Revista Brasileira de Geomorfologia, Ano 6, Nº 1 (2005) 109-114

Detection of neotectonic deformations along the Rio do Peixe Valley, Western São Paulo State, Brazil, based on the distribution of late Quaternary allounits

Mario Lincoln Etchebehere [1], Antonio Roberto Saad [1-2], Vicente José Fulfaro[1-2], José Alexandre J. Perinotto [1-2]

1Universidade Guarulhos - UnG - metchebehere@ung.br

[2]- Universidade Estadual Paulista Unesp

Abstract
Terrace deposits (34 10 ka) were mapped in the Rio do Peixe valley and submitted to an allostratigraphic analysis. Three allomembers (viz. “A”, “B”, and “C”) were established in the medium to lower river valley and other three allounits (allomembers “ L”, “M” and “N”) were defined in the upper valley. It is probable that “B” and “M” allomembers represent the same stratigraphic level. The spatial distribution of these allomembers shows the influence of the Recent base-level changes, due to neotectonics events. Longitudinal cross-section of the Rio do Peixe valley shows that it is possible to define some areas with differential tectonic movements, that includes uplift blocks (prone to erosion and terrace deposit destruction), and other areas with relative subsidence, controlling both the Recent alluvial plains and the preservation of some ancient terrace deposits. This scenery is in accordance with regional tectonic studies.

Keywords: fluvial terrace deposits, Late-Quaternary deposits, Allostratigraphy, Neotectonic**s**

Resumo
Depósitos de terraços (34 10 ka) do vale do rio do Peixe foram mapeados e submetidos à análise aloestratigráfica. Foram estabelecidos três alomembros para o baixo (“A”, “B” e “C”) e outros três (“L”, “M” e “N”) para o alto vale. É provável que os alomembros “B” e “M” representem mesmo nível estratigráfico. A distribuição espacial dos alomembros reflete influência de mudanças recentes no nível de base devido a eventos tectônicos. A seção longitudinal do vale do rio do Peixe mostra a possibilidade de existência de áreas com blocos alçados e rebaixados, que controlam a planície aluvial e os depósitos de terraço. Este cenário concorda com os estudos tectônicos regionais.

Palavras-chave: depósitos de terraços fluviais, depósitos quartenários recentes, aloestratigrafia, neotectônica

1. Introduction

Terrace deposits (34 10 ka) were mapped in the Rio do Peixe valley and submitted to an allostratigraphic analysis (Fig1). Six allounits were studied: three allomembers (viz. “A”, “B”, and “C”) were established in the medium to lower river valley and other three allounits (allomembers “ L”, “M” and “N”) were defined in the upper valley, all of them in the named Rio do Peixe Alloformation (cf. NACSN 1983; Etchebehere 2002). These deposits are formed by sandy facies and sandy gravel facies, which can be massive or cross-stratified, interposed between gravel beds and mudstones. In

this last case, holding lenses with decimetric thickness and clay beds with metric thickness. This set was interpreted as being formed in a braided fluvial context with some transition to psamitic meandering types; the thickest mudstone facies were associated to lacustrine deposition. Although they are not common in fluvial contexts of high energy, they may occur due to tectonic barriers. The sedimentation took place under a dry weather and colder than the current one according to palinologic data analyses (Etchebehere et al. 2003). Under those conditions, the vegetation covering must have been herbaceous with isolated trees. Therefore, the soil was exposed to erosional condition during episodic rainstorms and a great clastic supply was carried to a drainage network. The terrace deposit may be up to 40 m thick and the radiocarbon datings show ages ranging between 34 and 10 ka BP. Indian objects have been found in colluviums that cover these terraces and also in the exposed gravel lenses leading to the conclusion that these deposits are at least 7,000 years old as shown by anthropological data available about human occupation in this part of the São Paulo State inland territory (Etchebehere, 2000).

