Pesquisas em Geociências

<http://seer.ufrgs.br/PesquisasemGeociencias>

Biochronostratigraphy (conodonts and palynology) from a selected strata of the Itaituba Formation (Pennsylvanian of the Amazonas Basin) at Itaituba, Pará State, Brazil

Sara Nascimento, Larissa Smaniotto, Paulo Souza, Valesca Lemos, Ana Karina Scmazzon
Pesquisas em Geociências, 36 (1): 37-47, jan./abr., 2009.

Versão online disponível em:

<http://seer.ufrgs.br/PesquisasemGeociencias/article/view/17873>

Publicado por

Instituto de Geociências

Portal de Periódicos
UFRGS

UNIVERSIDADE FEDERAL
DO RIO GRANDE DO SUL

Informações Adicionais

Email: pesquisas@ufrgs.br

Políticas: <http://seer.ufrgs.br/PesquisasemGeociencias/about/editorialPolicies#openAccessPolicy>

Submissão: <http://seer.ufrgs.br/PesquisasemGeociencias/about/submissions#onlineSubmissions>

Diretrizes: <http://seer.ufrgs.br/PesquisasemGeociencias/about/submissions#authorGuidelines>

Data de publicação - jan./abr., 2009.

Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil

Biochronostratigraphy (conodonts and palynology) from a selected strata of the Itaituba Formation (Pennsylvanian of the Amazonas Basin) at Itaituba, Pará State, Brazil

Sara NASCIMENTO¹, Larissa P. SMANIOTTO¹, Paulo A. SOUZA¹, Valesca B. LEMOS¹ & Ana Karina SCOMAZZON²

1. Programa de Pós-Graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul. Av. Bento Gonçalves, 9500, CEP 91509-970, Porto Alegre, RS. E-mail: aiatha@yahoo.com.br

2. Engenharia Geológica/Engenharia de Petróleo, Universidade Federal de Pelotas. Praça Domingos Rodrigues, nº 2, CEP 96010-440, Pelotas, RS. akscomazzon@yahoo.com.br

Recebido em 01/2008. Aceito para publicação em 04/2009.

Versão online publicada em 19/11/2009 (www.pesquisasemgeociencias.ufrgs.br)

Abstract - This study constitutes a new biostratigraphic approach from an outcrop of the Itaituba Formation, in the Itaituba City, southern Amazonas Basin, Pará State, Brazil, integrating conodont and palynological data. Conodont associations includes *Idiognathodus incurvus*, *Idiognathoides sinuatus*, *Adetognathus lautus*, *Hindeodus minutus*, *Diplognathodus coloradoensis*, *D. orphanus* and *D. ellesmerensis*. Among the palynomorphs, *Costatascyclus crenatus*, *Protohaploxypinus amplus*, *Spelaetriletes arenaceus*, *S. triangulus*, *Meristocarpus explicatus*, *Striomonosaccites incrassatus* and *Meristocarpus* sp. B constitute important biostratigraphic species, suggesting a middle Atokan age for the study section, in agreement with conodont biostratigraphy.

Keywords: Conodonts, Palynology, Biochronostratigraphy, Itaituba Formation, Amazonas Basin.

Resumo - BIOESTRATIGRAFIA (CONODONTES E PALINOLOGIA) DA FORMAÇÃO ITAITUBA (PENSILVANIANO DA BACIA DO AMAZONAS), EM UM DEPÓSITO SELECIONADO EM ITAITUBA, ESTADO DO PARÁ, BRASIL. Este trabalho objetiva apresentar uma nova abordagem de estudo com a integração de dados bioestratigráficos advindos de conodontes e palinórmofos recuperados de uma mesma seção aflorante da Formação Itaituba, na cidade homônima, borda sul da Bacia do Amazonas, Estado do Pará, Brasil. A associação de conodontes inclui *Idiognathodus incurvus*, *Idiognathoides sinuatus*, *Adetognathus lautus*, *Hindeodus minutus*, *Diplognathodus coloradoensis*, *D. orphanus*, *D. ellesmerensis*. Dentre os palinórmofos, *Costatascyclus crenatus*, *Protohaploxypinus amplus*, *Spelaetriletes arenaceus*, *S. triangulus*, *Meristocarpus explicatus*, *Striomonosaccites incrassatus* e *Meristocarpus* sp. B constituem espécies bioestratigraficamente importantes, indicando posicionamento do afloramento no Atokano médio, corroborando dados obtidos pelos conodontes.

Palavras-chave: conodontes, palinologia, biocronoestratigrafia, Formação Itaituba, Bacia do Amazonas.

