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CONODONT BIOSTRATIGRAPHY OF THE LOWER ITAITUBA FORMATION (ATOKAN, PENNSYLVANIAN), AMAZONAS BASIN, BRAZIL

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ABSTRACT – This study reports on the conodonts from an outcrop region in the south Amazonas Basin that comprises the lower part of the Itaituba Formation. The studied area consists of two limestone quarries, informally named 1 and 2, owned by CAIMA, a cement industry. The conodont association includes Pa elements of *Idiognathodus incurvus, Idiognathoides sinuatus, Neognathodus roundyi, N. medadultimus, N. bassleri, N. atokaensis, Adetognathus lautus, Hindeodus minutus, Diplognathodus coloradoensis,* and *Idioprioniodus* sp. It is herein proposed one informal taxon-range zone and one subzone, respectively: *Idiognathoides sinuatus* zone and *Neognathodus roundyi* subzone. The conodonts occur mainly in the packstones, and subordinately in the wackestones and mudstones. The Itaituba Formation is the richest interval containing normal marine organisms in the Pennsylvanian of Amazonas Basin. The associated fauna includes brachiopods, crinoids, echinoids, bryozoans, gastropods, foraminifers, sponges, ostracodes, trilobites, scolecodonts, bivalves and fish teeth and scales. The studied interval is characterized by moderate to high levels of bioturbation. Burrows are common in the packstones and wackestones. The predominant trace fossil observed was classified as *Thalassinoides*, occurring mainly in the packstones and wackstones. *Zoophycos* occurs less commonly, in the mudstones and packstones. Because of the presence at the conodonts *Neognathodus atokaensis* and *Idiognathodus incurvus*, it is possible to suggest an Atokan age for the analyzed interval. The associated fauna, bioturbation, and lithology suggests shallow, nearshore waters, with mudstones of low-energy, wackestones and packstones of moderate-energy, and grainstones of relatively high-energy marine conditions.

Key words: Conodonts, Morrowan, Atokan, Amazonas Basin, biostratigraphy.

RESUMO – Este estudo tem por objetivo analisar a fauna de conodontes na região sul da Bacia do Amazonas, compreendendo a porção mais inferior da Formação Itaituba e, através desses organismos, refinar a idade sugerida para este intervalo, discutindo o limite Morrowano-Atokano nesta região. A área de estudo é representada por duas pedreiras de calcário, denominadas informalmente como 1 e 2, exploradas pela indústria de cimento CAIMA. Dentre os conodontes encontrados estão: *Idiognathodus incurvus, Idiognathoides sinuatus, Neognathodus roundyi, N. atokaensis, N. medadultimus, N. bassleri, Diplognathodus coloradoensis, Adetognathus lautus, Hindeodus minutus* e *Idioprioniodus* sp. Foi aqui informalmente proposta uma zona de ocorrência de *Idiognathoides sinuatus* e uma subzona de ocorrência de *Neognathodus roundyi*. Os conodontes ocorrem predominantemente nos *packstones* e secundariamente nos *wackestones* e *mudstones*. A Formação Itaituba é o intervalo mais abundante em fósseis do Pensilvaniano da Bacia do Amazonas, com espessos pacotes de carbonatos marinhos ricos em organismos de fauna marinha normal, sendo composta por braquiópodes, gastrópodes, crinóides, briozoários, foraminíferos, ostracodes, trilobitas, escolecodontes, dentes de peixes e fragmentos orgânicos. O intervalo estudado é caracterizado por níveis de moderada a alta bioturbação. As bioturbações são freqüentes nos *packstones* e *wackestones*. O traço fóssil predominante foi classificado como icnogênero *Thalassinoides*, ocorrendo principalmente nos *packstones* e *wackstones* e *Zoophycos*, ocorrendo secundariamente em *mudstones* e *packstones*. Os conodontes estudados, principalmente *Neognathodus atokaensis* e *Idiognathodus incurvus*, sugerem uma idade Atokana para o intervalo analisado. Além disso, a fauna associada, bioturbação e caracteres litológicos descritos, atestam um ambiente de água rasa, proximal, com *mudstones* de energia baixa, *wackestones* e *packstones* de energia moderada e *grainstones* de energia relativamente alta.

Palavras-chave: Conodontes, Morrowano, Atokano, bacia do Amazonas, bioestratigrafia.

INTRODUCTION

The Pennsylvanian Itaituba Formation has the thickest marine carbonate deposits and the richest preservation of marine organisms of the Amazonas Basin. This formation has been intensively studied in terms of its sedimentary deposits and fossil constituents. The study area is located in the Amazonas Basin, northern Brazil. It comprises two calcareous quarries situated 30 km of Itaituba city, corresponding to the map locations 1 and 2 (Figure 1).

Preliminary studies regarding the fossil assemblages were undertaken to determine the systematic classification, the biostratigraphic range and correlation of the conodont group (Lemos, 1990; Lemos & Medeiros, 1996; Scomazzon, 1999, among others).