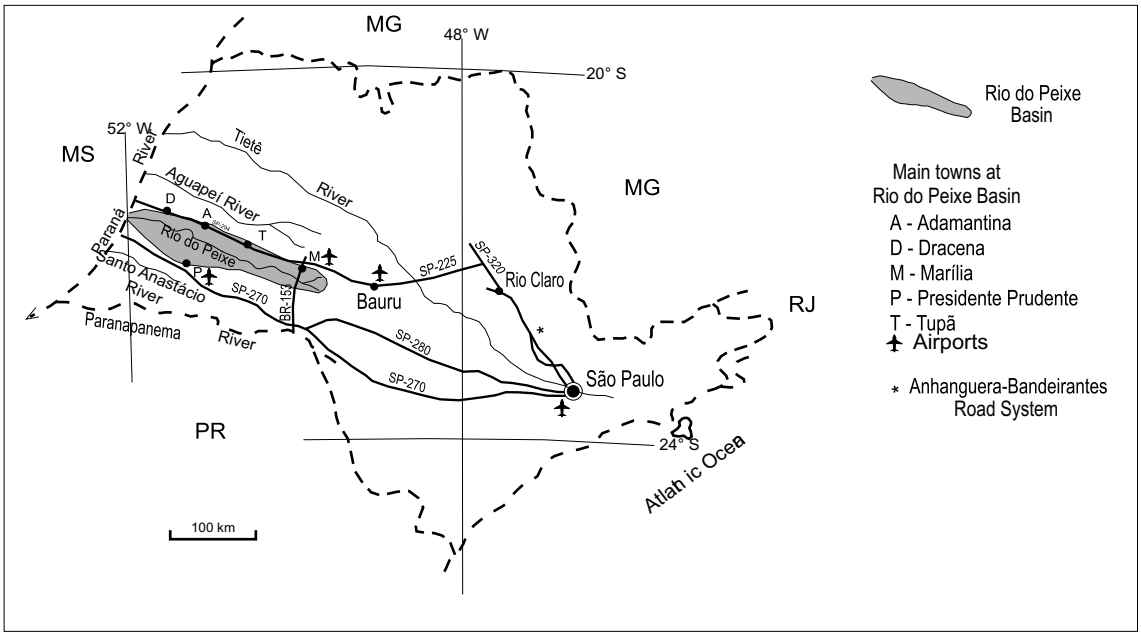

Figure 1 - Rio do Peixe Hydrographic Basin location in the São Paulo state.

The purpose of this paper is to highlight the importance of the terrace deposits studied under an allostratigraphic point of view. This approach helps to understand the Late Cenozoic history of this part of the São Paulo State territory. Moreover, it guides the understanding of the neotectonic implications that arise from this picture.

2. Neotectonics

The definition of neotectonics is not yet unanimous (cf. Discussion presented by Hasui & Sena Costa [1996]), since the word was introduced in the geological literature by Obrushev (1948, apud Mello 1997) with the aim to refer to the movements of the Earth crust that occurred in the Late Tertiary and Quaternary. For the purpose of this research paper, however, the definition given by INQUA (International Union for Quaternary Research) will be used. Thus, the word neotectonics refers to any movement of the Earth or deformation of the geodesic reference level, its mechanism, its origins, independently of its starting age, its practical implications and its future extrapolations.

Leaving out the chronological idea, which is implicit in this definition, allows us to go back to the beginning of the neotectonic deformations in a given area up to the moment in which the current tension system is installed.

3. Tectonics Inferences Based On Allostratigraphy

The allostratigraphic approach based on the discontinuity allounits boundaries has a tectonic component implicit in the base level oscillation which can be locally or regionally controlled by deformations caused by Present tension field. Certainly, other agents, such as

allocyclic (e.g., eustasy, climate variations) and autocyclic factors related to the fluvial dynamics, may be elements that control the discontinuities and consequently, control the spatial distribution of the deposits. In the Rio do Peixe valley, however, the tectonic connection hypothesis is more consistent.