1. Introduction

The Amazonas Basin is a large intracratonic sedimentary basin, occupying ca. 500,000 km² in the northern portion of Brazil, in the states of Amazonas and Pará (Milani & Zalán, 1998), and has been subject of geological interest, mainly for

petroleum. Stratigraphic and structural studies were carried out by Petróleo Brasileiro S.A. (PETROBRAS), based on subsurface data from ca. 200 wells, most of them continuously cored, furnishing information for lithostratigraphic subdivisions (Caputo, 1984). On the other hand, due to an extensive rainforest and deep soil cover

on this region, outcrops are scarce and confined to marginal areas, including the outcropping section analyzed herein. Essentially Paleozoic strata constitute the geological sedimentary record of this basin, encompassing Ordovician to Permian deposits, covered by thin Upper Cretaceous to Paleogene fluvial and lacustrine deposits.

During the Pennsylvanian and the Permian, the Amazonas Basin was located in the north border of the western portion of the Gondwana, constituting a wide intracratonic basin subjected to sea level oscillations. Expressive carbonates and evaporitic beds were deposited, bearing a diversified microfossil record. Such sedimentary deposits correspond to the Tapajós Group, composed by the lithostratigraphical units Monte Alegre, Itaituba, Nova Olinda (Pennsylvanian) and Andirá (Permian) formations (Caputo *et al.*, 1971; Caputo, 1984). Age estimations for the Tapajós Group have been based on spore-pollen assemblages (Daemon & Contreiras, 1971; Playford & Dino, 2000a, 2000b), fusulinids (Altiner & Savini, 1991, 1995) and conodonts (Lemos, 1992a, 1992b; Lemos & Scomazzon, 2001; Nascimento *et al.*, 2005; Scomazzon & Lemos, 2005).

This paper complements previous taxonomic and biostratigraphical works focusing the Itaituba Formation, based on conodont data of outcrops along the southern area of the Amazonas Basin, in the Pará State. Furthermore,

preliminary palynological data are presented herein, which are integrated with biostratigraphic information given by conodonts, in order to promote best accuracy to the biostratigraphy of this unit in the studied area. The section examined is concerned to a limestone quarry, named as “quarry 3”, which is located in the ITACIMPASA Cement Company, 40 km far from the Itaituba City. Conodonts are presented for the first time to this quarry, as well as palynomorphs. Integrated data from both groups furnish a significant contribution for biostratigraphy and respective attributed relative ages to the Itaituba Formation.

2. Geological and biostratigraphical setting

2.1. Geology

According to Cunha *et al.* (1994), the Paleozoic stratigraphic framework of the Amazonas Basin (Fig. 1) includes four units: a) Upper-Silurian Lower Devonian Sequence (Trombetas Group); b) Middle Devonian-Lower Carboniferous Sequence (Urupadé and Curuá Groups); c) Upper Carboniferous-Permian Sequence (Tapajós Group); d) Middle Cretaceous-Recent Sequence (Javari Group). The Pennsylvanian - Permian sequence, of interest herein includes four lithostratigraphical units, in ascending order, Monte Alegre, Itaituba, Nova Olinda and Andirá formations (Fig. 2).

Figure 1. Location map of Amazonas Basin, with location of studied area identified by a star (modified from Scomazzon, 2004).

Figure 2. Chronostratigraphic chart of the Tapajós Group (modified from Matsuda, 2003).

The Itaituba Formation is constituted of a thick package of marine carbonates related to the first Pennsylvanian marine ingression in the basin and has been commonly regarded from late Morrowan to early Desmoinesian in age, according to data of conodonts (Lemos, 1992a, 1992b; Lemos & Scmazzon, 2001; Scmazzon & Lemos, 2005; Nascimento *et al.*, 2005), fusulinids (Altiner & Savini, 1991, 1995) and palynomorphs (Daemon & Contreiras, 1971; Playford & Dino, 2000a, 2000b). This unit overlies the Monte Alegre Formation, of late Morrowan-Atokan in age, based on conodonts and palynomorphs. The Itaituba Formation varies from 110 m in thickness in the southern outcropping area to 420 m in the central part of the basin (subsurface). A diverse marine fauna with U.S. Midcontinent affinities characterizes the carbonate units, and is the richest known fauna of the Amazonas Basin, including corals, bryozoans, crinoids, trilobites, ostracods, gastropods,

bivalves, brachiopods and fish remains, besides microfossils. Shale and siltstone beds often contain crustaceans and plants indicative of episodic freshwater deposition, which are interpreted as shallow marine subtidal to supratidal deposits. The Itaituba Formation is overlaid conformably by the Nova Olinda Formation.

The deposits of quarry 3 are about 20 m long, beginning with sandstones overlapping silty facies, rich in organic matter, with levels of fossil plants and coal. Upwards, it comprises mainly carbonate and siliciclastic rocks, often containing physical and biogenic structures indicative of episodic freshwater deposition interpreted as shallow supratidal deposits by Matsuda (2003) and Moutinho (2006), in which the palynomorphs here discussed were found (Fig. 3).