This work aims to describe the conodonts and associated fauna of two calcareous quarries in the lower part of the Itaituba Formation, Pennsylvanian of the Amazonas Basin. The studied conodonts are characteristic of the early Pennsylvanian, Morrowan and Atokan stages and have been used to biostratigraphically refine the Carboniferous of the Amazonas Basin. The study involves the establishment of one informal biostratigraphic taxon-range zone and one subzone, and determination of the paleoecological conditions in which these microfossils were deposited.

MATERIALS AND METHODS

Seventy-five samples, totalling thirty-seven kg of rocks, mainly carbonates, were processed for the study of conodonts. The laboratory techniques followed the methodology of Austin (1987).

In addition, 15 carbonates thin-sections from quarry 1 and 12 thin-sections from quarry 2 were prepared. From the thin-sections the associated fauna was described and examples photographed in the Laboratory of Paleontology at UFRGS (Universidade Federal do Rio Grande do Sul). The conodonts presented in this study belong to the collection of the Departamento de Paleontologia e Estratigrafia, UFRGS (MP-M).

GEOLOGIC SETTING

The Amazonas Basin is a large intracratonic sedimentary basin occupying 500,000 km^2 within the northern Brazilian states of Amazonas and Pará. Its strata cover the Precambrian provinces of the Guyanas Shield to the north and the Guaporé Shield to the south. To the east, it is separated from the Marajó Basin by the Gurupá Arch. To the west, is separated from Solimões Basin by a subsurface basement-high, the N-S trending Purus Arch. In its depocenter, the basin preserves a stratigraphic record up to 5,000 m thick deposited from Proterozoic through Tertiary time. The Carboniferous-Permian strata accounts for more than half of the total thickness (Milani & Zalán, 1998).

In structural and depositional terms, the Amazonas Basin is divisible into three distinct sectors, a northern plataform, a southern platform, and a deep central basin area. These trend generally east-west, and evolved geologically for 500 Ma. Along both the northern and southern boundaries of the basin are outcrops of Paleozoic rock.

The stratigraphic framework of the Amazonas Basin includes three Paleozoic units covered by Cretaceous to Recent continental clastics (Cunha *et al*., 1994): the Ordovician – Devonian Unit, Devonian – Mississippian Unit, and Pennsylvanian – Permian Unit. The latter unit accumulated following intense erosion caused by the early Hercynian Orogenic episode. It represents a transgressive to regressive cycle from the Pennsylvanian through the Permian time associated with significant climatic changes from cold to warm and arid (Scotese & Mckerrow, 1990). This cycle corresponds to the rocks of the Tapajós Group, which consists of four conformable formations, in ascending order the Monte Alegre, Itaituba, Nova Olinda and Andirá formations (Cunha *et al*., 1994).

The Itaituba Formation overlies the Monte Alegre Formation. The Monte Alegre is considered to be late Morrowan-Atokan in age. The Itaituba varies from 110 m thick in the southern outcrop area to 420 m thick in the central part of the basin. The dominant lithologies include mainly intercalated carbonates and evaporates, and secondarily, clastics. A diverse marine fauna with Andean and U.S. Midcontinent affinities characterizes the carbonate units, and are the richest known from the Amazonas Basin. Groups represented include foraminifers, corals, bryozoans, crinoids, trilobites, ostracodes, gastropods, brachiopods, scolecodonts, fish remains and conodonts. Shale and siltstone beds often contain crustaceans and plants indicative of episodic freshwater deposition and are interpreted as shallow marine subtidal to supratidal environments. The Itaituba Formation is overlaid conformably by the Nova Olinda Formation of Atokan-early Desmoinesian age.

Age estimations of the Itaituba Formation have been based on microfossil assemblages, including spores and pollen (Playford & Dino, 2000), fusulinids (Altiner & Savini, 1995), and conodonts (Lemos, 1990, 1992a,b; Neis, 1996, Scomazzon, 1999), but they are controversial.

CONODONT BIOSTRATIGRAPHIC ANALYSIS

The first discussion of the conodont biostratigraphy in the Amazonas Basin based on multielement taxonomy was made by Lemos (1990, 1992 a,b), followed by Lemos & Medeiros (1996), Neis (1996), Scomazzon (1999), and Lemos & Scomazzon (2001), each analyzing different areas in the Amazonas region.

Lemos (1990) described three assemblage zones: *Neognathodus symmetricus/Rhachistognathus muricatus*, *Diplognathodus orphanus*/*D. coloradoensis*; and *Streptognathodus elongatus*/*Idiognathodus ellisoni*. The first zone contains *R. muricatus* and *N. symmetricus* which are characteristic of early Morrowan age. These species occur in the Monte Ale-

