UNIVERSIDADE DE BRASÍLIA
INSTITUTO DE GEOCIÊNCIAS

PALINOLOGIA DA FORMAÇÃO SOLIMÕES, NEÓGENO DA BACIA DO SOLIMÕES, ESTADO DO AMAZONAS, BRASIL: IMPLICAÇÕES PALEOAMBIENTAIS E BIOESTRATIGRÁFICAS

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Aos meus pais que me ensinaram a maior de todas as ciências.

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ABSTRACT

The Iquitos arch influenced significantly the landscape since its uplift in the late Miocene and it is possible to verify the forebulge dynamics, originally observed in outcrops, in the sub-surface sediments. The palynology, mineralogy and isotope geochemistry of a Miocene / Pliocene cored section in Brazil made possible the correlation of the Solimões Formation with the Pebas and Nauta formations near the Iquitos arch in Peru, now with the advantage of a biostratigraphic framework that enable a direct dating for the sediments. The interval between 401 m and 300 m (middle / upper Miocene), deposited under a mainly fresh water environment with some marine influence, corresponds to the Pebas Formation. The following interval between 300 m and 185 m (upper Miocene / Pliocene) corresponds to the 'Uppermost Pebas' Formation. The Uppermost Pebas Formation unconformably overlies the Pebas Formation in this section as well as in some areas in Peru. It is suggested here that the top of the Pebas Formation in Brazil is younger than in Peruvian Amazonia, and thus diachronic. The lower part of the interval (299,05 – 238,33 m) is in the Asteraceae Interval Zone and the upper part (238,33 – 185,00) is in the *Psilatricolporites caribbiensis* Interval Subzone. It was not observed any evidence of discontinuity between both biozones. The last interval from *ca*. 185,00 m to the surface is a typical fluvial system deposit and is correlated here to the Nauta Formation. It is considered Pliocene, corresponding to the upper part of the *Psilatricolporites caribbiensis* Interval Subzone, a younger age than the originally proposed to it. The palynological systematic results consist of 95 palynomorphs identified whenever possible up to species level. Most of them were pollen grains of angiosperms with 85 types classified. Only one species of gymnosperm was present and always in small quantity. The spores were very abundant although only eight types were identified. Eight new species are proposed and formally described: *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilaperiporites elizabetei, Psilatricolporites hoornii, Retitricolporites toigoi*.

RESUMO

O arco de Iquitos influenciou a paisagem da região noroeste da América do Sul desde o Mioceno tardio. Reflexos da sua dinâmica de soerguimento, antes vistos apenas em afloramentos, podem também ser observados em sub-superfície. O estudo de palinologia, mineralogia e geoquímica de isótopos de uma seção da Formação Solimões possibilitou a sua correlação com as formações Pebas e Nauta da região de Iquitos. Essa correlação possibilita a aplicação direta de um arcabouço palinostratigráfico nos sedimentos. O intervalo 401 – 300 m do poço 1 AS 33 AM (Mioceno inferior / médio), depositado em ambiente principalmente de água doce com alguma influência marinha, corresponde à Formação Pebas. O intervalo seguinte 300 – 185 m (Mioceno superior / Plioceno) corresponde à camada superior da Formação Pebas, designada na literatura como 'Uppermost Pebas'. Na seção estudada esta camada recobre discordantemente a Formação Pebas, assim como em algumas localidades no Peru. É sugerido aqui um diacronismo para essa unidade uma vez que a idade atribuída a ela é mais jovem que a descrita na literatura. A porção inferior desse intervalo (299,05 – 238,33 m) está na zona de intervalo Asteraceae e a porção superior (238,33 – 185,00m) está na subzona de intervalo *Psilatricolporites caribbiensis*. Não foi observada nenhuma discordância entre as duas biozonas. O último intervalo de *ca.* 185 m até a superfície é formado por depósitos típicos de sistema fluvial e é correlacionado aqui com a Formação Nauta. É considerado Plioceno por corresponder à parte superior da subzona de intervalo *Psilatricolporites caribbiensis*, idade mais jovem que a proposta anteriormente. Os resultados sistemáticos de palinologia consistem em 95 tipos identificados sempre que possível em nível específico. A maioria deles são grãos de pólen de angiospermas com 85 espécies. Apenas uma espécie de gimnosperma foi encontrada e sempre em quantidades reduzidas. De esporos, apesar muito abundantes, somente oito espécies foram identificadas. Oito novas espécies são propostas e formalmente descritas: *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilaperiporites elizabetei, Psilatricolporites hoornii, Retitricolporites toigoi*.

