the concavity of the contour lines towards the normal fault planes (see text for explanation).

area, shows that small scale release faults and release fractures are likely to occur in the hangingwall of the Fazenda Pedra da Onça Fault along its entire length.

To explain the cases where cross faults are not perpendicular to the strike of normal faults, most extension models invoke the reactivation of pre-existing weaknesses (Gibbs 1984, Letouzey 1986, Colletta *et al.* 1988). Although both oblique release and oblique transfer faults may reactivate weak zones, oblique release faults are not considered to depend primarily upon old weaknesses, but upon the geometry of the normal faults, which may be curved or approximately linear in map view (Fig. 7). The causes of this difference in the fault geometries are not well known, as both patterns may coexist in a given area (e.g. the Sergipe–Alagoas Basin). For example, the Fazenda Pedra da Onça Fault, which has a curved fault trace in map view (Fig. 3), is 4 km long and has maximum throw of about 1300 m (Destro & Masiero 1993), giving a ratio length/displacement of nearly 3. This relatively small ratio is consistent with steep dipping beds observed around the Fazenda Pedra da Onça Fault (Fig. 3). In contrast, the Neópolis Fault, situated near the São Francisco River (Fig. 8), and presenting a rather linear fault trace, is about 35 km long and has maximum throw of about 1700 m (Destro & Masiero 1993), which gives a ratio length/displacement of about 20. Bedding dips are less than 10° near the Neópolis Fault.

The concavity of the contour lines towards the normal fault planes is also a result of the varying throws along the strike of the normal faults. The greater curvature of the contour lines shown in Fig. 7(b), compared with those in Fig. 7(a), is a result of a greater curvature of the normal fault plane in map view and a smaller ratio length/displacement of the normal fault of Fig. 7(b). The Fazenda Pedra da Onça Fault fits the example shown in Fig. 7(b).

Because the increase in length of the hangingwall is due to bending and not due to extension along the strike of the normal fault, release faults do not indicate regional three-dimensional strain in rifts or basins. Release faults are usually not vertical, so the net slip vectors have a finite down-dip component, and release faults must produce some local elongation. Thus, between the terminations of a normal fault, three-dimensional strain deformation is considered to occur (Fig. 1). However, regionally, the global strain may not have any net elongation parallel to the axis of rift and basins. Release faulting probably acts to maintain plane strain deformation during extension, unless there is additional evidence for overall three-dimensional strain.

## SUBSURFACE EXAMPLES OF RELEASE FAULTS IN THE SERGIPE–ALAGOAS BASIN

In the Sergipe–Alagoas Basin (Fig. 2), other examples of release faults occur in the Itaporanga High, a basin compartment located in its southern portion (Figs. 8 and 9). The release faults are nearly perpendicular or oblique to the Pedrinhas Fault (Fig. 9). In the dip direction (Fig. 10a) a broad roll-over structure formed by listric normal faulting is apparent. In the strike direction (Fig. 10b) two release faults and the Itaporanga Transfer Fault are shown. The sinuous aspect of the reflectors results from the varying throw along the strike of the Pedrinhas Fault (Fig. 9). The release faults are geometrically necessary to accommodate that sinuosity as a consequence of brittle faulting. Release faults appear as simple normal faults in seismic sections (Fig. 10b), as vertical displacements predominate over strike-slip displacements. Release faults do not show footwall uplift either, as they only accommodate differential descending vertical displacements. Although they appear as simple normal faults, release faults do not indicate extension along strike for the study area. In fact, regional mapping suggests that conditions of plane strain operated during the northwest–southeast extension.

The undulation of the reflectors shown in Fig. 10(a) could suggest compression strain along the strike of the Sergipe–Alagoas Basin. In fact, Lana (1990) interpreted undulating reflectors as representing compression derived from strike-slip movements in strike parallel sections in the northern portion of the Sergipe–Alagoas Basin. However, recent surface mapping (Destro *et al.* 1990) and the subsurface seismic data used in this paper do not support evidence for regional syn- or post-rift compression, nor strike-slip movements in the basin. Thus, the undulation of reflectors in along-strike seismic sections is suggested here to be a predictable characteristic of release faulting and fracturing, unless there is additional evidences for regional compression.