The sandstones deposits in the basal strata of quarry 3 were considered by Matsuda

(2003) as stratigraphically equivalent to the Mark 65 of Carozzi *et al.* (1972), a lithostratigraphic standard attributed to the Morrowan – Atokan limit. However, Scmazzon (2004) provided evidence by means of conodonts and

lithostratigraphic correlation that the Carozzi's Mark 65 would actually be correlated with the siliciclastic deposits of the lower strata of the Tapajós section, corroborated by Nascimento *et al.* (2005) and Nascimento *et al.* (submitted).

Figure 3. Stratigraphic profile of part of the Itaituba Formation, in the Quarry 3, with sampling for conodonts and palynology.

2.2. Conodont biostratigraphy

Marine deposits of the Itaituba Formation are especially rich in conodonts, which allowed the establishment of biozones for that unit (Lemos, 1992a, 1992b; Lemos & Scmazzon, 2001; Nascimento *et al.*, 2005; Scmazzon & Lemos, 2005). Late Morrowan, Atokan and early Desmoinesian ages have been furnished by this microfossil group, including several common taxa of the North American Midcontinent stages, as briefly discussed bellow.

Lemos (1990) studied 18 wells from diverse localities of north, south and central area of the Amazonas Basin, and described three assemblage zones, in ascending stratigraphic order: the *Neognathodus symmetricus/Rhachistognathus muricatus* Zone, the *Diplognathodus orphanus/Diplognathodus coloradoensis* Zone and the *Streptognathodus elongatus/Idiognathodus ellisoni* Zone. The guide fossils of the first zone (*Rhachistognathus muricatus* and *Neognathodus symmetricus*) occur in the Monte Alegre Formation and lower part of the Itaituba Formation and indicate an early Morrowan age. The second zone contains *D. orphanus*, which is typical of the Atokan and *Diplognathodus coloradoensis*, typical of the early Desmoinesian, which was recovered from the middle part of the Itaituba Formation. The third zone is characterized by the presence of *Streptognathodus elongatus* and *Idiognathodus ellisoni*, which were interpreted to be of Middle-Late Pennsylvanian age, recovered from the Nova Olinda Formation.

Based on four wells from north and south area of the Amazonas Basin, Neis (1996) suggested two assemblage zones: *Idiognathoides ouachitensis / Rhachistognathus muricatus* and *Diplognathodus* spp. The first zone is typical of Morrowan age and occurs from the Monte Alegre to the lower Itaituba Formation. The second zone, with *Diplognathodus* spp. suggests an Atokan age and occurs within the Itaituba Formation. The author suggested a late Morrowan to middle Atokan age for the analyzed interval.

Scmazzon (1999) studied the uppermost part of Monte Alegre Formation and the Itaituba Formation from outcrops of south platform area, erecting three local interval zones: *Idiognathodus sinuosus/Rhachistognathus muricatus* (late Morrowan), comprising the uppermost part of Monte Alegre Formation and the lower part of the Itaituba Formation; *Idiognathodus klappe-*

ri/Streptognathodus parvus (late Morrowan-Atokan) corresponding to the Itaituba Formation; *Idiognathodus claviformis/Idiognathodus incurvus* (early Desmoinesian) to the uppermost part of Itaituba Formation.

Lemos & Scmazzon (2001) redesigned the third zone of Lemos (1990), formerly the *Streptognathodus elongatus/Idiognathodus ellisoni* Zone, as the *Idiognathodus claviformis/Idiognathodus incurvus* Zone. This biozone occurs near the base of the Nova Olinda Formation estimating an early Desmoinesian age to carbonate and shales of 18 wells and 4 outcrops.

Based on eighteen wells and 3 south outcrops, comprising a profile from north through south platform of the Amazonas Basin, Scmazzon (2004) established a taxon-range zone of *Idiognathodus incurvus* to the Itaituba Formation and lower part of Nova Olinda Formation and a sub-zone of *Diplognathodus coloradoensis* to the Itaituba Formation, suggesting middle Atokan - early Desmoinesian age to the analyzed section.

Nascimento *et al.* (2005) proposed one taxon-range zone and one sub-zone to the strata of quarries 1 and 2, of the ITACIMPASA Cement Company, located in the south region of the Itaituba Formation, respectively: *Idiognathoides sinuatus* zone and *Neognathodus roundyi* sub-zone. The *Idiognathoides sinuatus* zone extends from the lower part of quarry 1 to the upper part of quarry 2, and is recognized by the occurrence of the species nominated zone. The *Neognathodus roundyi* sub-zone is recognized by the local occurrence of this species in the basal portion of quarry 2. The proposed zone and sub-zone helps to estimate an Atokan age to this profile.