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1. INTRODUÇÃO

O tamanho e complexidade da Amazônia atual sugere um passado igualmente fascinante. O número de estudos aumentou significativamente nas últimas duas décadas, mas continuam sendo insuficientes para esboçar um panorama completo do seu desenvolvimento desde o soerguimento dos Andes.

As interpretações paleoambientais de dados obtidos através de diferentes ferramentas metodológicas são muitas vezes contraditórias (Westaway, 2006). A abrangência e duração de incursões marinhas ocorridas durante o Mioceno constitui o cerne da polêmica. A paleoflora, paleofauna e os dados de isótopos de conchas de moluscos da bacia do Solimões são interpretados como indicativos de um grande paleolago (Lago Pebas) ocupando a Amazônia ocidental ao longo do Mioceno, com esporádicas incursões marinhas (Hoorn, 1993, 1994; Kandoorp *et al.*, 2005; Monsh *et al.*, 1998; Vonhof *et al.*, 1998, 2003; Wesselingh *et al.*, 2002; Whatley *et al.*, 1998). Estudos sedimentológicos e de icnofósseis de afloramentos nas bacias do Acre e Solimões indicam paleoambiente predominantemente estuarino (Mar Pebas) com canais de maré intercalados com ambientes continentais (Gingras *et al.*, 2002; Hovikoski *et al.*, 2005; Räsänen *et al.*, 1995; Rebata *et al.*, 2006ab).

Uma das causas de controvérsia quanto à interpretação paleoambiental é a dificuldade de datação direta dos sedimentos. A concentração de fósseis em alguns níveis e o reduzido número de estudos bioestratigráficos dificultam uma precisa correlação dos estratos neógenos. Nesse caso, a palinologia representa uma importante ferramenta tanto para estudos paleoambientais como bioestratigráficos uma vez que o registro fóssil palinológico, apesar de suas limitações, é mais facilmente recuperado em distintos ambientes deposicionais.

Foram poucos os estudos palinológicos feitos na região. Cruz (1984) definiu a posição cronoestratigráfica da Formação Solimões no Neógeno (Mioceno/Plioceno, 23,5 - 1,6 Ma). Hoorn (1993) propôs um biozoneamento palinoestratigráfico para a Formação Solimões no Brasil e Formação Pebas na Colômbia, considerando-as como equivalentes e coevas, depositadas entre o Eomioceno e o princípio do Neomioceno. Rebata *et al.* (2006a) apresentou alguns dados palinológicos da parte superior da Formação Pebas datada como Neomioceno pela presença de associação palinológica característica da zona de intervalo Asteraceae *sensu* Lorente (1986), idade essa mais jovem que a apresentada por Hoorn (1993) para o topo da Formação Pebas.

A correlação das unidades é também dificultada pela movimentação tectônica característica das bacias de ante-país. O arco de Iquitos é um alto estrutural que separa as

bacias do Acre e Solimões no Brasil, porém sua exata localização variou muito nas publicações que trataram do tema (Wesselingh *et al.* 2006). De acordo com Caputo & Silva (1990), o arco foi formado no Eocretáceo como conseqüência da orogenia andina que sobrecarregou a margem continental causando soerguimento periférico e erosão dos sedimentos mais antigos até a exposição do embasamento. Este foi posteriormente recoberto por sedimentos cretáceos e cenozóicos. Roddaz *et al.*(2005ab) apresentou um modelo flexural mais detalhado e propôs com base na estratigrafia que o seu soerguimento teria se dado no Mesomioceno. A partir desse período o arco influenciou de forma significativa o paleoambiente da área.

O presente trabalho consiste numa tese de doutoramento apresentada em três artigos centrados nos estudos palinológicos de amostras de cilindro de sondagem (1 AS 33 AM) da Formação Solimões no Estado do Amazonas. Com os dados apresentados nesses trabalhos pôde-se alcançar os seguintes objetivos propostos para a presente tese:

1) classificar e quantificar os palinomorfos presentes no poço 1 AS 33 AM; 2) identificar marcadores biostratigráficos que possibilitem o enquadramento da seção estudada em um dos arcabouços palinostratigráficos propostos para o norte da América do Sul; 3) estabelecer as afinidades taxonômicas dos grãos visando o entendimento do paleoambiente; 4) correlacionar os intervalos estudados com as unidades estratigráficas descritas na região; 5) e por fim, aplicar um biozoneamento a esseas camadas e contribuir para um melhor entendimento da evolução paleoambiental do Neógeno da Amazônia.