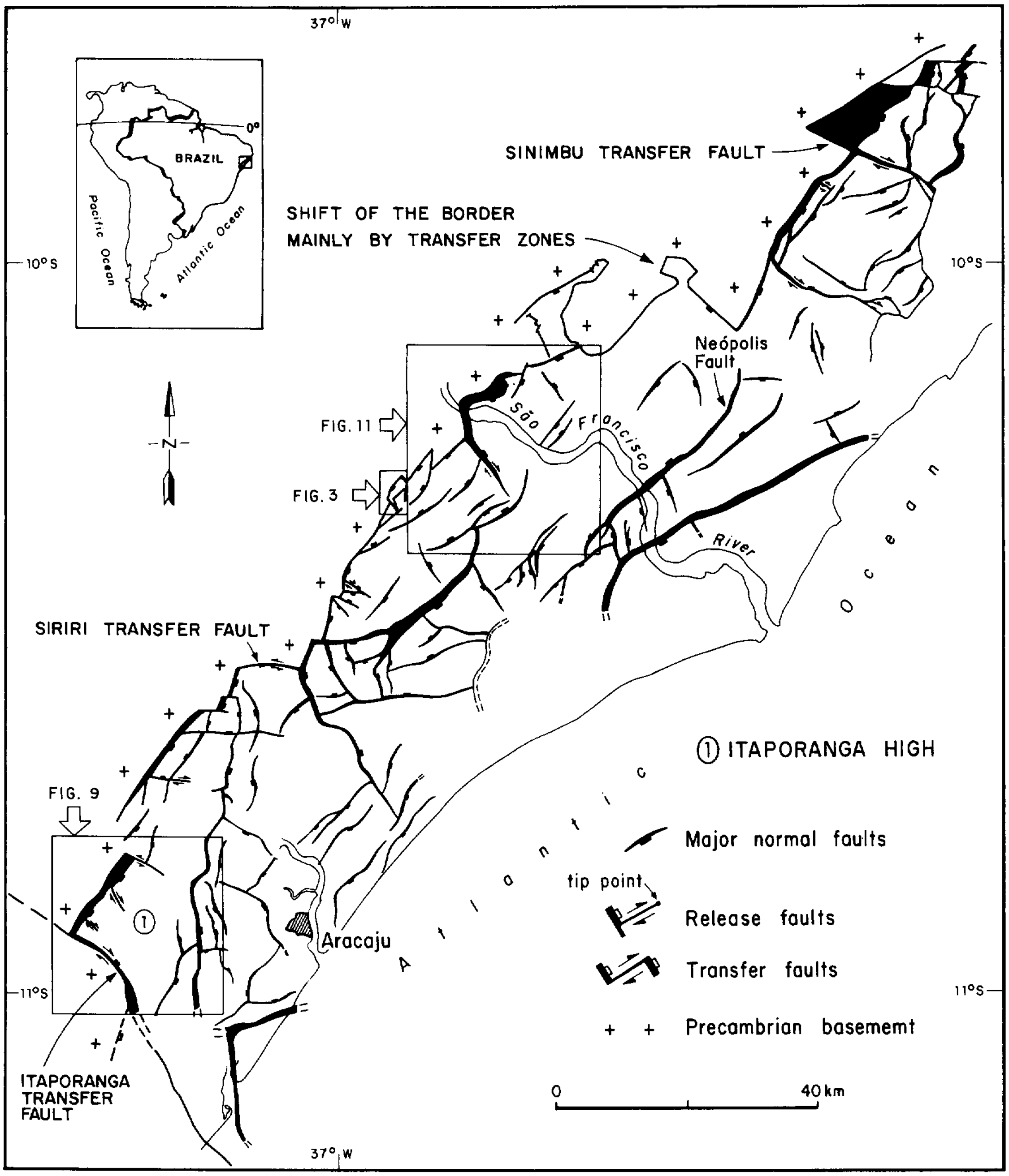


Fig. 8. Simplified tectonic map of the study area (PETROBRÁS/DENEST 1992) (see Fig. 2 for location). The transfer faults are identified by names and other cross faults are considered release faults. Note that the release faults offset only the hangingwall, whereas the transfer faults offset both the hangingwall and the footwall. The transfer faults are responsible for shifts in the border fault system, and for the compartmentation of the basin.

Two examples of release faults associated with the Propriá Fault are shown in Fig. 11. One, the São Miguel Fault, is located near the southern extremity of the Propriá Fault, and the other formed near the northern extremity of the Propriá Fault. In the dip direction (Fig. 12a), a broad roll-over associated with the Propriá Fault is observed. The change in displacement along the São Miguel Fault is shown in Fig. 11 and Figs. 12(b) & (c). Significant dip of the hangingwall reflectors towards the São Miguel Fault (Fig. 12b) is observed in the domal feature shown in Fig. 11, and near this fault are drag-folded reflectors. As there is no extension along the strike of the Propriá Fault, space is not created in that direction, and thus the hangingwall experienced mainly vertical descending movements resulting in the steep dips near that fault. Dips of 50° are found in outcrops near release faults associated with the border fault system of the Sergipe–Alagoas Basin. Displacement on the São Miguel Fault is greatest near the Propriá Fault, and it dies out farther southeast (Fig. 11). Near this southeastern termination, the apparent sense of displacement along the São Miguel Fault is sinistral, as shown by the shifted contour lines. However, the expected sense of displacement would be dextral. In fact it is, and the false apparent sinistral sense of displacement is due to the influence of the descending movement of the hangingwall of the Japoatã Fault (Fig. 11), which causes the inversions in the positions of the contour lines.