Two taxon-range zones named *Rhachistognathus muricatus* and *Diplognathodus orphanus* were proposed by Nascimento *et al.* (submitted). The former zone corresponds to the Morrowan stage, correlated in lithostratigraphic terms, sandstones of the upper strata of the Monte Alegre Formation and lower Itaituba Formation. The latter zone corresponds to the Atokan stage, correlating in lithostratigraphic terms to the Itaituba Formation. An assemblage zone named *Idiognathodus incurvus/Neognathodus atokaensis/Neognathodus medadulimus* was also proposed, corresponding to the Atokan stage and correlated in lithostratigraphic terms to the Itaituba Formation. The occurrence of *Diplognathodus orphanus* in to the level P3C16 and

Idiognathodus incurvus from the level P3C57 up to the level P3C19 (quarries 2 and 3) confirms an Atokan age to the studied section (Nascimento *et al.*, submitted).

2.3. Palynostratigraphy

An extensive taxonomic work was developed by Playford & Dino (2000a, 2000b), from core samples and cuttings of 26 boreholes distributed in the Amazonas Basin, encompassing all the lithostratigraphic units of the Tapajós Group. Seven palynozones were erected by those authors, based on the spore-pollen distribution. These authors used stratigraphic restricted species as well as other features such as the abundance and the concurrence of certain species for the palynozone definition and characterization.

In stratigraphic ascending order, these palynozones are: *Spelaeotriletes triangulus* Zone, *Striomonosaccites incrassatus* Zone, *Illinites unicus* Zone, *Striatosporites heyleri* Zone, *Raistrickia cephalata* Zone, *Vittatina costabilis* Zone and the *Tornopollenites toreutos* Zone. The *Spelaeotriletes triangulus* Zone was recognized within the Monte Alegre Formation and the lowermost Itaituba Formation, and was assigned to the Westphalian A/B (Morrowan/Atokan) age. The subsequent *Striomonosaccites incrassatus* Zone and the *Illinites unicus* Zone also belong to the Itaituba Formation and were regarded as Westphalian C (Atokan/Desmoinesian) in age. The *Striatosporites heyleri* and the *Raistrickia cephalata* Zone occur within the basal and middle portion of the Nova Olinda Formation, assigned to the Westphalian C/D (Desmoinesian) age. The upper Nova Olinda Formation and the lower Andirá Formation constitute the *Vittatina costabilis* Zone, assigned to the Sakmarian/Kazanian (Wolfcampian/Wordian) age, and the *Tornopollenites toreutos* Zone, related to the middle and upper Andirá Formation, was assigned to the Kazanian/Tatarian (Wordian/Capitanian) age. Based on the ages attributed by Playford & Dino (2000b, text-fig. 5), a significant hiatus characterizes the limit between the Pennsylvanian *Raistrickia cephalata* Zone and the Early Permian *Vittatina costabilis* Zone, within the Andirá Formation.

3. Material and methods

The study strata is located in the North region of Brazil, Itaituba, Pará State, constituting area of exploration of the ITACIMPASA Cement Company (previously known as Caima Cement Company). In this area, a vertical section of ca. 80 m of the Itaituba Formation outcrops along four localities: in the margin of the Tapajós river, and 3 quarries. These deposits correspond to part of the outcropping sections of the south margin of the Amazonas Basin (Fig. 1). Samples used herein were collected in the “quarry 3” (P3), which corresponds to the uppermost section of the Itaituba Formation in this area. A total of six levels from the quarry 3 were sampled for conodont analysis and processed according to the methods of Austin (1987). A total of 21 levels of this quarry were sampled for conodonts and palynology; among them, only 6 have provided results for conodonts and one for palynology, as demonstrated in the figure 3.

Palynomorphs were retrieved using the standard palynological method for Paleozoic samples (Quadros & Melo, 1988). Carbonates and silicates were removed using hydrochloric acid. Palynomorphs were concentrated for miospore study with sieves of 20-250 μ m. Glass slides were prepared from few drops of residue mounted with polyester resins (“Celosize” and “Entellan”). The taxonomic study and the photographs were made under optical light microscopy.

Slides are housed in the Paleontological Museum of the Paleontology and Stratigraphy Department, Geosciences Institute, Rio Grande do Sul Federal University. Conodont slides are codified under numbers MP-M 816 to MP-M 822, and palynological ones under catalogue numbers MP-P 5559 to MP-P 5565.

4. Results

The micropaleontological content of the studied levels includes conodonts and palynomorphs (miospores), which are listed in the Appendix 1 and 2. Selected species are illustrated in the figures 4 and 5.

Stratigraphic distribution of conodont species (based on six levels) and palynology (one level) is shown in the figure 3. Furthermore, undetermined megaspores and plant remains (preliminary attributed to *Lepidodendrum*) were also recorded in quarry 3 (P3C6 level), associated with palynomorphs. Megaspores specimens show low variety and are very well preserved. They constitute focus of detailed studies in development.