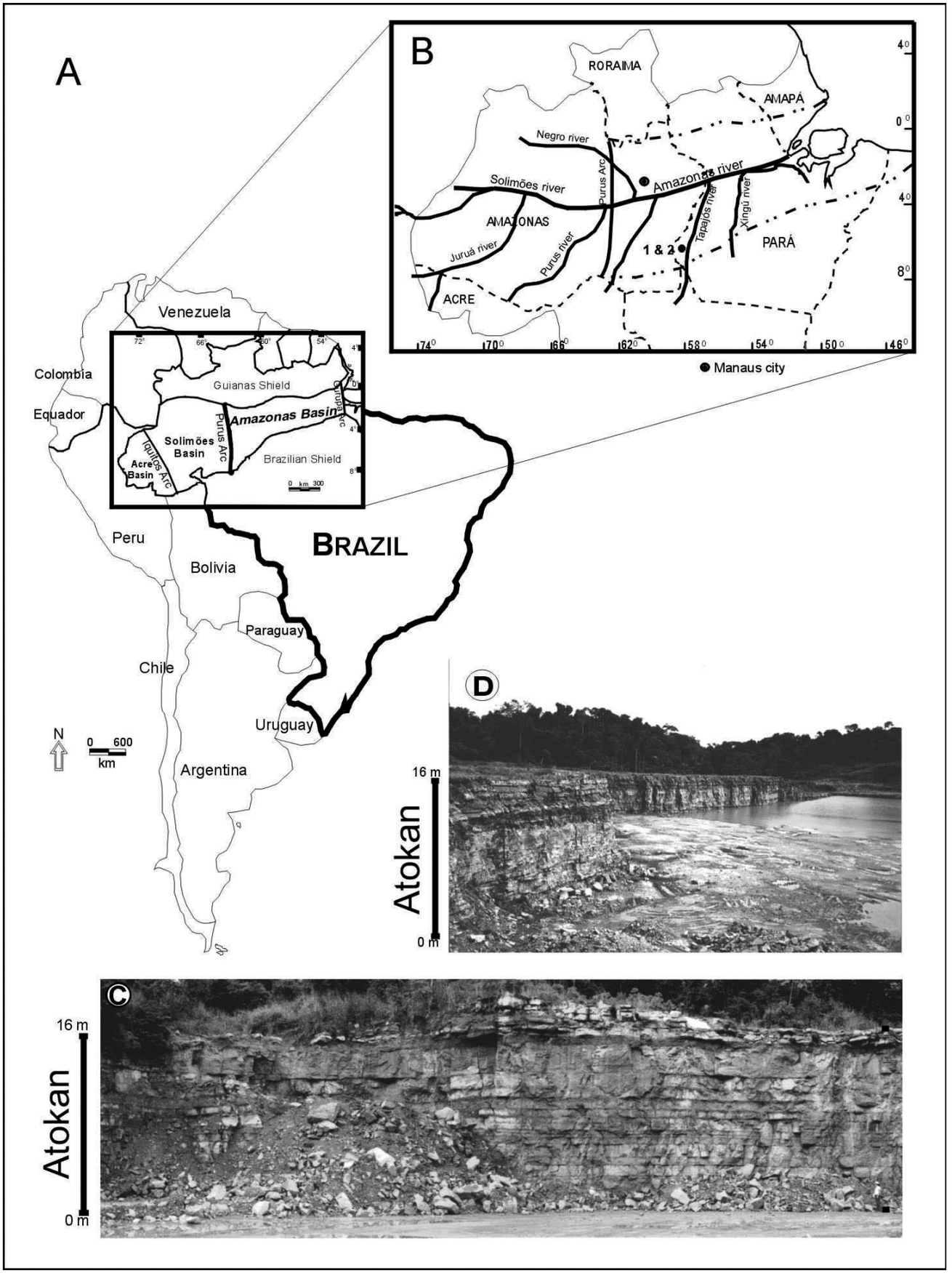

Figure 1. Collecting site map: **A,** Location map of the Amazonas Basin, northern Brazil; **B,** location map of the quarries 1 and 2; **C,** quarry 1; **D,** quarry 2 (modified from Scomazzon,1999).

gre Formation and lower part of the Itaituba Formation. The second zone contains *D. orphanus*, which is typical of the Atokan, and *Diplognathodus coloradoensis*, typical of the early Desmoinesian, and were recovered from the middle part of the Itaituba Formation. The third zone is characterized by *S. elongatus* and *I. ellisoni*, which were interpreted to be of Middle-Late Pennsylvanian age, recovered from the Nova Olinda Formation.

Neis (1996) suggested two zones: *Idiognathoides ouachitensis/Rhachistognathus muricatus*; and *Diplognathodus* spp. The first zone is typical of Morrowan age rocks, with *Rhachistognathus muricatus* and *Idiognathoides ouachitensis*. The second zone, with *Diplognathodus* suggests an Atokan age. The conodont associations studied by Neis (1996) suggest a late Morrowan to middle Atokan age for this interval in the Itaituba Formation.

Scomazzon (1999), who also studied the Itaituba Formation, suggested three interval zones: *Idiognathodus sinuosus*/*Rhachistognathus muricatus* - late Morrowan; *Idiognathodus klapperi*/*Streptognathodus parvus* - late Morrowan-Atokan; and *Idiognathodus claviformis*/*Idiognathodus incurvus* - early Desmoinesian.

Lemos & Scomazzon (2001) redesignated the third zone of Lemos (1990), formerly the *Streptognathodus elongatus*/*Idiognathodus ellisoni* zone, as the *Idiognathodus claviformis/Idiognathodus incurvus* zone.