The spatial distribution of the allounits mapped in the upper and medium valleys of the Rio do Peixe may be seen in the longitudinal profile of the detailed area (Fig. 2). The subdivision in two distinct sets, medium and upper valleys respectively, represents a compartimentalization of a major degree that may have a tectonic connection. Another important point is the existence of preserved 40 meter-thick terrace section (Point MH 27, for example). Therefore, it can be concluded that the fluvial sedimentary dynamics is not the only movement responsible for such a significant accumulation of alluvium. It is important to salient that excavations and drill holes campaigns performed in alluviums in the lower Rio do Peixe valley and even in bigger water courses such as in the valleys of Paranapanema and Paraná Rivers, have shown that the sedimentary thickness of the alluvial plain is not over ten meters thick (cf. IPT 1992; Santos 1997; Souza 2000).

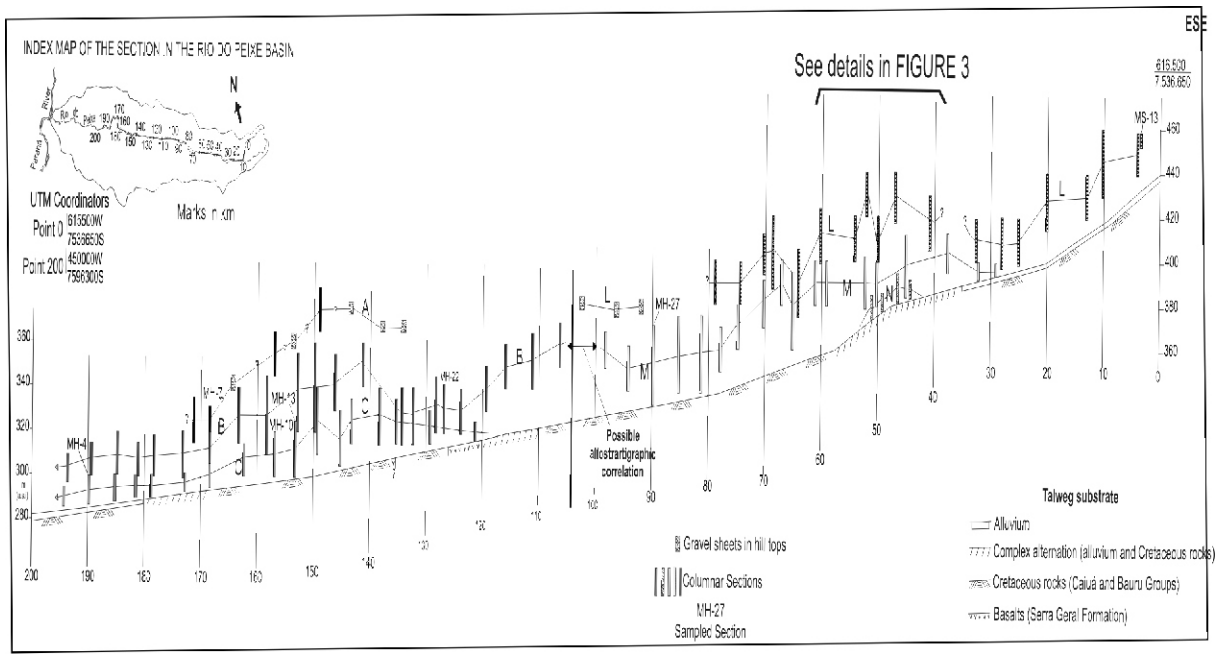

Figure 2 - Longitudinal section of the rio do Peixe Basin showing the proposed stratigrafhic correlation. See text for more details.

Some initial considerations can be made by analyzing Figure 2, which includes the separation area between two sets of allomembers (A, B, C downstream, and L, M, and N upstream). Between the 80 km and 110 km, the allounits become rarer. They are limited to small relicts, mixed with gravel beds in hill tops. The longitudinal profile in this area shows a possible stratigraphic correlation between the allomembers B and M.