O primeiro artigo trata do estudo comparativo das técnicas de processamento de amostras palinológicas com o objetivo de avaliar a compatibilidade dos espectros polínicos obtidos através de diferentes métodos. O estudo baseia-se nos resultados de quatro amostras de sedimento processadas no Instituto de Geociências da Universidade de Brasília (UnB) e no Institute for Biodiversity and Ecosystem Dynamics (IBED) da Universidade de Amsterdã. Este será submetido no XIX Congresso Brasileiro de Paleontologia.

Os dois outros artigos foram submetidos no periódico *Palynology* da American Association of Stratigraphic Palynologists (AASP).

O segundo artigo consiste nos resultados sistemáticos palinológicos das amostras de cilindro de sondagem (1 AS 33 AM) da Formação Solimões. Noventa e cinco tipos polínicos foram identificados em nível específico sempre que possível e sete novas espécies foram propostas e formalmente descritas.

O terceiro artigo trata da integração dos dados palinológicos, mineralógicos e isotópicos dessa seção da Formação Solimões. Reflexos da dinâmica de soerguimento do arco

de Iquitos, antes vistos apenas em afloramentos, puderam ser observados também em sub-superfície. O estudo possibilitou a correlação da Formação Solimões com as formações Pebas e Nauta descritas na região de Iquitos, Peru, e a aplicação direta de um arcabouço palinostratigráfico a essas unidades.

2. BACIA DO SOLIMÕES

2.1. Contexto tectônico-sedimentar

A origem da plataforma Sul-Americana remonta-se ao final da orogênese Brasiliana/Pan-Africana desenvolvida no Proterozóico, entre cerca de 725 e 500 Ma, quando blocos continentais resultantes da fragmentação de Rodínia suturaram-se em cinturões móveis, acrescendo-se à parte ocidental do Gondwana (Almeida & Carneiro, 2004).

Durante o Cambro-Ordoviciano a plataforma Sul-Americana passou uma fase de transição entre as orogenias do ciclo Brasiliano e a consolidação. Como consequência, originaram-se as grandes sinéclises separadas por áreas mais elevadas do embasamento pré-cambriano. Entre as que se encontram nesse contexto estão as bacias do Acre, Solimões e Amazonas (Almeida & Carneiro, 2004) (Figura 1).

Na margem ocidental da placa Sul-Americana deu-se a orogenia Andina, que apresenta dois picos de atividade tectônica: fase Incaica e fase Quechua. Na primeira, ocorrida no Eoceno (49-34 Ma), as taxas de convergência entre as placas Farallon e Sul-Americana foram altas. A fase Quechua, atuante do Neo-Oligoceno ao Recente (26-0 Ma), caracterizou-se pelo rompimento da placa Farrallon em outras duas, Nazca e Cocos, e pela convergência entre Nazca e América do Sul (Zalán , 2004). Esta fase pode ser dividida em três sub-fases.

No sul do Peru, Quechua 1 (17 – 15 Ma) é responsável por estruturas monoclinais e falhas reversas, além de incisões de grande escala ocasionadas por um pulso de soerguimento de 400m. Nas bacias de ante-país registra-se eventos trangressivos em torno de 15 Ma (Hoorn *et al*., 1995), possivelmente relacionados ao aumento da subsidência em algumas áreas (Jaillard *et al.*, 2000).

Quechua 2 (9 – 8 Ma) corresponde a um período de compressão, espessamento da crosta e rápido soerguimento da zona de arcos devido à propagação da margem orogênica dos Andes para leste. Essa fase é marcada por erosões, com áreas de deposição restritas (Jaillard *et al.*, 2000 e Roddaz *et al*. 2005a).

A fase Quechua 3 (7 –5 Ma) nas bacias de ante-país é caracterizada por uma forte subsidência flexural, com grande acúmulo de sedimento. Na bacia de Marañon, um hiato

deposicional separa os depósitos pelíticos do Meso – Neomioceno, dos arenitos do final do Neomioceno/Plioceno. A partir do Plioceno a região sofreu soerguimento, permitindo que os sedimentos antes depositados fossem cortados por drenagens atuais (Jaillard *et al.*, 2000).