The conodont fauna analyzed herein comprises twenty-four specimens collected from quarry 1 (Table 1), and eighty-two specimens from the quarry 2 (Table 2), totalling one-hundred and six specimens assigned to seven genera and ten species. The fauna is dominated by Pa elements of *Idiognathodus incurvus*, *Idiognathoides sinuatus* and *Neognathodus* spp., and to a lesser extent by *Adetognathus lautus*, *Hindeodus minutus*, *Diplognathodus coloradoensis*, *D. orphanus* and *Idioprioniodus* sp. (Figure 2). The conodonts were recovered from the upper part of quarry 1 and the lower part of quarry 2. *Idiognathoides sinuatus* and *Idiognathodus incurvus* are the most abundant in quarry 1. *Neognathodus* spp. appears only in the quarry 2. *Idiognathodus incurvus* and *Neognathodus* spp. are the most common conodonts in quarry 2.

ZONATION

It is herein proposed one informal taxon-range zone and one subzone, respectively: *Idiognathoides sinuatus* zone and *Neognathodus roundyi* subzone.

Idiognathoides sinuatus Zone

The *Idiognathoides sinuatus* zone extends from the lower part of quarry 1 to the upper part of the quarry 2, and is recognized by the occurrence of *I. sinuatus*. The associated fauna comprises abundant *Idiognathodus incurvus* and *Neognathodus* spp., and less common *Diplognathodus coloradoensis*, *Idioprioniodus* sp., *Hindeodus minutus* and *Adetognathus lautus* (Figure 3).

According to Manger & Sutherland (1984), *I. sinuatus* is characteristic of the Morrowan age, although it ranges into the Atokan. *Idiognathoides sinuatus* is very common in both quarries 1and 2, totalling thirty-five specimens. The occurrence of *I. sinuatus* might suggest a Morrowan age for this interval, but the presence of *I. incurvus* in the lower strata of quarry 1 indicates an Atokan age. *Idiognathodus incurvus* is an excellent Atokan index for the Atokan and is abundant in both quarries. It is not recommended as a zone marker here because many specimens are probably juveniles. According to Merrill & von Bitter (1976), *D. coloradoensis* occurs from Morrowan to early Desmoinesian, being typical of late Atokan. Two specimens of *D. coloradoensis* were found near the top of quarry 1.

Neognathodus roundyi Subzone

The *Neognathodus roundyi* subzone is recognized by the local occurrence of this species in the basal portion of quarry 2. This subzone contains *Neognathodus medadultimus* and *N. atokaensis*. The conodont fauna is characterized by *N. roundyi*, *Idiognathoides sinuatus*, *Idiognathodus incurvus*, *Hindeodus minutus* and *Adetognathus lautus*.

Grayson & Lambert (1987) suggest that *Neognathodus* is the most important conodont genus for biostratigraphy of Early-Middle Pennsylvanian strata. *Neognathodus* is abundant in quarry 2, where 21 specimens were collected. *Neognathodus atokaensis*, considered an index fossil for the Atokan, was collected in the lower part of quarry 2.

Manger & Sutherland (1984), working the biostratigraphy of the Morrowan - Atokan boundary in Texas, studied an assemblage composed mainly of *N. medadultimus* and *N. roundyi*. They suggest an Atokan-early Desmoinesian age for the strata studied. The same species were observed in quarry 2, with *N. roundyi* most abundant in the lower portion of quarry 2, from which we named the zone.

According to the presence of *N. atokaensis*, *N. medadultimus* and *N. roundyi*, the former species restricted to Atokan age and the latter two typical of the Atokan-early Desmoinesian age, it is possible to suggest an Atokan age to the lower part of quarry 2, which includes the *N. roundyi* zone.

PALEOENVIRONMENTAL ANALYSIS

The two quarries are mainly composed of interbedded fossiliferous carbonates, subordinate shales and nodular anhydrite. To complement the paleoecologial interpretations, thin-sections were made of the fossiliferous carbonates sampled for conodonts. Based on field descriptions and petrographic studies, it was possible to define three distinct environments within the