It is important to take into account that in this area where the terrace occurrence becomes scarce the area is aligned with several hanging valleys that leads to the possible action of a ruptile tectonics. Besides, it is also important to take into consideration the existence of a thick section (about 40 m thick) of Allomember M (Point MH 27) upstream where gravel beds in hill crests outcrop and form expressive subsident areas located next to uplifted areas. In these areas the occasional terrace Deposits went through a crumbling process and only some concentrations interpreted as elluvium were found as remainings. In the same longitudinal profile, two anomalous reaches were noticed based exclusively in the spatial distribution of several allomembers. One of these sectors is found between the 35 km and the 55 km of the referred section, specified by the occurrence of a younger terrace level (Allomember N). In this area, a clear convexity of the thalweg is observed and according to the analysis method suggested by Burnett & Schumm (1983) indicating the influence of a young uplift in the lower terrace occurrence. It is also important to point out that the thalweg bedrock constitution shows an alternation of reaches where the river flows over alluvium and Cretaceous bedrocks. Moreover, there is a vast recent alluvium plain located upstream that can

be interpreted as being controlled by existing lithic barriers within the ambit of an uplifting context. This area is shown in Figure 3 where a great incidence of small hanged valleys can be noticed. This indicates the possibility of a recent brittle tectonics. This kind of deformity may have been caused by tilt movements, including abrupt ones, of the terrace tops.

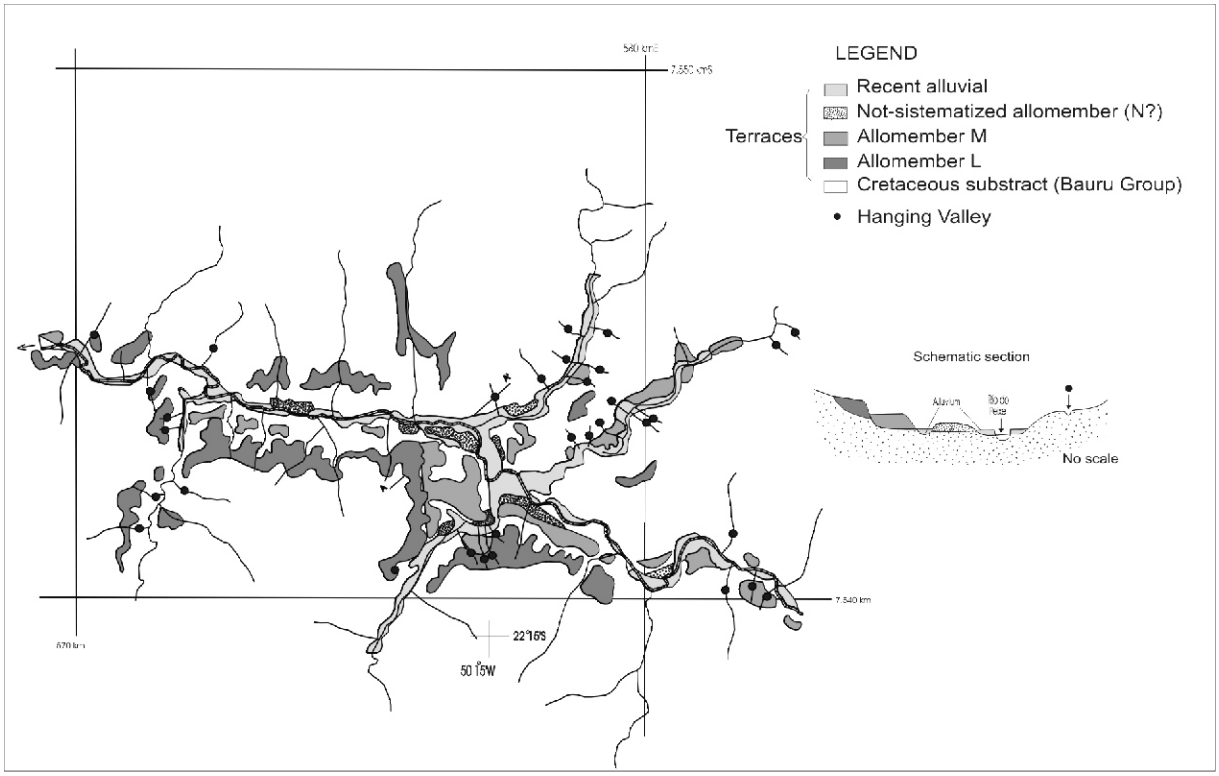

Figure 3- Example of some allounit distribution in the upper rio do Peixe Valley.