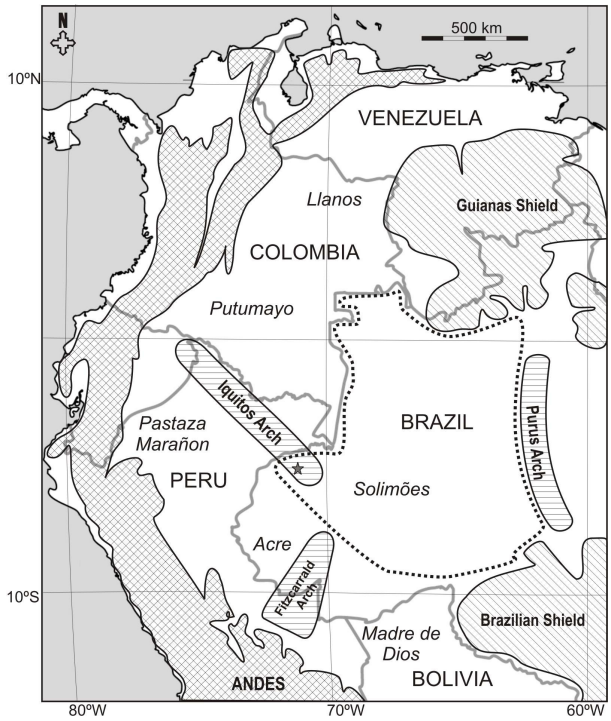


Figura 1: Mapa de localização da bacia do Solimões.
★ Localização do poço 1AS 33 AM. Nomes das bacias em *itálico*. Dados estruturais extraídos de Caputo (1984), Baby et al. (2005), Roddaz et al. (2005a) e USGS website.

A bacia do Solimões, denominada inicialmente bacia do Alto Amazonas, recebeu a atual designação por Caputo (1984) para diferenciá-la da bacia do Amazonas, uma vez que apresentava evolução geológica distinta. Extende-se por 400.000km^2 e limita-se ao norte pelo escudo das Guianas, ao sul pelo escudo Brasileiro, a leste pelo arco de Purus, a oeste pelo arco de Iquitos (Eiras *et al.*, 1994) (Figura 1).

A estratigrafia da bacia do Solimões pode ser dividida em duas seqüências sedimentares de primeira ordem: a paleozóica, não aflorante e intrudida por diques e soleiras de diabásio, e a mesozóica-cenozóica. Os pacotes sedimentares estão separados por discordâncias bem marcadas, que permitem o reconhecimento de seis seqüências deposicionais de segunda ordem: Ordoviciano, Siluriano-Devoniano, Devoniano-Carbonífero, Carbonífero-Permiano, Cretáceo e Paleógeno-Neógeno (Eiras *et al.*, 1994). A espessura máxima dos sedimentos é de 3500m, incluindo rochas paleozóicas, mesozóicas e cenozóicas (Caputo, 1984). A porção paleozóica representa a maior parte desse pacote sedimentar (Figura 2).

Do ponto de vista econômico, foram encontradas reservas de gás associadas às rochas paleozóicas dos alinhamentos de Juruá e de Jutaí, Jandiatuba e Itaguaí, e reservas de petróleo estruturalmente trapeadas em reservatórios da Formação Juruá (Almeida & Carneiro, 2004).