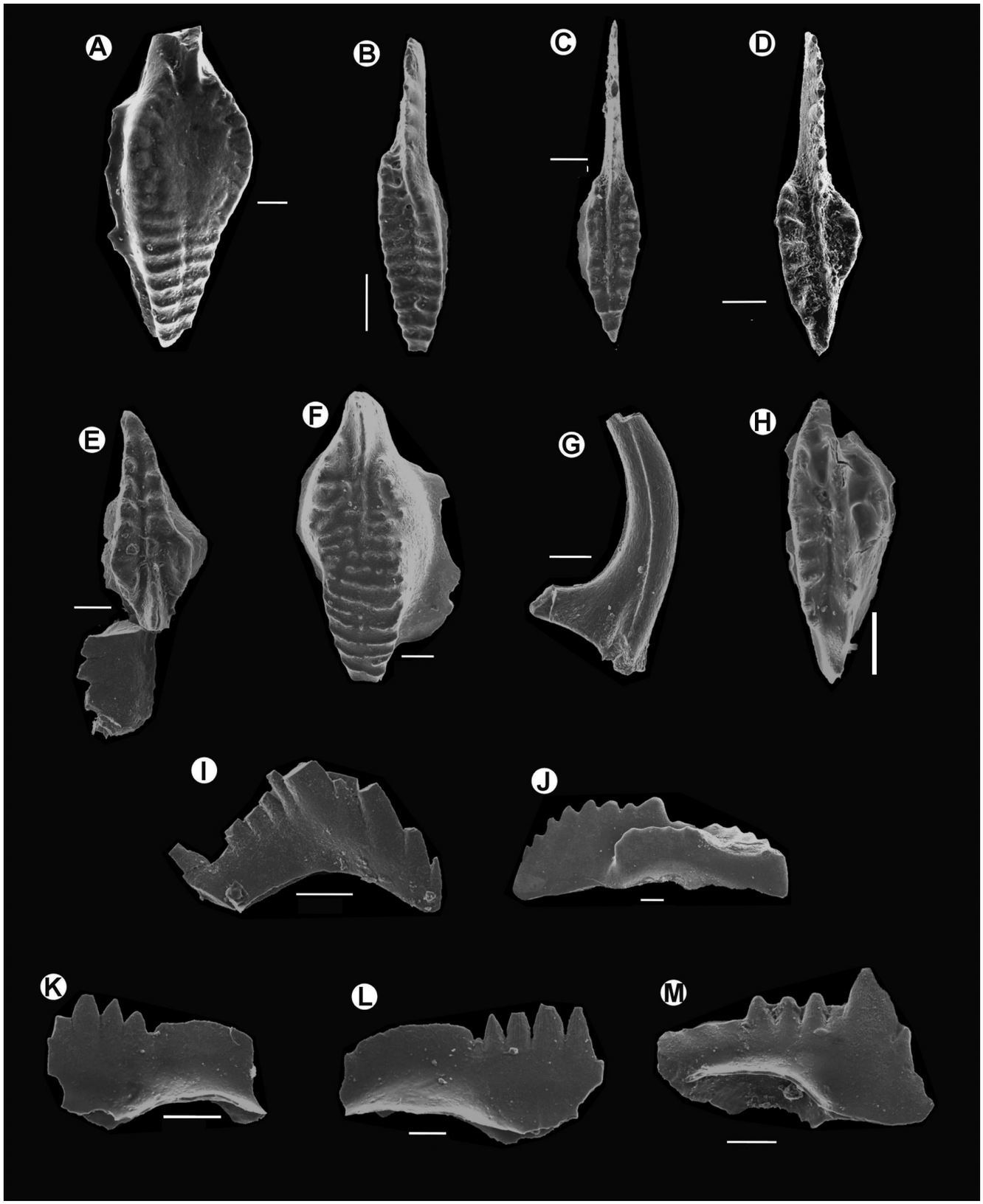

Figure 2. Conodonts from Itaituba Formation, all hypotypes in oral (A-F,H) and lateral (G,I-M) views. **A,** *Idiognathodus incurvus* Dunn, P2 30C2, MP-M-661; **B,** *Idiognathoides sinuatus* (Harris & Hollingsworth), P2 160 C10, MP-M-680; **C,** *Idiognathodus incurvus* Dunn, P2 160 C10, MP-M-648; **D**-**E,** *Neognathodus roundyi* (Gunnell), P2 30 C2: **D,** MP-M-700; **E,** MP-M-676; **F,** *Idiognathodus incurvus* Dunn, P2 30C2, MP-M-699; **G,** *Idioprioniodus* sp. (Gunnell), P2 430 C9b, MP-M-701; **H,** *Neognathodus roundyi* (Gunnell), P2 30 C2, MP-M-702; **I,** *Hindeodus minutus* (Ellison), P2 30 C2, MP-M-685; **J,** *Adetognathus lautus* (Gunnell), P1 925 C 19, MP-M-703; **K-L,** *Diplognathodus coloradoensis* (Murray & Chronic), P1 925 C 19: **K,** MP-M-688; **L,** MP-M-687; **M,** *Hindeodus minutus* (Ellison), P1 925 C 19, MP-M-704. Scale bar = 100 µm.

Table 1. Conodont distribution in quarry 1.

SAMPLE	CONODONT	ASSOCIATED FAUNA	LITHOLOGY
P1 430 C 9 b	*Idiognathodus incurvus (4)* *Idioprioniodus sp (1)* *Idiognathoides sinuatus (6)* *Hindeodus minutus (1)*	Fish teeth and bryozoans	Bioclastic packstone
P1 840 C 16	*Idiognathoides sinuatus (2)*	Fish teeth, scolecodonts, brachiopods and crinoids	Bioclastic packstone
P1 925 C 19	*Adetognathus lautus (3)* *Diplognathodus coloradoensis (20)*	Fish teeth, scolecodonts, sponges	Dolomite
P1 950 C 20	*Idiognathodus incurvus (1)*	Scales and fish teeth, scolecodonts, brachiopods	Mudstone
P1 1000 C 21	*Idiognathoides sinuatus (1)*	Fish teeth, scolecodonts, brachiopods, crinoids	Dolomite
P1 1035 C 22	*Idiognathodus incurvus (2)*	Scolecodonts	Dolomite
P1 1570 C 29	*Idiognathoides sinuatus (1)*	Fish teeth	Bioclastic wackestone/ packstone

interval analyzed. These environments are mainly characterized by differences in water energy, depth, consistency of the substrate and faunal composition.