The conodonts in the quarry 3 are mainly Pa elements of *Idiognathodus*, *Diplognathodus*, *Idiognathoides*, *Adetognathus* and *Hindeodus*. The species *Idiognathodus incurvus* and *Diplognathodus orphanus* are the most abundant. However, associations of conodonts are in general poorly diverse and show bad preservation. Besides, the elements are rare in all levels, excepting the level P3C16, which corresponds to a wackestone (Fig. 3). Below this section, the quarry 2 shows a great variety of conodonts, which are abundant and well preserved.

Four species of spores, 12 of pollen grains and one algae (chlorophycean) were recorded in the level P3C6 as indigenous taxa. Such assemblage is relatively diversified, being pollen

grains dominant, mainly those ones with radial symmetry, such as *Cannanoropollis* spp. Among the spores, most frequent species are the pseudosaccate ones (mainly *Spelaotriletes arenaceus* and *S. triangulus*).

Indigenous species of spores are: *Apiculatasporites daemonei*, *Vallatisporites punctatus*, *Spelaotriletes arenaceus* and *Spelaotriletes triangulus*. Pollen grains are: *Potonieisporites novices*, *Potonieisporites congoensis*, *Costatascyclus crenatus*, *Cannanoropolis janakii*, *Cannanoropolis densus*, *Plicatipollenites malabarensis*, *Striomonosaccites incrassatus*, *Meristocarpus explicates*, *Meristocarpus* sp. B, *Illinites unicus*, *Protohaploxylinus amplus* and *Cycadopites* sp. Specimens of Chlorophycean algae was also recorded (*Botryococcus braunii*).

Furthermore, recycled species were also recorded, which is more common from Devonian strata of the South American intracratonic basins, such as *Maranhites insulatus* Burjack & Oliveira 1989. These reworked species are generally semi-destroyed, while indigenous species are relatively better preserved.

Figure 4. Photomicrographs of selected conodonts from quarry 3. A. *Idiognathoides sinuatus* (Slide MP-M:816, from the level P3C16); B. *Idiognathodus incurvus* (MP-M: 817, P3C16); C. *Idiognathodus incurvus* (MP-M: 818, P3C16); D. *Adetognathus lautus* (MP-M:819, P3C21); E. *Idiognathodus incurvus* (MP-M: 823, P3C16); F. *Hindeodus minutus* (MP-M:820, P3C14), G. *Diplognathodus orphanus* (MP-M:821, P3C16), H. *Diplognathodus coloradoensis* (MP-M:822, P3C16).

Figure 5. Photomicrographs of selected palynomorphs from quarry 3. A. *Apiculatasporites daemonii* (Slide MP-P: 5563, from the level P3C6); B. *Vallatisporites punctatus* (MP-P: 5559, P3C6); C. *Spelaeotriletes triangulus* (MP-P: 5564, P3C6); D. *Spelaeotriletes arenaceus* Neves & Owens, 1966 (MP-P: 5559, P3C6); E. *Potonieisporites novicus* Bhardwaj, 1954 (MP-P: 5565, P3C6); F. *Striomonosaccites incrassatus* Playford & Dino, 2000 (MP-P: 5559, P3C6); G. *Meristocarpus* sp. B Playford & Dino, 2000 (MP-P: 5564, P3C6); H. *Meristocarpus* sp. B Playford & Dino, 2000 (MP-P: 5559, P3C6); I. *Meristocarpus explicatus* Playford & Dino, 2000 (MP-P: 5564, P3C6); J. *Protohaploxypinus amplus* (Balme & Hennelly) Hart, 1964 (MP-P: 5563, P3C6); K. *Cycadopites* sp. (MP-P: 5564, P3C6); L. *Botryococcus braunii* Kützing, 1949 (MP-P: 5564, P3C6). (Scale bar corresponds to 10 μ m).

5. Discussion

This work reports for the first time conodonts and palynomorphs associations found in quarry 3 and the lithostratigraphic conclusions obtained from both methods seem compatible, as discussed herein. The occurrence of *Diplognathodus orphanus* is an excellent marker of Atokan age for the level P3C16, as well as *Idiognathodus incurvus*. The former occurs from the level P2C57 (quarry 2) up to the level P3C19 (quarry 3), while the last one was recorded in all quarries and in the outcrop at the margin of the Tapajós river. These last taxa, as well as species of *Idiognathoides*, *Adethognathus* and *Hindeodus* show a close affinity with North American assemblages, especially those from the Mid Continent, as discussed by Nascimento *et al.* (submitted). *Idiognathodus incurvus* is regarded a guide species for the middle Atokan in North America (Grayson *et al.*, 1989; Grayson, 1990) and in Turkey (Ekmekcu & Kozur, 1999). The genus *Diplognathodus* was used by Lane (1977) for the recognition of the Morrowan/Atokan boundary in the North America. The first appearance of *D. orphanus* was interpreted by Bender (1980) and Manger & Sutherland (1984) as the basal limit of the Atokan. This genus is very rare in the deposits stratigraphically below the studied quarry 3. where, this genus is more abundant. It has the last occurrence within the P3C16 level, upon the studied palynological level.