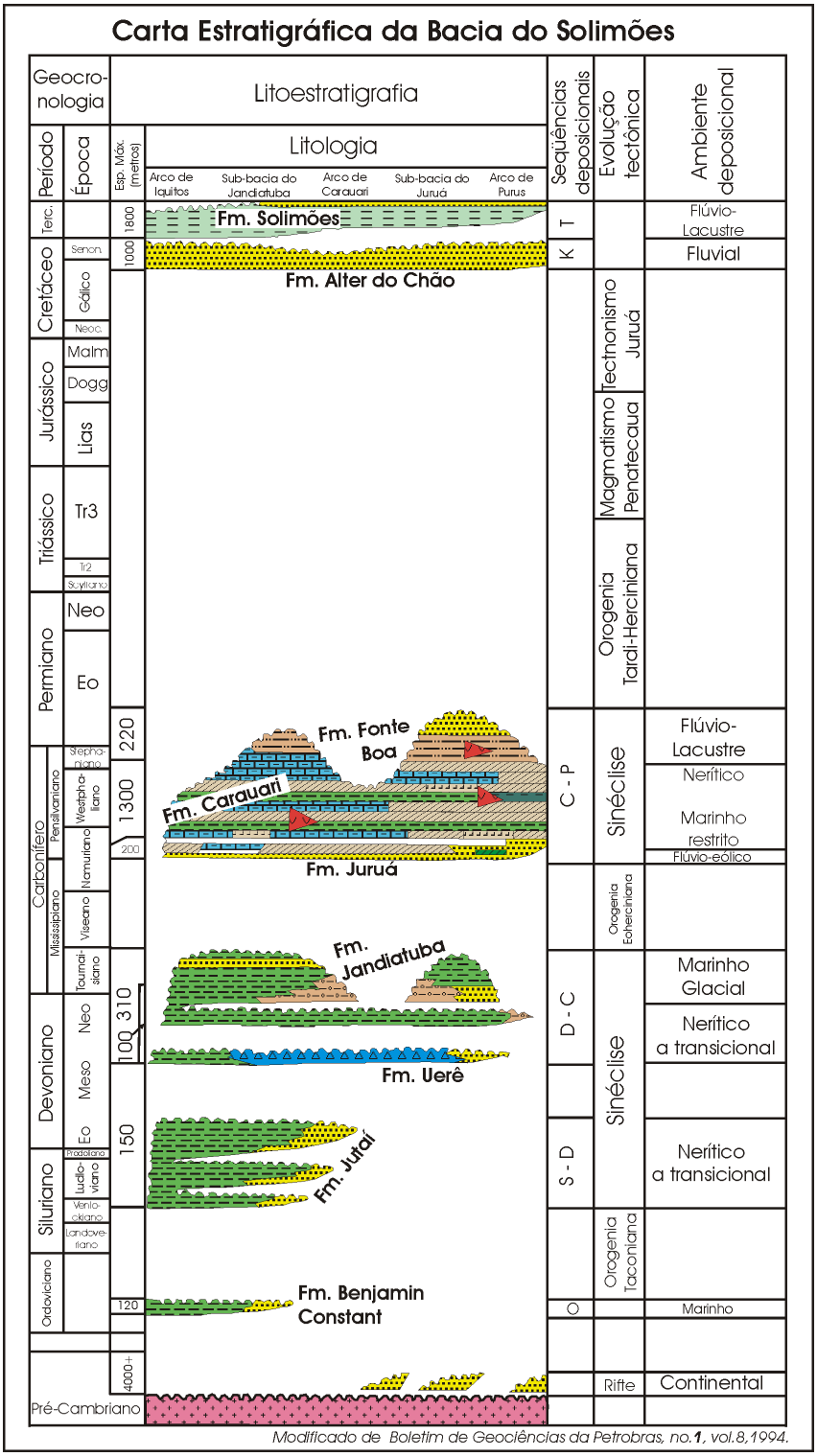


Figura 2: Carta estratigráfica da bacia do Solimões (Eiras *et al.*, 1994).

2.2. Arco de Iquitos

O arco de Iquitos corresponde à faixa de anomalias positivas (20-60 mgals) que pode ser observada na composição de dois mapas de anomalia Bouguer do Peru e Brasil (Anexo 3, Figura 2). Há autores que discutem a validade do termo "arco", pois engloba uma grande variedade de feições geológicas e geomorfológica (Wesselingh and Salo, 2006), porém como essa questão ainda segue em debate, esse termo será utilizado no presente estudo.

Roddaz *et al*. (2005ab) reconheceram quatro unidades sedimentares na região próxima às cidades de Iquitos e Nauta no Peru: formações Pebas, Nauta, Areias Brancas (*White Sands*) e Amazonas. Propuseram que no Neomioceno/ Plioceno o arco de Iquitos atuou como um divisor de drenagens. Com o soerguimento o ambiente mudou de lagunar (*paramarine megalake*) que depositou a Formação Pebas (Wesselingh *et al*., 2002) para planície aluvial que originou a Formação Nauta (Figura 3). No Plioceno o preenchimento da bacia de ante-país e um pulso orogênico resultaram no recobrimento do arco e sua posterior erosão por rios oriundos dos Andes.

Na mesma região, Rebata *et al.* (2006ab) individualizaram um nível no topo da Formação Pebas, denominada '*Uppermost Pebas*'. Esta camada é caracterizada pela ausência de conchas de moluscos fósseis e pela pouca matéria orgânica nos sedimentos. Esse intervalo foi datado como Neomioceno pela presença de associação palinológica característica da zona de intervalo Asteraceae *sensu* Lorente (1986). De acordo com esses autores, o Serviço Geológico do Peru – INGEMMET designa essa camada de Formação Ipururo, separada da Formação Pebas por uma inconformidade regional. No entanto, Rebata *et al.* (2006b) não observaram essa discontinuidade e descreveram-na como uma transição gradual entre as formações Pebas e Nauta. A Formação Nauta foi dividida em diversas fácies características de canais predominantemente de contra-maré e porções inativas de delta aluvial ao redor de um sistema lagunar raso de água salobra (Figura 3).