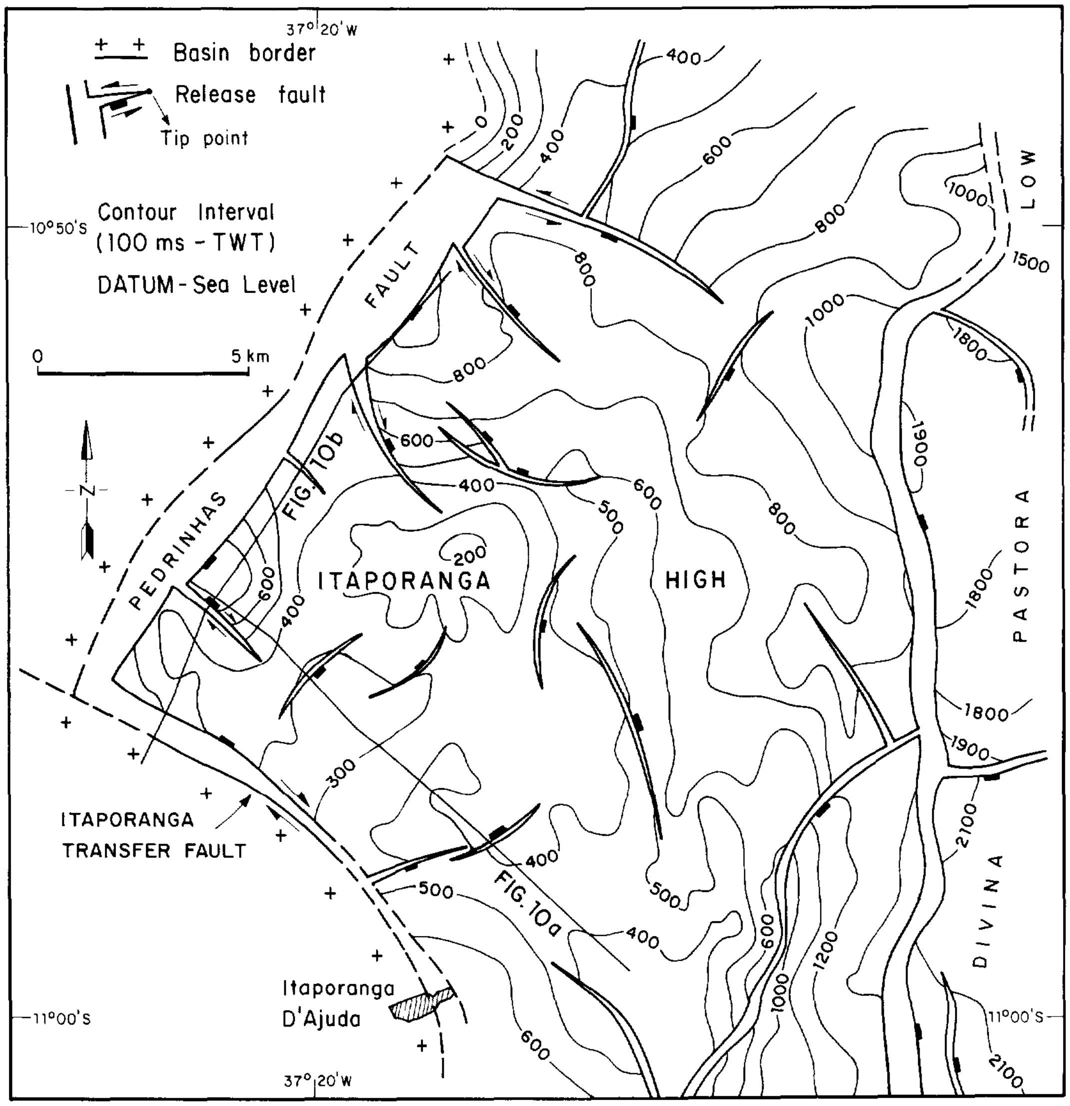


Fig. 9. Structural contour map of the Pre-Late Aptian Unconformity for the Itaporanga High (After Sá & Bacellar 1989) (see Fig. 8 for location). The release faults are located on strike ramps, and are nearly perpendicular or oblique to the strike of the Pedrinhas Fault, in order to cut the contour lines at high angles. Note also that near the Pedrinhas Fault the contour lines are concave towards that fault.

The São Miguel Fault, which occurs near the end of the Propriá Fault, conforms with the model of release fault shown in Fig. 6(c). In this area, a series of granitic plutons occur (Fig. 11). These intrusions, of Brasiliano (Pan African) age, may have caused a deflection of the Propriá Fault for it exhibits an accentuated curvature in map view. These intrusions probably weakened the crust, and may have determined the position of the São Miguel Fault. This acts as a typical release fault, as it forms to accommodate the varying displacement along the strike of the Propriá Fault, as shown in Fig. 11 by the shallowing of the basement northeastwards towards the city of Igreja Nova, as indicated by the contour lines.

The release fault located in the strike ramp farther north (Fig. 11) is almost subvertical and has a smaller length than the São Miguel Fault, but it accommodates larger vertical displacements. This fault does not appear in any of several seismic sections run normal to its strike southeast of the surface termination of the fault, so it must die out suddenly to the southeast. For this reason, I infer that this fault is a release fault and not a transfer fault.

## TRANSFER FAULTS

In the study area of the Sergipe–Alagoas Basin (Fig. 8), transfer faults in the sense of Gibbs (1984) are responsible for several shifts in the border of the basin. Three main transfer faults are shown: the Itaporanga, the Siriri, and the Sinimbu transfer faults. Those faults do fit Gibbs' definition for transfer faults; that is, they connect distinct normal faults, and their slips are in the opposite direction to the mapped offset of the normal faults (Gibbs 1990). Transfer faults are also called compartmental faults by Gibbs (1987), for they separate distinct compartments within rift and basins. In fact, they play an important role in the compartmentalization of the Sergipe–Alagoas Basin.