Supratidal environment

Represented by recrystalized mudstones of low energy, originally from micritic muds and frequently showing detrital quartz and evidence of subaerial exposure, characterized by dissication cracks and dissolution features with anhydrite and gypsum. Bioclasts are rare and represented by sparse fragments of fibrous brachiopods, ostracodes and trilobites. Dolomitization was intense.

Intertidal environment

Represented by moderate to high energy grainstones. Peloidal Grainstone are composed of pellets, crinoids and fusulinacean foraminifers. This microfacies characterizes moderate energy conditions. Bioclastic grainstones are composed of fragmented organisms such fibrous brachiopods, bryozoans, foraminifers, ostracodes, trilobites, crinoids and echinoids; sparse ooids and pellets can be found. Bioturbation and sparry cement are common features. This microfacies characterizes high energy conditions. Oolitic grainstones are composed of non-skeletal, allochthonous components, generally quartz grains with micritic envelopes. Sparry cement is commonly present. Rare oncoids with crinoidal nuclei and pellets can be found, and bioturbation is common. These microfacies characterize high energy conditions.

Subtidal environment

Represented by bioclastic wackestones and packstones. These microfacies represent normal marine bottom conditions and are composed of bioclasts from a normal marine fauna. Mudstones with gastropods correspond to a restricted microfacies and is composed of bioclasts of gastropods floating in a micritic matrix. Secondarily ostracodes, foraminifers, brachiopods and crinoids are present. Bioclasts do not show preferential orientation. This microfacies suggests a muddy low energy depositional environment, probably in a back shoal. Bioclastic wackestones are composed of bioclasts from normal marine fauna, such as fibrous and prismatic brachiopods, crinoids, echinoids, bivalves, bryozoans, foraminifers, trilobites and ostracodes. Bioturbation is common. Bioclastic packstones are the most common texture of the carbonates deposited during the Pennsylvanian in the Amazonas Basin. The bioclastic constituents represent a normal marine fauna, including brachiopods, crinoids, echinoids, bivalves, bryozoans, foraminifers, trilobites and ostracodes. Bioturbation is common. The orientation of the bioclasts suggests that these sediments were deposited in settings affected by normal waves, under some energetic conditions, but insufficient to remove the matrix, which suggests a subtidal environment.

The conodonts

The conodont fauna characterized by *Idiognathodus*, *Idiognathoides* and *Neognathodus* occurs widely in both quarries in the bioclastic packstones of the subtidal environment.

Davis & Webster (1985) studied biofacies represented by *Idiognathodus*, *Idiognathoides* and *Declinognathodus*, and suggested that these conodonts represent shallow marine, subtidal deposits with muddy substracte, low to moderate energy and normal salinity. *Neognathodus* biofacies generally represent lagoon deposits characterized by calcareous mudstones and common co-occurrence with *Adetognathus* or with *Idiognathodus* in shallow waters. *Adetognathus* biofacies typically represent more shallow waters of intertidal to lagoon deposits, characterized by moderate to high energy and high salinity conditions.

According to Dunn (1976), *Diplognathodus coloradoensis* is usually common in shallow marine waters, with relatively high energy conditions. Elements of *D. coloradoensis* were found in only one level of quarry 1, associated with *Adetognathus lautus*.

In quarry 1, the predominant occurrence of bioclastic packstones and *Idiognathodus* and *Idiognathoides* suggest an environment of shallow waters with low to moderate energy, which grades to more shallow and moderate to high energy in the lower part of quarry 2

with the presence of *Neognathodus* associated with *Adetognathus*. The presence of *Idiognathodus* and *Idiognathoides* through the lower to upper levels of the quarry 2 suggests a return of shallow water with low to moderate energy conditions.

According to some authors (Merrill & von Bitter, 1976)