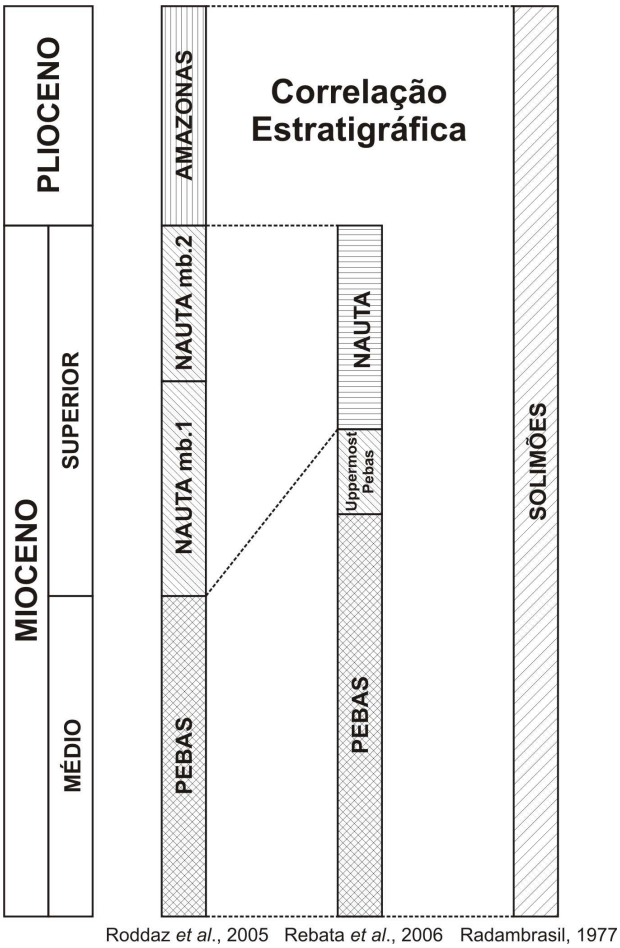


Figura 3: Correlação estratigráfica das unidades descritas na região do arco de Iquitos (Roddaz *et al*., 2005; Rebata *et al*., 2006 e Radambrasil, 1977).

2.3. Formação Solimões

A Formação Solimões é composta por argilitos, siltitos, arenitos argilosos finos a médios, brechas com fragmentos sub-angulares, com concreções carbonáticas, gipsíferas e ferruginosas e intercalações de linhitos (Radambrasil, 1977; Hoorn, 1993). No topo da seção aparecem arenitos brancos pouco consolidados, com grãos sub-angulares a sub-arredondados com granulometria fina a grossa (Caputo, 1984). A espessura varia entre 200 a 600m em função da paleotopografia do embasamento, acunhando-se para leste, próximo ao arco de Purus (Radambrasil, 1977).

O nome Séries Solimões foi usado pela primeira vez por Rego (1930 *apud* Caputo, 1984), num trabalho sobre a geologia do território do Acre. Posteriormente, Caputo *et al.* (1971 *apud* Caputo, 1984) correlacionaram várias seções descritas nas bacias do Acre e Solimões e denominaram esses depósitos pelíticos de Formação Solimões (Caputo, 1984). Os estudos palinológicos de Cruz (1984) definiram a posição cronoestratigráfica dessa unidade no Neógeno (Mioceno/Plioceno, 23,5 - 1,6 Ma).

Esta recobre discordantemente a Formação Alter do Chão, de idade cretácea. Aparentemente o lapso de tempo compreendido por essa descontinuidade aumenta da bacia do Acre para a bacia Solimões até o arco de Purus (Caputo, 1984). No topo, uma discordância separa a Formação Solimões da Formação Içá, de idade pleistocênica.

A Formação Solimões tem continuidade lateral nas bacias vizinhas, recebendo outras denominações. Nas bacias Pastaza, Marañón e Madre de Dios do Peru os depósitos pelíticos de idade neógena são chamados de formações Pebas, Ipururo e Nauta. Na Colômbia, nas bacias Amazonas e Putumayo, são conhecidos como Terciário Amazônico e camadas La Tagua (Hoorn, 1993, 1994; Campbell *et al*., 2001, Roddaz *et al.,* 2005a, Rebata *et al.* 2006ab).

2.4. Interpretações paleoambientais

A Formação Solimões e suas unidades litológicas correspondentes nos países vizinhos foram objeto de diversos estudos geológicos e paleontológicos chegando a conclusões às vezes conflitantes. A abrangência e duração de incursões marinhas ocorridas durante o Mioceno constitui o cerne da polêmica. Um detalhado histórico da controvérsia foi elaborado por Westaway (2006).

Ao propor as Séries Solimões, Rego (1930 *apud* Caputo, 1984) descreveu os sedimentos ao longo do rio Solimões como típicos de ambiente estuarino. Estudos posteriores, feitos em área muito mais extensa e com diversos afloramentos e poços, sugeriram um ambiente deposicional fluvial meandrante e lagos formados por canais abandonados (Maia *et al*., 1977; Cruz, 1984; Eiras *et al.,* 1994).