Another area that can be considered anomalous in the longitudinal profile of the valley as the one located between the kilometers 130 and 165, formed by a clear convexity of the stratigraphic correlation lines of the mapped allomembers. Also in this case the terraces show top tilting and autocyclic variations. The spatial disposition of Allomember A characterized by the alternation of preserved terraces and gravel beds of uplifted tops, would be another indication of tectonics deformation of ruptile nature. In this case the uplifted blocks went through a greater erosive action ruining the pre-existent terrace deposits that were reduced to a simple elluvium concentration. It is important to point out the presence of basalts in the thalweg bedrock, which are the most resistant rocks to erosion in this part of the Planalto Ocidental Paulista. Although these rocks influence some rapids in Rio do Peixe, neither morphometric anomalies in the terrace distribution nor modifications in the spatial distribution of terraces have been observed. This observation reinforces the importance of the tectonic movements that are responsable to the anomalies observed in the terrace arrangements in other parts of the basin.

Downstream km 173 in the longitudinal profile of the Rio do Peixe, there is a relative homogeneity in relation to terrace thickness (Allomembers B and C) as for their relative position considering the present alluvial plain. Perhaps the allomembers B and C were formed and preserved due to the lowering of the base level represented by the Paraná River.

Finally, the multiplicity of located levels of terrace make some of the allomembers cover up two or more terraces of local expression, as can be seen near the point MH 7. This multiplicity of terrace levels may mean that locally, that area was subjected to differential tectonic processes in relation to adjacent terraces expressing a major number of uplift events as found in San Joaquin, California, USA (Keller&Pinter 1996, P. 57-58). The expressive incidence of lineaments in point MH 7 could be an indicator of tilted blocks, separating compartments with differential taxes of uplifting, confirming the action of brittle

deformation processes.

4. Final Considerations

The development, as well as the preservation and the crumbling of the terrace deposits, were influenced by a tectonic movement that controlled the base levels. This explains the elevate thicknesses (up to 40 m) of these bodies which by no means could have been accumulated only by autocyclic processes .

Neotectonics activities in the Western São Paulo State have been observed by several authors (e.g., Magalhães et al. 1996; Nakasu 1988; Magalhães 1999; Stein 1999; Etchebehere et al. 1999; Etchebehere & Saad 1999, 2002). Kinematics studies in specific areas or regional areas and paleoseismics approaches have also been observed. The kinematics data available in the geologic literature about the Western São Paulo State (e.g., Hasui 1990, IPT 1992; Magalhães et al. op. cit.; Riccomini 1997; Hasui et al. 1999; Magalhães op. cit.) point out the action of dextral slip transcurrent fault movementation in large EW lineament swarms. That would reflect a pattern of tectonic interior movements possibly connected to a South America tectonic plate dislocation to the west. In areas between two lineament swarms, as it is the case of the Rio do Peixe valley, the stress ellipsoid has its maximum axis oriented to NW-SE direction influencing the appearance of transpressive and transtensional structures, that end up controlling both the fluvial dynamics in the area as well as the formation and preservation - or destruction - of the alluvial deposits. Meanwhile, pieces of information collected by the GPS satellite network (Global Positioning System), allow the monitoring of the station in several parts of the tectonic plaques with milimetric precision for the variations of latitude, longitude and altitude. The closest control stations to Planalto Ocidental Paulista are in Brasilia, Rio del Plata, and Fortaleza (CE). They show a persistent plate drift of the South America tectonic plate towards NNW, at about 2 cm/year (Heflin and others, 2003, apud Caltech op.cit.). Based on systematic studies of lineaments taken from satellite images, Corsi et al. (2003) determined the major lineament swarms drawing the attention to the modes N280º, N315º, N350º, N15º, N40º, and N80º. Putting this geometric picture together with the information given by the GPS system, it is assumed that the lineament mode N350º appears as the most probable hydraulic tensor for the Planalto Ocidental Paulista because it represents the distensional direction. The lineament swarms N315º and N40º, as well as those grouped together in mode N115º may favor transcurrent movements: dextral for the NW quadrant and sinistral for the other two directions with transtensive and transtative deformations that are dependent on the local geometry of the fracture plains and local stress fields. This tectonics has acted for at least 34 ka BP. However, the exact dating of the beggining of the current stress picture can not be exactly determined yet.