Transfer faults in the Sergipe–Alagoas Basin are located over discontinuities in the Precambrian

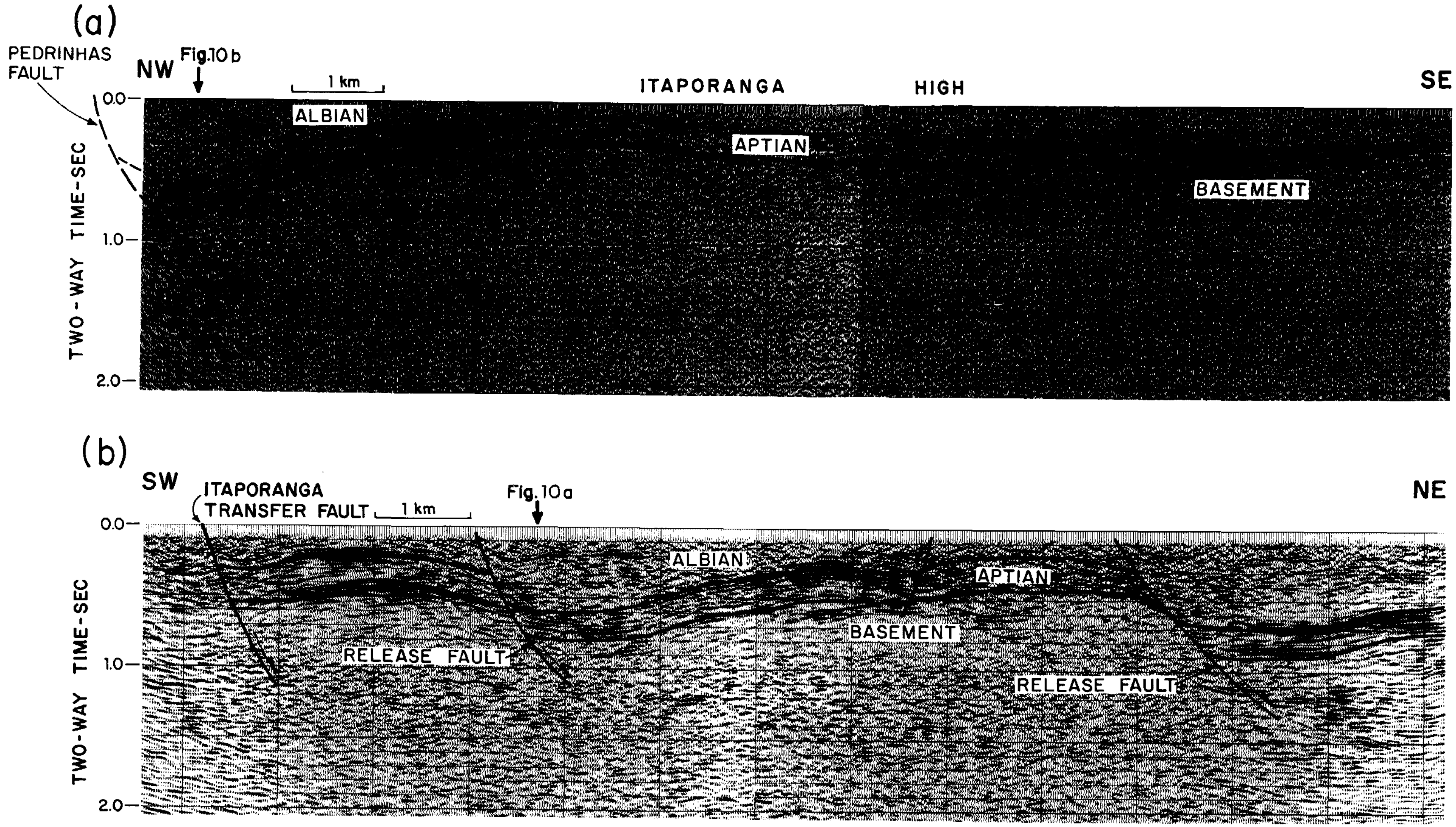


Fig. 10. Seismic sections through the Itaporanga High area (see Fig. 9 for location). (a) Dip section (NW–SE oriented) showing a broad roll-over associated to the Pedrinhas Fault. (b) Strike section showing two release faults and the Itaporanga Transfer Fault (see also Fig. 9). The release faults form due to the bending of the beds (reflectors), and as surprising as it may appear, there is no extension along the strike of that section. Note also that although there is an apparent footwall uplift in the release faults, their footwall blocks belong, in fact, to a major descending hangingwall of the Pedrinhas Fault (see Fig. 9).