Os dados palinológicos apresentados por Cruz (1984), apesar de terem sido interpretados como de ambiente fluvial, registram as ocorrências *Zonocostites ramonae, Verrutricolporites rotundiporus* e *Psilatricolporites crassus*, que têm afinidade botânica com espécies características de mangue: *Rhizophora mangle, Pelliciera rizhophorae* e *Crenea maritima*, respectivamente.

Levantamentos geológicos e estudos palinológicos foram feitos por Hoorn (1993, 1994) em 15 afloramentos e uma perfuração localizados na região da fronteira entre Brasil, Peru e Colômbia. As associações polínicas indicaram um ambiente complexo e dinâmico composto por rios, planícies de inundação, lagos, e planície costeira, com mangues e pântanos. A associação de ambientes transicionais inclui elementos marinhos, como microforaminíferos e dinoflagelados, e grandes quantidades de *Zonocostites ramonae*. Com isso, puderam ser registradas duas incursões marinhas na região, uma no Eomioceno e outra

no intervalo Meso/Neomioceno. Hoorn *et al.* (1995), através de estudos tectônicos associados aos dados anteriores, concluíram que o soerguimento final da cordilheira Oriental e de Mérida, durante o Neomioceno/Pleistoceno, coincidiu com a inversão da direção do rio Amazonas e o fim das incursões marinhas na região.

Os sedimentos da Formação Solimões aflorantes na bacia do Acre ao longo dos rios Acre e Purus foram interpretados por Räsänen *et al.* (1995) como sendo depósitos de maré, com base na ciclicidade e estruturas sedimentares. A idade estimada por esses autores para esses afloramentos é de 10Ma. De acordo com Webb (1995) esses dados seriam a primeira comprovação da hipótese de uma conexão marinha atravessando o continente sul-americano até o final do Mioceno proposta inicialmente por Von Ihering (1927, *apud* Räsänen *et al.,* 1995).

Em comentário ao artigo de Räsänen *et al.* (1995), Hoorn (1996) indicou que nesse período se deu a maior queda do nível do mar registrada no Mioceno (Haq *et al*., 1987), sendo pouco provável que se desse uma incursão marinha desse porte. Por sua vez, Paxton *et al.* (1996) afirmam que a paleoictiofauna encontrada nos sedimentos descritos por Räsänen *et al.* (1995) indicam ambiente de água doce. Marshal & Lundberg (1996), porém, atribuem uma origem tectônica, e não eustática, à incursão marinha desse período. Argumentam que na fase orogênica Quechua, a subsidência das bacias de ante-país foi mais intensa que o preenchimento sedimentar, pelo menos inicialmente, ficando em alguns locais metros abaixo do nível do mar, o que permitiu a entrada do mar pelo norte na bacia do Solimões. Admitem uma possível conexão entre o "mar de Pebas" e o "mar do Paraná", mas afirmam não existirem dados geológicos até então que a comprovassem. Segundo esses autores, a deposição da Formação Solimões se deu, portanto, em parte sob condições marinhas, que gradativamente se tornaram continentais a medida que o preenchimento da bacia provocava a regressão.

Com o objetivo de determinar a salinidade da água, Vonholf *et al*. (1998) analisaram isótopos de estrôncio em conchas de moluscos provenientes de afloramentos da Formação Solimões (Pebas), na Colômbia, próximo da fronteira com o Brasil e Peru. Foram selecionados diversos níveis interpretados por Hoorn (1993) como fluvio-lacustres e um no qual foi identificada uma incursão marinha. A idade de ~11 Ma (fim do Mesomioceno e o início do Neomioceno) foi obtida através de palinologia. Os dados confirmaram a deposição em ambiente de água doce, predominantemente alimentado por drenagens oriundas dos Andes. As amostras da camada da incursão marinha apresentaram resultados indicativos de

ambiente mixohalino. Essa incursão seria oriunda do Atlântico Norte que, passando ao longo da margem oeste do escudo das Guianas, teria atingido a bacia do Solimões.

Analisando a ictiofauna do Mioceno da mesma região, Monsch (1998) encontrou restos de peixes marinhos, de água doce e salobra, que atestam influência marinha na área no Eomioceno, Mesomioceno e início do Neomioceno. Representantes das famílias Pristidae, Dasyatidae e Myliobatidade indicam ambiente marinho periférico de águas rasas. Outros taxons de peixes e crocodilos indicam clima quente. O autor discute a possibilidade de retrabalhamento, mas devido às características do depósito e à relação quantitativa entre fósseis marinhos e de água doce rejeita essa hipótese.