Based on the study of lineaments and drainage networks obtained in images of remote sensors, Etchebehere (2000) presented a series of structural sectors with areas of hundreds of km2 that can correspond to blocks with specific tectonics deformation. These deformations can be deduced from the reflections found in the assimetry of the drainage basins in the area enclosed by each block (indicating possible dips); in the fluvial incision of the land (that can reflect areas with vertical movements); in the arrangement of the mapped alllomembers (more preserved in lowered blocks; more frequent terraces may indicate areas with uplift pulses); and in the dominant sedimentary facies (gravel beds in uplift tops may indicate areas with more erosion tax). The transformation of the alluvial plains in fluvial terraces caused by base level modifications defines the allostratigraphic limits and this register, helps to unfold the tectonic history belonging to this part of the São Paulo State territory.

Acknowledgments

The authors wish to acknowledge Miss Liliana Covino for the careful review of the English version of this paper and Mr. Fabio da Costa Casado for drawings.

References

Burnett, A.W. & Schumm, S.A. 1983. Alluvial river response to neotectonic deformation in Louisiana and Mississippi. Science, v. 222: 49-50.

Caltech - California Institute Of Technology. 2004. GPS Time Series. Jet Propulsion Laboratory. http://sideshow.jpl.nasa.gov/mbh/series.html. Accessed in 13.03.04.

Corsi, A. C., Etchebehere, M. L. C., Saad, A. R., Perinotto, J. A. J., Fulfaro, V. J., Morales, N. 2003. Avaliação do arcabouço estrutural do Planalto Ocidental Paulista mediante análises de lineamento. In: Encontro de Pesquisa UnG - 2003, 2003, Guarulhos/SP.

Etchebehere, M.L.C. 2000. Terraços neoquaternários no vale do Rio do Peixe, Planalto Ocidental Paulista: implicações estratigráficas e tectônicas. Rio Claro. 2v. (Ph.D. Thesis, Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista - UNESP).

Etchebehere, M.L.C. 2002. Aloestratigrafia Revisão de conceitos e exemplos de aplicação, com ênfase nos depósitos neoquaternários de terraço da Bacia do Rio do Peixe, SP. Revista Universidade

Guarulhos Geociências, v. VII (6): 15-34.

Etchebehere, M.L.C. & Saad, A.R. 1999. Relação Declividade / Extensão de Curso (RDE) aplicada à detecção de deformações neotectônicas regionais na bacia hidrográfica do Rio do Peixe, SP. In: Simpósio de Geologia do Sudeste, 6, São Pedro, 1999. Abstracts... Rio Claro, SBG-SP/RJ-ES/UNESP, p. 93.

Etchebehere, M.L.C. & Saad, A.R. 2002. Feições de liqüefação em sedimentos quaternários no vale do Rio do Peixe, região ocidental paulista - Implicações paleossísmicas. Geociências, v. 21(1-2).: 43-56.

Etchebehere, M.L.C.; Saad, A.R.; Fulfaro, V.J. 1999. Neotectônica no vale do Rio do Peixe, SP Evidências de liqüefação em sedimentos cenozóicos. In: Simpósio De Geologia Do Sudeste, 6, São Pedro, 1999. Abstracts.. Rio Claro, SBG-SP;RJ-ES/UNESP, p. 94.

Etchebehere, M. L. C., Saad, A. R., Garcia, M. J., Brandt-Neto, M., Zanardo, A. 2003.Fácies Pelíticas em Depósitos de Terraços no Vale do Rio do Peixe, Região Ocidental Paulista, Brasil: Considerações Paleoambientais e Econômicas. Revista Geociências - UNESP, v.22:17-31.