The samples analyzed for palynology provided some important species for biostratigraphy, such as *Spelaeotriletes arenaceus*, *S. triangulus*, *Costatascyclus crenatus*, *Protohaploxyypinus amplus*, *Meristocarpus explicatus*, *Striomonosaccites incrassatus* and *Meristocarpus* sp. B of Playford & Dino (2000a). This assemblage concerns to the *Striomonosaccites incrassatus* Zone (Playford & Dino, 2000b), which is characterized by the introduction of some pollen species, such as *Illinites unicus*, *Striomonosaccites incrassatus* and *Meristocarpus explicatus*. This zone shows relatively high frequencies of *Spelaeotriletes triangulus* and *S. arenaceus*; its upper boundary is manifested by the disappearance of *Costatascyclus crenatus* and *Potonieisporites seorsus*. Therefore, the records of *Costatascyclus crenatus*, *Striomonosaccites incrassatus*, *Meristocarpus explicatus*, *Illinites unicus* besides the high frequencies of *Spelaeotriletes arenaceus* and *Spelaeotriletes triangulus* in the studied sample are in accordance with the main

characteristics of the *S. incrassatus* Zone.

Lithostratigraphically, the *S. incrassatus* Zone corresponds to the lower to middle portions of the Itaituba Formation (Playford & Dino, 2000b), which contain the richest faunas of the Tapajós Groups, including brachiopods, bryozoans, crinoids, fusulinids and conodonts (Playford & Dino, 2000b). Some levels bearing fusulinids in this unit have suggested a Morrowan-early Atokan age (Altiner & Savini, 1995), on the basis of correlation with U.S. Midcontinent and Western Europe assemblages of fusulinids, where they are found in Namurian C-Westphalian A deposits. However, a Westphalian A-C age was attributed by Playford & Dino (2000b) for this palynozone. According to these authors, the joint association of *Illinites unicus*, *Protohaploxyypinus amplus*, *Cannanoropollis jankii*, *Striomonosaccites incrassatus*, *Costatascyclus crenatus*, *Spelaeotriletes arenaceus* and *S. triangulus* corresponds to a late Westphalian age, probably Westphalian C (middle/upper Atokan).

Pennsylvanian palynological assemblages known from the neighbor Parnaíba Basin were described from the Piauí Formation by Dino & Playford (2002) and Souza *et al.* (submitted). Taking into account the zones established to the Amazonas Basin, these assemblages were compared to the *Illinites unicus* Zone and the *Raistrickia cephalata* Zone, respectively, with younger ages (latest Atokan to Desmoinesian).

6. Concluding remarks

Ages attributed by pollen-spores assemblages along the Gondwana basins are used as a tool for correlations, mainly for those strata where international guides are absent, such as fusulinids and certain intertebrates. Conodonts constitute an important group for age determinations and correlations, especially used from the Euramerican Paleozoic deposits. The integrative analysis obtained herein corroborates a middle Atokan age established particularly on the basis of each group of microfossils, demonstrating the importance of both tools in biostratigraphic studies. Paleoenvironmental data obtained from this study corroborates a shallow marine interpretation for most part of the sections in the quarries 1, 2 and 3. However, the record of megaspores and plant remains indicates a strong continental influence, testifying proximal facies within the Itaituba Formation, previously

regarded as predominantly (or exclusively) marine in origin. Descriptions of megaspores and plant remains, as well as the complete list of taxa, with taxonomic news are subject of a detailed study in preparation by the authors (LPS and PAS), and will expand and improve the paleoenvironmental results exposed herein.

Acknowledgements - Authors thank to José Emidio and Paulo Rubens from ITACIMPASA Cement Company for allowing access to sampling, and Cristiane Pakulski da Silva for support in samples processing and figures. This research was supported by grants from CNPq (472153/2003, 483947/2007-5).