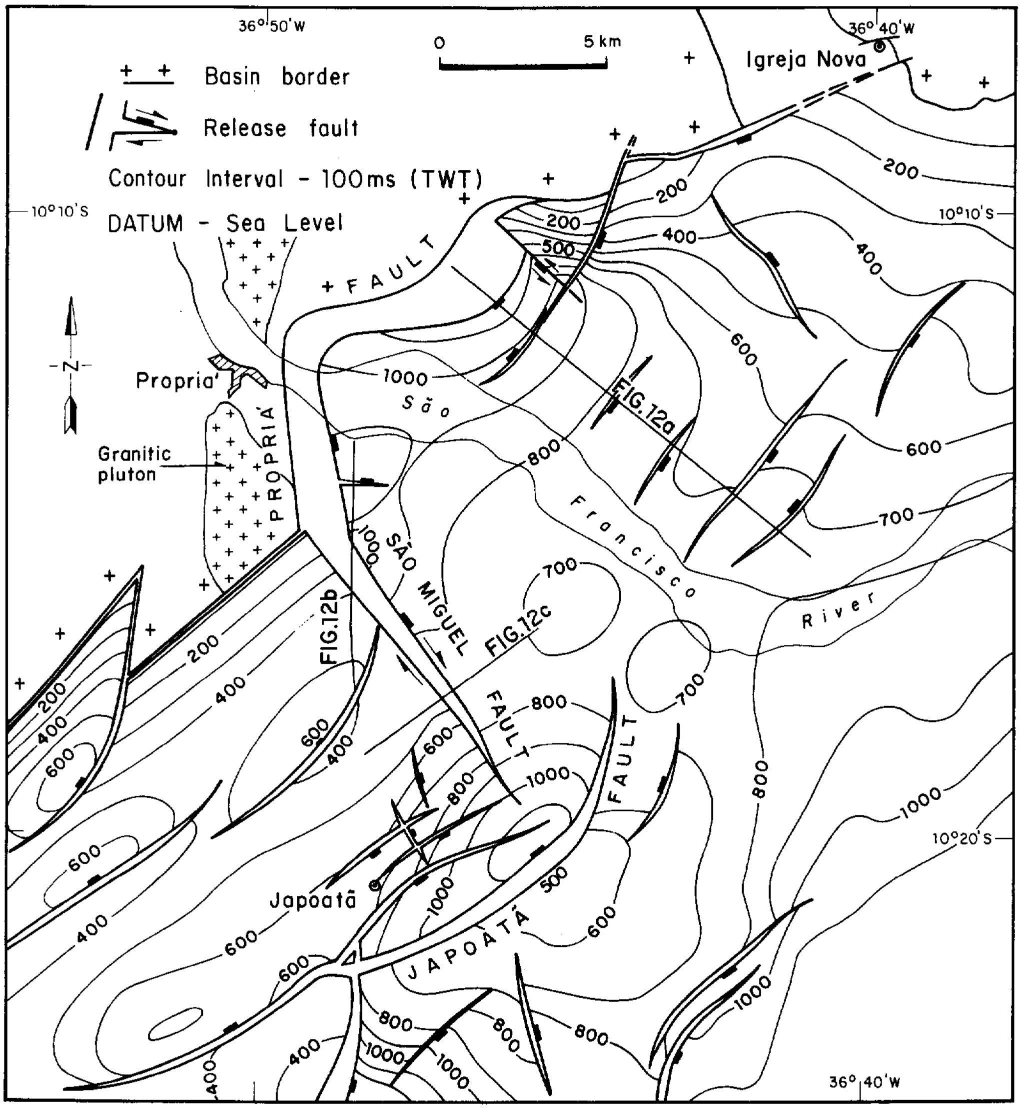


Fig. 11. Structural contour map on top of basement for the Propriá area (simplified from Destro & Masiero 1992) (see Fig. 8 for location). There are two release faults associated to the Propriá Fault. The larger is named São Miguel Fault, and the smaller is situated in the strike ramp further north at high angle and near the northern extremity of the Propriá Fault. The Propriá Fault has an overall northeast–southwest orientation, but it is deflected locally to the north–south direction, probably due to the Precambrian granitic plutons that occur in the basement near Propriá. Note that in the hangingwalls the contour lines are concave towards the major normal faults.

basement (Fig. 13). The Itaporanga Transfer Fault, located to the southern extremity of the basin, is the boundary between the São Francisco Craton and the Sergipano Fold Belt. The Siriri Transfer Fault corresponds to a major suture zone which separates the Sergipano Fold Belt and the Baixo São Francisco Fold Belt (Destro *et al.* 1993). The Sinimbu Transfer Fault, to the north, is located approximately at the contact between the Baixo São Francisco Fold Belt and the Pernambuco–Alagoas Massif.

## DISCUSSION ON RELEASE AND TRANSFER FAULTS

The term 'transfer fault' is widely used in the description of extensional settings. Transfer faults are also recognized in the work described here, but that term may embrace a range of cross faults other than that originally described by Gibbs (1984). The inclusion of a variety of cross faults under the umbrella-term, transfer fault, has led to confusion over their meaning and tectonic implications. Moreover, some basic assumptions made for transfer faults may be invalid for a number of cross faults. The usage of the term 'transfer fault' as well as recognition of these faults and the related processes by which they form has become ambiguous (Rosendahl *et al.* 1986, Scott & Rosendahl 1989, Morley *et al.* 1990).