Etchebehere, M.L.C.; Saad, A.R.; Fulfaro, V.J.; Perinotto, J.A.J. In press. Aplicação do Índice "Relação Declividade-Extensão RDE" na Bacia do Rio do Peixe (SP) para detecção de deformações neotectônicas. Revista Geologia USP.

Hasui, Y. 1990. Neotectônica e aspectos fundamentais da tectônica ressurgente no Brasil. In: Workshop Sobre Neotectônica E Sedimentação Cenozóica Continental No Sudeste Brasileiro, 1, Belo Horizonte. Proceedings... Belo Horizonte, SBG-MG: 1-31.

Hasui, Y. & Sena Costa, J.B. 1996. Neotectônica - Fundamentos, métodos e técnicas de análise. In: Simpósio De Geologia Da Amazônia, 5, Belém, 1996. Course Notes... Belém, SGB-Núcleo Norte, 20 p.

Hasui, Y.; Sena Costa, J.B.; Borges, M.S.; Jimenez-Rueda, J.R.; Morales, N. 1999. Compartimentação neotectônica do lineamento Paranapanema. In: Simpósio Nacional De Estudos Tectônicos -SNET, 7, Lençóis, BA, 1999. Proceedings... Lençóis, SBG-BA, Sessão 4: 37-39.

IPT - INSTITUTO DE PESQUISAS TECNOLÓGICAS DO ESTADO DE SÃO PAULO S.A. 1992. Sismotectônica e dinâmica superficial na área do Complexo Hidrelétrico Canoas. São Paulo. 4v. (IPT, Relatório 30.924).

Keller, E.A. & Pinter, N. 1996. Active tectonics - Earthquakes, uplift, and landscape. New Jersey. Prentice Hall. 338 p.

Magalhães, F.S. 1999. Tensões regionais e locais: casos no território brasileiro e padrão geral. São Carlos. 225 p. (Ph.D., Escola de Engenharia de São Carlos - Universidade de São Paulo - USP).

Magalhães, F.S.; Etchebehere, M.L.C.; Saad, A.R.; Fulfaro, V.J. 1996. Análise estrutural do Grupo Bauru na região do alto Rio do Peixe, Estado de São Paulo. In: Simpósio Sobre O Cretáceo Do Brasil, 4, Rio Claro. Proceedings... Rio Claro, 1996, UNESP: 283-287.

Mello, C.L. 1997. Sedimentação e tectônica cenozóica no médio vale do Rio Doce (MG, Sudeste do Brasil) e suas implicações na evolução de um sistema de lagos. São Paulo. 288 p (Ph.D. Instituto de Geociências da Universidade de São Paulo USP).

Nakasu, L. 1998. Recursos minerais do rio Paraná a montante de Guaíra. Rio Claro. 212 p. (Ph.D. Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista - UNESP).

North American Comission On Stratigraphic Nomenclature - Nacsn. 1983. North American Stratigraphic Code. Am. Assoc. Petr. Geol. Bull., v. 67(5): 841-875.

Riccomini, C. 1997. Arcabouço estrutural e aspectos do tectonismo gerador e deformador da Bacia Bauru no Estado de São Paulo. Rev. Bras. Geoc., v. 27 (2): 153-162.

Salvador, E.D. & Riccomini, C. 1995. Neotectônica da região do alto estrutural de Queluz (SP-RJ, Brasil). Rev. Bras. Geoc., v. 25,(3): 151-164.

Santos, L. S. 1997. Estratigrafia e evolução do sistema siliciclástico do rio Paraná no seu curso superior: ênfase à arquitetura dos depósitos, variação longitudinal das fácies e processos sedimentares. Porto Alegre. 2 v. (Ph.D. Thesis.Universidade Federal do Rio Grande do Sul - UFRGS).

Souza, I.A. 2000. Mudança no canal do rio Paraná durante o Holoceno. Rio Claro. 139 p. (M.Sc.Thesis. Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista - UNESP).

Stein, D.P. 1999. Avaliação da degradação do meio físico - Bacia do rio Santo Anastácio, Oeste Paulista. Rio Claro. (Ph.D.Thesis. Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista - UNESP).