References

- Altiner, D. & Savini, R. 1991. *Pennsylvanian Foraminifera and Carbonate Microfacies from the Amazon and Solimões Basins: Biostratigraphic, Paleocologic and Paleogeographic Results*. Rio de Janeiro, PETROBRAS (Internal report).
- Altiner, D. & Savini, R. 1995. Pennsylvanian foraminifera and biostratigraphy of the Amazonas and Solimões Basin (North Brazil). *Revue de Paleobiologie*, 14(2): 417-453.
- Austin, R.L. 1987. *Conodonts: Investigative techniques and applications*. Ellis Horwood, 562 p., British Micropaleontological Society Series.
- Bender, K.P. 1980. Lower and Middle Pennsylvanian conodonts from the Canadian Arctic Archipelago. *Geological Survey of Canada*, 79(15): 1-24
- Caputo, M.V. 1984. *Stratigraphy, tectonics, paleoclimatology and paleogeography of northern basins of Brazil*. 1984, 582p., Ph.D. Dissertation, University of California, Santa Barbara.
- Caputo, M.V., Rodrigues, R. & Vasconcelos, D.N.N. 1971. *Litoestratigrafia da Bacia do Amazonas*. Belém, PETROBRAS/RENOR (Internal report).
- Carozzi, A.V., Alves, R.J. & Castro, J.C. 1972. Controle tectônico sedimentar dos carbonatos permocarboníferos das formações Itaituba e Nova Olinda da Bacia do Amazonas. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 26., 1972, Belém. *Anais...*, Belém, Sociedade Brasileira de Geologia, v. 3, p. 47 - 64.
- Cunha, P.R.C., Gonzaga, F.G., Coutinho, L.F.C. & Feijó, F.J. 1994. Bacia do Amazonas. *Boletim de Geociências da Petrobras*, 8(1): 47-55.
- Daemon, R.F. & Contreiras, C.J.A. 1971. Zoneamento palinológico da Bacia do Amazonas. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 25., São Paulo. *Anais...*, Sociedade Brasileira de Geologia, v. 3, p. 79-88.
- Dino, R. & Playford, G. 2002. Stratigraphic and palaeoenvironmental significance of a Pennsylvanian (Upper Carboniferous) palynoflora from the Piauí Formation, Parnaíba Basin, northeastern Brazil. *Paleontological Research*, 6(1): 23-40.
- Ekmekçi, I.E. & Kozur, H.W. 1999. Conodonts of Middle Moscovian Age from the Kongul Formation. *Geological Croatia*, 52(1): 1-8.
- Grayson Jr., R.C. 1990. Canyon Creek: A Significant Exposure of a Predominantly Mudrock. Succession Recording Essentially Continuous Deposition from the Late Devonian through the Middle Pennsylvanian. *Oklahoma Geological Survey Guidebook*, 27: 85-114.
- Grayson Jr., R.C., Merrill, G.K., Lambert, L.L. & Turner, J. 1989. Phylogenetic Basis for Species Recognition within the Conodont Genus *Idiognathodus*: Applicability to Correlation and Boundary Placement. In: Boardman II, D. R., Barrick, J.E., Cocke, J. & Nestell, M.K. (Ed.), *Middle and Late Pennsylvanian Chronostratigraphic boundaries in northcentral Texas*. Texas Tech University Studies in Geology, v. 2, p. 75-94.
- Lane, H.R. 1977. Morrowan (Early Pennsylvanian) conodonts of northwestern Arkansas and northeastern Oklahoma, In: P.K. Sutherland & W.L. Manger (ed.), Upper Chesterian Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in Northeastern Oklahoma and northwestern Arkansas. *Oklahoma Geological Survey Guidebook*, v. 18, p. 177-180.
- Lemos, V.B. 1990. *Assembléias de Conodontes do Carbonífero da Bacia do Amazonas*. Porto Alegre, 259p. Tese de Doutorado, Programa de Pós-graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul.
- Lemos, V.B. 1992a. Conodontes do Carbonífero das Bacias do Amazonas e Solimões. *Taxonomia Parte I. Pesquisas*, 19(1): 75-93.
- Lemos, V.B. 1992b. Conodontes do Carbonífero das Bacias do Amazonas e Solimões. *Taxonomia - Parte II. Pesquisas*, 19(2): 120-131
- Lemos, V.B. & Scamozzi, A.K. 2001. Carboniferous biostratigraphy of the Amazonas Basin, Brazil, based on conodonts. Correlação de Sequências Paleozóicas Sul-Americanas. In: Melo, J.H.G. & Terra, G.S.T. (Ed.), *Ciência Técnica Petróleo, Seção: Exploração de Petróleo*, 20: 131-138.
- Manger, W.I. & Sutherland, P.K. 1984. Preliminary conodont biostratigraphy of the Morrowan-Atokan boundary (Pennsylvanian), eastern Llano Uplift, central Texas. *Oklahoma Geological Survey Bulletin*, 136: 115-122
- Matsuda, N.S. 2003. *Carbonate sedimentation cycle and origin of dolomite in the Lower Pennsylvanian intracratonic Amazon Basin, Northern Brazil*. Tokyo, 231p. PhD Thesis, Department of Earth & Planetary Sciences, University of Tokyo.
- Milani, E.J. & Zalán, P.V. 1998. *The geology of paleozoic cratonic basins and mesozoic interior rifts of Brazil. (Brazilian Geology Part I)*. AAPG International Conference & Exhibition, 184p.
- Moutinho, L.P. 2006. *Assinaturas tafonômicas dos*