The occurrence of transfer faults in extensional systems is not disputed. However, to clarify genetic implications, the term 'release fault' is appropriate to separate a class of geometrically similar but kinematically distinctive faults. Gibbs (1984) formally suggested the term 'transfer fault' in analogy with 'tear faults' in thrust systems (Dahlstrom 1969). He pointed out that transfer faults 'allow leakage' between extensional faults with differing slip rates and that 'the presence of a strike-slip

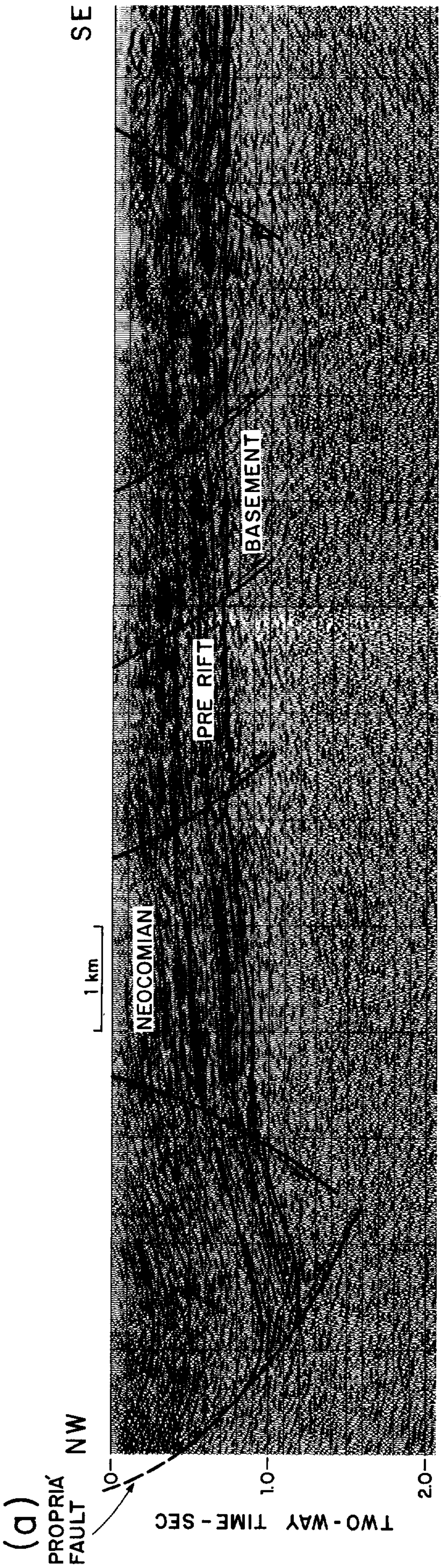
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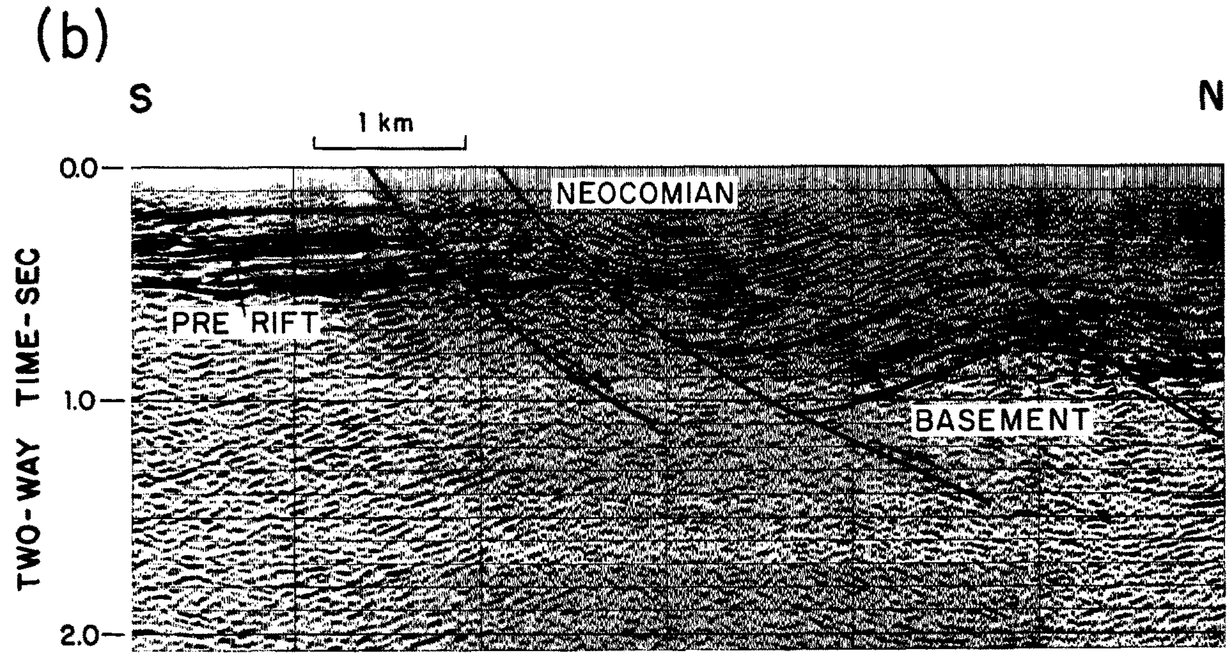
Fig. 12(a).