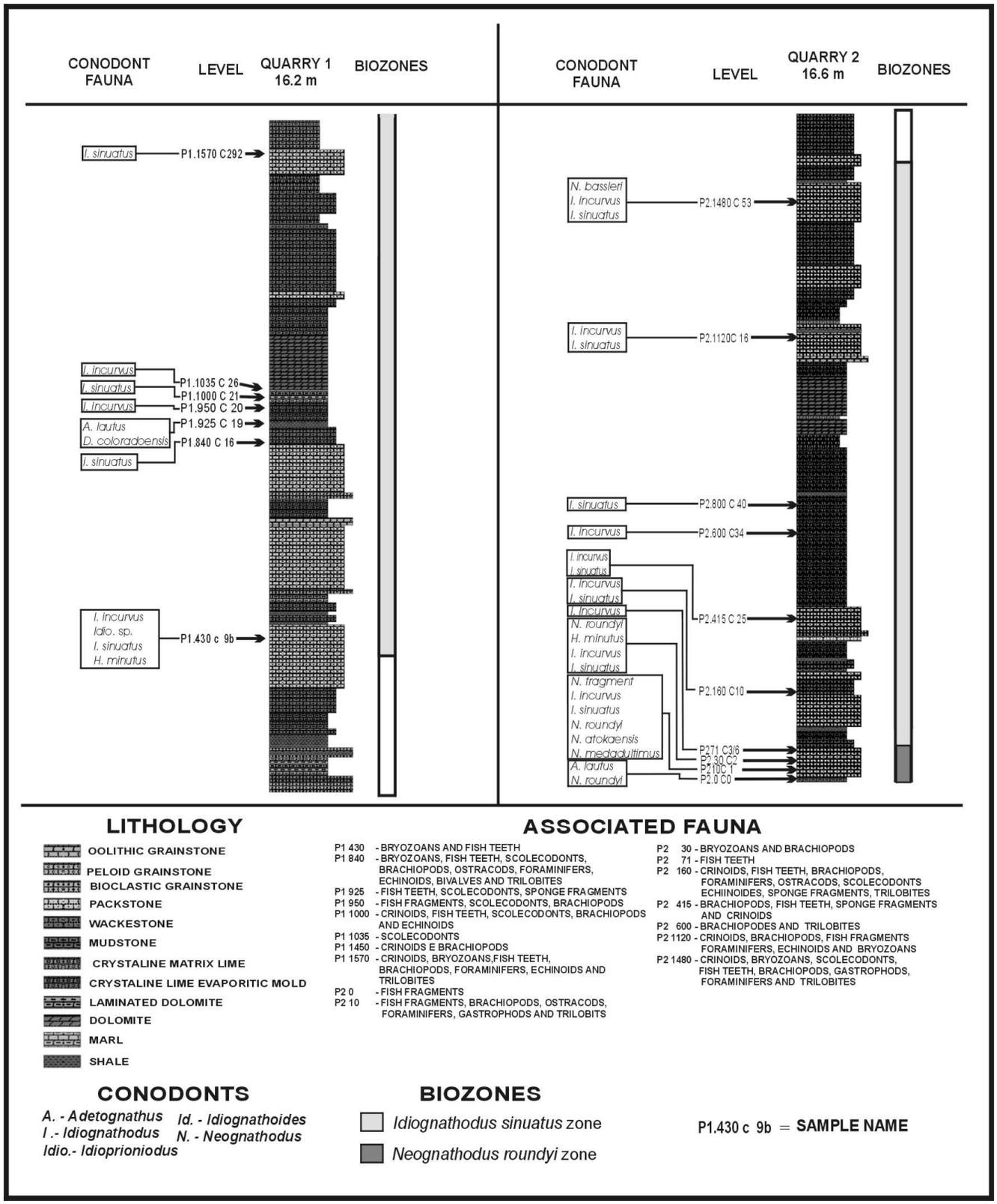

Figure 3. Stratigraphic profiles of the two quarries (modified from Matsuda, 2003).

Hindeodus and *Idioprioniodus* are more abundant in deep waters. *Idioprioniodus* was rare in the basal strata of quarry 1, and absent in the quarry 2. *Hindeodus* is also rare in both quarries, suggesting that the studied interval represents shallow waters.

Thus, according to field description, facies analyses, environmental characteristics and conodont fauna, we suggest a general transgressive episode through quarry 1, grading to a regressive episode in the lower part of quarry 2, which shifted to transgressive deposits through the rest of quarry 2.

The associated fauna

The Itaituba Formation is the richest interval containing normal marine organisms in the Pennsylvanian of Amazonas Basin. The associated fauna in the studied quarries contain brachiopods, crinoids, echinoids, bryozoans, gastropods, foraminifers, sponges, ostracodes, trilobites, scolecodonts, bivalves and teeth fish fragments. The brachiopods are the most abundant group, represented mainly by the Productida Order. Secondarily abundant are fish teeth and scales, mainly actinopterygians of the Paleonisciforms Order. In the studied material specimens of the Acanthodii and Chondrichthyes Classes (identified by Dr. Martha Richter, an expert in fossil fish) were recovered.

The associated fauna represents normal marine bottom conditions, with relatively shallow, quiet and warm waters, and muddy substrate suggesting subtidal environmental deposition. The occurrence of fragmented organic material in the lower levels of quarry 2 (P2 0 C0, P2 10 C1, P2 30 C2 and P2 71 C3/6) suggest possible reworking by currents and/or bioturbation in moderate energy conditions. The presence of bryozoans, crinoids and brachiopods indicates good oxygenation and abundance of nutrients.

The material studied is characterized by moderate to high levels of bioturbation. Burrows are frequent in packstones and wackestones. The predominant trace fossil observed was classified as the ichnogenus *Thalassinoides*. Trilobites

Table 2. Conodont distribution in quarry 2.