- invertebrados da Formação Itaituba – Aplicação como ferramenta de análise estratigráfica e paleológica na seção pensilvaniana aflorante na porção sul da Bacia do Amazonas, Brasil*. 325p. Tese de Doutorado, Programa de Pós-graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Porto Alegre.
- Nascimento, N., Scmazzon, A.K., Lemos, V.B., Moutinho, L.P. & Matsuda, N. S. Conodont Biostratigraphy and Paleogeology of a Lower Pennsylvanian Marine Calcareous Profile - Itaituba Formation, Southern Region of Amazonas Basin. *Pesquisas em Geociências* (submetido).
- Nascimento, S., Scmazzon, A.K., Moutinho, L.P., Lemos, V.B. & Matsuda, N.S. 2005. Conodont Biostratigraphy of the Lower Itaituba Formation (Atokan, Pennsylvanian), Amazonas Basin, Brazil. *Revista Brasileira de Paleontologia*, 8(3): 193-202.
- Neis, P.A. 1996. *Resultados biocronoestratigráficos das associações de conodontes da Formação Itaituba, Carbonífero Superior (Pensilvaniano), da Bacia do Amazonas*. Porto Alegre. 138p. Dissertação de Mestrado, Programa de Pós-graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul.
- Playford, G. & Dino, R. 2000a. Palynostratigraphy of upper Palaeozoic strata (Tapajós Group), Amazonas Basin, Brazil: Part one. *Palaeontographica* Abt. B. Bd., 255: 1-46.
- Playford, G. B. & Dino, R. 2000b. Palynostratigraphy of upper Palaeozoic strata (Tapajós Group), Amazonas Basin, Brazil: Part two. *Palaeontographica* Abt. B, 255:87-145.
- Quadros, L.P. de. & Melo, J.H.G. 1988. Método prático de preparação palinológica em sedimentos pré-mesozóicos. *Boletim de Geociências da Petrobrás*, 1(2): 205-214.
- Scmazzon, A.K. 1999. *Refinamento bioestratigráfico com base em conodontes, Pensilvaniano da Bacia do Amazonas, região do Tapajós*. Porto Alegre, 142p. Dissertação de Mestrado, Programa de Pós-graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul.
- Scmazzon, A.K. 2004. *Estudo de conodontes em carbonatos marinhos do Grupo Tapajós, Pensilvaniano inferior a médio da Bacia do Amazonas com aplicação de isótopos de Sr e Nd neste intervalo*. Porto Alegre, 294p. Tese de Doutorado, Programa de Pós-graduação em Geociências, Instituto de Geociências, Universidade Federal do Rio Grande do Sul.
- Scmazzon, A. K. & Lemos, V. B. 2005. *Diplognathodus* occurrence in the Itaituba Formation, Amazonas Basin, Brazil. *Revista Brasileira de Paleontologia*, 8(3): 203-208.
- Souza, P.A., Matzembacher, L.T., Abelha, M. & Borghi, L. Palinologia da Formação Piauí, Pensilvaniano da Bacia do Parnaíba: biocronoestratigrafia de intervalo selecionado do poço 1-UN-09-PI (Caxias, MA). *Revista Brasileira de Paleontologia* (submetido).

Appendix 1. Taxonomic basis of palynomorphs.

Spores

- Apiculatasporites daemonii* Playford & Dino 2000
Spelaeotriletes arenaceus Neves & Owens 1966
Spelaeotriletes triangulus Neves & Owens 1966
Vallatisporites punctatus (Marques-Toigo) Souza, Dino & Petri 2003

Pollen grains

- Cannanoropolis densus* (Lele) Bose & Maheshwari 1968
Cannanoropolis janaki. Potonié & Sah 1960
Costatascyclus crenatus Felix & Burbridge emend Urban 1971
Cycadopites sp.
Illinites unicus Kosanke 1950
Meristocarpus explicatus Playford & Dino 2000
Meristocarpus sp. B of Playford & Dino (2000)
Plicatipollenites malabarensis (R. Potonié & Sah) Foster 1975
Potonieisporites congoensis Bose & Maheshwari 1968
Potonieisporites novicus Bharadwaj 1954
Protohaploxypinus amplus (Balme & Hennelly) Hart 1964
Striomonosaccites incrassatus Playford & Dino 2000

Algae

- Botryococcus braunii* Kützing 1949

Appendix 2. Taxonomic basis of conodonts.

- Adetognathus lautus* Gunnell, 1933
Diplognathodus coloradoensis Murray & Chronic, 1965
Diplognathodus ellesmerensis Bender, 1980
Diplognathodus orphanus Merrill, 1973
Hindeodus minutus Ellison, 1941
Idiognathodus incurvus Dunn, 1966
Idiognathoides sinuatus Harris & Hollingsworth, 1933