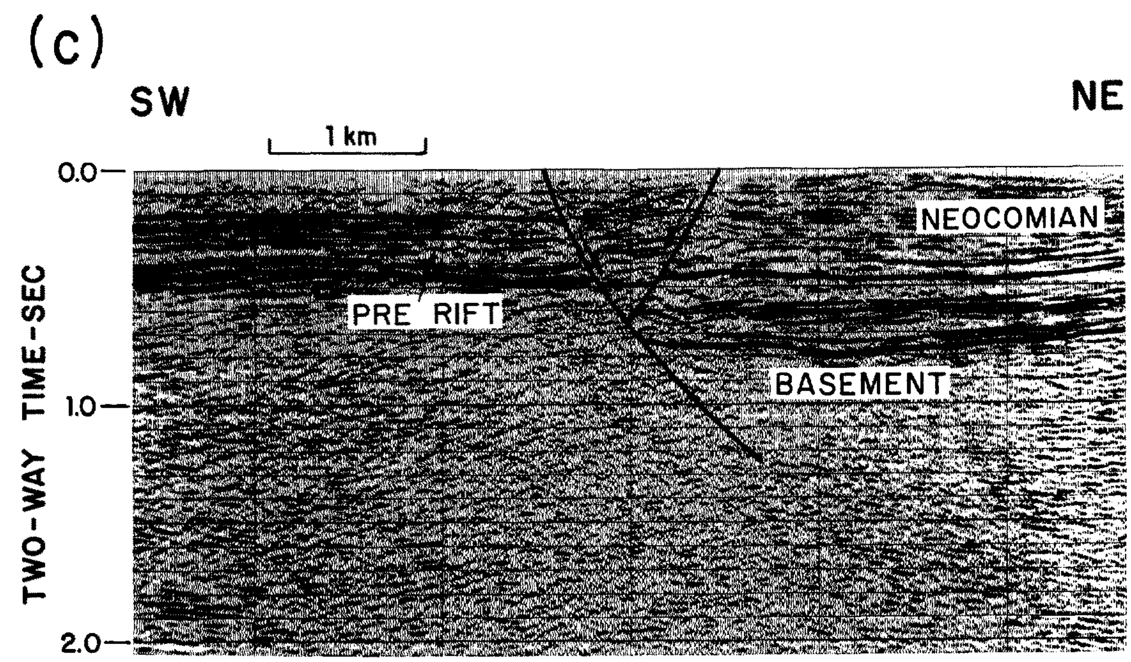




Fig. 12. Seismic sections from the Propriá area (see Fig. 11 for location). (a) Dip section (NW–SE oriented) showing a broad roll-over associated to the listric Propriá Fault. Sections (b) & (c) illustrate the changes in the throw along the São Miguel Release Fault. Towards the Propriá Fault the throw is greater (b), while farther southeast it is smaller (c) (see also Fig. 11). The transparent, chaotic zone near the minor fault may be a result of the strike-slip component of displacement along the São Miguel Fault.

component on transfer fault is important, as such faults will have displacements much larger than the dip-slip component apparent on a single geo-seismic line'. Release faults are distinct from transfer faults exactly in these two aspects: (1) they are associated with individual normal faults, dying out within the hangingwall before reaching other normal faults, and (2) vertical movements predominate over horizontal motion on them. Oblique transfer faults are considered to show a normal component of movement (Gibbs 1984). Release faults, either oblique or perpendicular, appear as simple normal faults in seismic lines, because in such cases the vertical component of displacement predominates in the hangingwall.

In the study area both release and transfer faults are recognized. One important consideration about release faults is whether they may or may not evolve to transfer faults. In the Sergipe–Alagoas Basin, the formation of release and transfer faults seems to depend on whether the faults are located within or between basin compartments. Gibbs (1987) considers transfer faults as compartmental faults, as they are located at the boundary