SAMPLE	CONODONTS	ASSOCIATED FAUNA	LITHOLOGY
P2 0 C 0	*Adetognathus lautus (1)* *Neognathodus roundyi (2)*	Fish teeth, crinoids and organic fragments	Mudstone
P2 10 C 1	*Neognathodus fragment (1)* *Idiognathodus incurvus (10)* *Idiognathoides sinuatus (1)* *Neognathodus roundyi (3)* *Neognathodus atokaensis (2)* *Neognathodus medadultimus (5)*	Scales, Fish teeth and organics fragments	Bioclastic packstone
P2 30 C 2	*Neognathodus roundyi (6)* *Hindeodus minutus (3)* *Idiognathodus incurvus (10)* *Idiognathoides sinuatus (2)*	Bryozoans and organic fragments	Bioclastic packstone
P2 71 C 3/6	*Idiognathodus incurvus (1)* *Idiognathoides sinuatus (12)*	Fish teeth and organic fragments	Bioclastic wackestone
P2 160 C 10	*Idiognathodus incurvus (2)*	Scolecodonts, scales, fish teeth, brachiopods, crinoids and sponges	Bioclastic wackestone/packstone
P2 415 C 25	*Idiognathodus incurvus (3)* *Idiognathoides sinuatus (7)*	Brachiopods, fish teeth, sponges and crinoids	Bioclastic packstone
P2 600 C 34	*Idiognathodus incurvus (1)*		Mudstone
P2 800 C 37	*Idiognathoides sinuatus (1)*		Mudstone
P2 1120 C 46	*Idiognathodus incurvus (3)* *Idiognathoides sinuatus (1)*	Crinoids, brachiopods, scales, fish teeth, and bryozoans	Bioclastic packstone
P2 1480 C 53	*Neognathodus bassleri (2)* *Idiognathodus incurvus (2)* *Idiognathoides sinuatus (1)*	Crinoids, fish teeth, scolecodonts and brachiopods	Bioclastic packstone

are associated in general with the bioturbation of the sediment, but the probable trace-maker was a general shrimp-like animal, adapted to live in environments with variable levels of oxygenation and salinity. *Zoophycos* is the second ichnogenus described, occurring mainly in mudstones and secondarily in packstones.

According to Doyle *et al.* (1994), the distribution of *Thalassinoides* ranges from intertidal to supratidal, low to moderate energy, nutrient-rich and dysaerobic settings, while *Zoophycos* is restricted to subtidal low energy, disaerobic and soft substrate environments.

CONCLUSIONS

Conodonts from the two quarries comprising strata of the lower Itaituba Formation, Amazonas Basin, were studied to refine the suggested age of this area and to interpret the paleoecological features observed. Conodonts are characterized by Pa elements of *Idiognathoides sinuatus, Idiognathodus incurvus, Diplognathodus coloradoensis, Hindeodus minutus, Idioprioniodus* sp. and *Adetognathus lautus* in quarry 1, and *I. sinuatus, I. incurvus, Neognathodus roundyi, N. medadultimus, N. atokaensis, N. bassleri, H. minutus* and *A. lautus* in quarry 2.

Idiognathodus, Idiognathoides and *Neognathodus* are the most abundant genera. In the carbonates of quarry 1, *Idiognathodus* and *Idiognathoides* are equally represented, followed by rarer *Idioprioniodus, Diplognathodus, Hindeodus* and *Adetognathus*.

In quarry 2 *Idiognathodus* and *Idiognathoides* were recovered in great abundance, and the first appearance of *Neognathodus* is in the basal strata of this quarry, with *N. atokaensis* typical of Atokan age and *N. medadultimus* and *N. roundyi,* typical of Atokan-early Desmoinesian age. Conodonts were mainly found in the packstones and secondarily in wackestones and mudstones.

One taxon-range zone and one subzone are informally proposed: *Idiognathoides sinuatus* zone, and *Neognathodus roundyi* subzone. The *I. sinuatus* zone extends from the lower part of the quarry 1 to the upper part of quarry 2, and recognized by the local occurrence of the nominate species. The conodont fauna comprises the index species *Idiognathoides sinuatus, Idiognathodus incurvus, Diplognathodus coloradoensis, Idioprioniodus* sp., *Hindeodus minutus* and *Adetognathus lautus*. The *N. roundyi* subzone is recognized by the local occurrence of *N. roundyi* in the lower part of quarry 2. The conodont fauna is characterized by *N. roundyi, N. medadultimus, N. atokaensis, I. sinuatus, I. incurvus, H. minutus* and *A. lautus*.

The Itaituba Formation is the richest interval containing normal marine organisms in the Pennsylvanian of the Amazonas Basin. The associated fauna contains brachiopods, crinoids, echinoids, bryozoans, gastropods, foraminifers, sponges, ostracodes, trilobites, scolecodonts, bivalves and fish teeth and scales. The presence in both quarries of the assigned organisms suggests good bottom conditions as warm and clean waters. The conodonts, associated fauna and facies analysis suggest relatively shallow, quiet and warm waters, with muddy substrates in a subtidal setting. At a larger depositional scale, a general trangressive-regressive-trangressive episode, characterizes these Atokan age deposits.

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