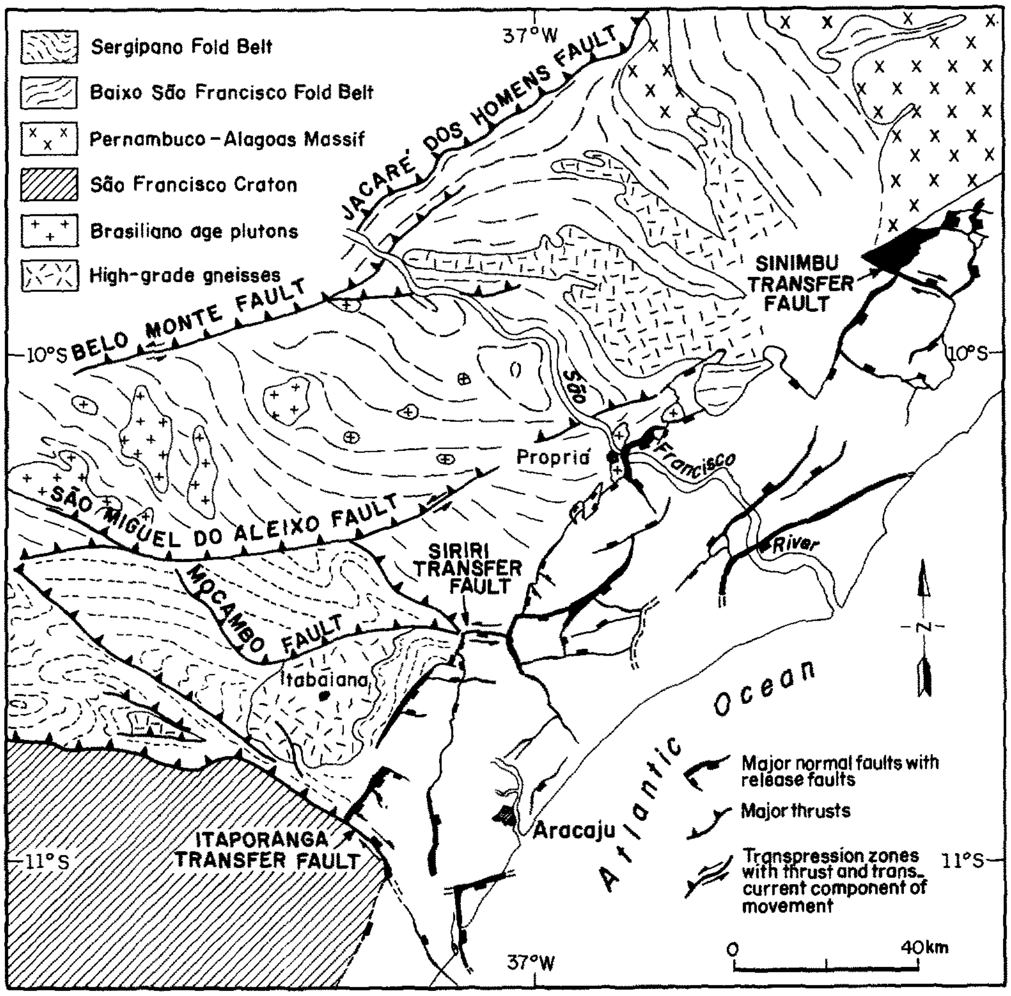



Fig. 13. Simplified tectonic map of the Sergipe–Alagoas Basin (adapted from PETROBRÁS/DENEST 1992) and major structures of the adjacent Precambrian basement (modified from Silva Filho *et al.* 1979, Davison & Santos 1989). The most important transfer faults in the Sergipe–Alagoas Basin are located on major previous weak zones of the basement.

between compartments. In the Sergipe–Alagoas Basin, transfer faults are, in fact, situated at compartment boundaries, whereas release faults are mainly located within compartments (Figs. 8 and 13). According to Gibbs (1990), transfer faults slips are in opposite direction to their mapped offsets, and this is also observed in the Sergipe–Alagoas Basin (Figs. 8, 9 and 13). Nevertheless, release fault slips are in the same direction to the mapped offsets of the hangingwall, as indicated by the offset of contour lines (Figs. 9 and 11).

In general one or two major release faults form in association with an individual normal fault, located over strike ramps or at the extremities of the normal fault. However, smaller release faults are observed in outcrops occupying intermediate positions, as for example in the Malhada dos Bois area. They have displacements on the order of centimetres or metres. Even in the strike ramps, when a large release fault does not form, small release faults may occur associated with pervasive release fracturing. This suggests that those structures may accommodate considerable displacement in the hangingwall, along the entire length of a normal fault, and would appear as chaotic or transparent zones in seismic sections.

## CONCLUSIONS

Release faults are cross faults formed to accommodate varying displacement along the strike of normal faults as a result of the increase in length of the hangingwall by bending or flexure in the strike direction. They release the bending stresses in the hangingwall mainly by brittle faulting. Release faults die out within the hangingwall before reaching other normal faults, and do not cut the normal fault planes nor detachment surfaces at depth. They appear as simple normal faults in seismic sections and although presenting oblique displacement, they commonly do not show Riedel-type structures. Release faults tend to appear at a high angle to: (1) structural contour lines (at depth), or (2) bedding traces (at surface). They may be obliquely oriented or nearly perpendicular to the strike of major normal faults. Their geometry does not necessarily depend upon previous weakness zones, instead it is a property of the release faults. Appearing as simple normal faults on seismic sections, release faults may erroneously suggest extension along the axis of rift and basins. Although three-dimensional strain occurs between the terminations of an individual normal fault, regionally plane strain conditions prevail during extension. Also, the undulation of reflectors on seismic sections along the strike of rift and basins may erroneously suggest compressive strain in that direction. Unless there is additional evidence of regional compression, the sinusoidal configuration of reflectors may be resultant of the varying throws along the strike of normal faults.

Release faults and transfer faults can be distinguished in structural contour maps, geologic maps or in outcrops on the basis of their distinctive features. In contour maps and geologic maps, release faults are associated with single normal faults, and die out within the hangingwall. In contrast, transfer faults often connect two or more normal faults and may present large horizontal displacements compared with the vertical ones. In the study area of the Sergipe–Alagoas Basin, release faults occur within compartments, whereas transfer faults separate distinct compartments and are located on discontinuities of the Precambrian basement. In outcrops, release faults appear as simple normal faults, although the pitch of the slickenside lineations on the release fault planes are smaller than on the normal faults. In transfer faults such pitches are still smaller, as they may present horizontal displacement much greater than the vertical ones.

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