Ainda na mesma área, Whatley *et al*. (1998) estudaram 78 amostras de 18 afloramentos e registraram uma fauna de ostracodes dominada pelo gênero *Cyprideis*, com 14 espécies diferentes. A grande diversidade desse gênero é atribuida à estabilidade da área e ao fato da salinidade da água ser demasiado alta para os demais gêneros dulcícolas de Cypridaceae. A baixa salinidade, porém, limitou a entrada de apenas alguns taxons tipicamente marinhos. Os autores interpretam a associação como típica de ambiente lacustre de água salobra de baixa energia, sem os indícios de ambiente fluvial encontrados por Hoorn (1993, 1994).

Num levantamento bastante abrangente, Wesseling *et al.* (2002) estudaram os moluscos da Formação Solimões provenientes de mais de 123 afloramentos. Esses dados foram compilados com os de Nutall (1990) e Romero-Pittman (1997 *apud* Wesseling *et al.*, 2002). A fauna encontrada é quase exclusivamente aquática, endêmica e extinta. Os gêneros *Pachydontinae* e *Cochliopina* dominam as associações em número de espécies e espécimens. A taxonomia, os dados de isótopos das conchas e os dados sedimentológicos são interpretados como indicativos da existência de um grande paleolago (Lago Pebas) ocupando a Amazônia ocidental ao longo do Mioceno, com esporádicas incursões marinhas. O trabalho de Vonhof *et al*. (2003) corrobora parcialmente essas conclusões.

Novos dados sedimentológicos e de ichinofósseis publicados por Hovikoski *et al.* (2005), parecem indicar o limite sul da influência marinha da Formação Solimões. Foram estudados afloramentos na Bolívia ao longo dos rios Madre de Dios (Cerro Colorado) e Manu (Cocha Cashu). A idade dos sedimentos é estimada em 9 Ma com base em datações de $^{40}Ar/^{39}Ar$ (Campbell *et al.,* 2001). A interpretação dada para esses depósitos foi de paleoambiente predominantemente estuarino (Mar Pebas) com canais de maré intercalados com ambientes continentais. Pela idade desses depósitos, essa incursão não poderia ser oriunda do norte, uma vez que a cordilheira oriental da Colômbia já estava soerguida (Hoorn

et al., 1995). Como alternativa, os autores acataram a proposta de Marshal e Lundberg (1996), de uma conexão com a bacia do Paraná e desta com o mar.

Estudos paleoclimáticos foram realizados por Kandoorp *et al*. (2005), a partir da análise da variação de isótopos de oxigênio ($\delta^{18}O$) em conchas de moluscos da Formação Solimões, de afloramento próximo à Iquitos (Peru). Esses autores verificaram sazonalidade no regime de chuvas (seca/chuva) no Mioceno comparável à atual, o que possibilitaria o desenvolvimento de floresta tropical úmida na região.

Recentemente Rodaz *et al*. (2005a) publicaram estudos geofísicos e sedimentológicos que indicam que o arco de Iquitos seria uma estrutura tipo *forebulge*, com origem no Neomioceno. A datação dos sedimentos foi feita por correlação com outros depósitos datados através da palinologia. O seu soerguimento teria causado grandes mudanças paleoambientais, retraindo e dividindo o Lago/Mar Pebas e abrindo novos espaços para a expansão da floresta.

Quanto à vegetação, os dados mais precisos restringem-se à palinologia, apesar de serem registrados muitos fósseis vegetais, como trocos e folhas, em outros trabalhos (Caputo, 1984, Eiras *et al*., 1994, entre outros). No Mioceno a composição da flora era muito semelhante a atual, mas os registros polínicos indicam uma maior variedade de espécies em relação ao recente (Hoorn, 1994). Uma explicação para este fato seria que as mudanças ambientais ocorridas nesse período podem ter acarretado diferentes tipos de estresse, causando extinções e favorecendo o processo de evolução e especiação. O levantamento da cordilheira dos Andes estimulou também a adaptação de espécies montanas e permitiu a entrada de taxons austrais e antárticos e, mais tarde, de gêneros árticos nas áreas frias e temperadas dos neotrópicos, dando origem a espécies adaptadas às novas circunstâncias (Van de Hammen & Hooghiemstra, 2000).

3. PALINOLOGIA

3.1. Conceitos gerais

O termo *Palinologia* foi cunhado por Hyde & Williams (1944 *apud* Jansonius & McGregor, 1996) a partir do verbo grego *palunein* (παλυνειν) que quer dizer pulverizar. Na botânica, Palinologia designa o estudo de pólen e esporos. Porém, com o avanço da técnica e o desdobramento de suas aplicações, passou a ser uma ciência que se delimita mais pela técnica utilizada do que pela relação entre o material estudado. Atualmente todo espécimen microscópico orgânico que resista ao tratamento químico corrosivo (HF, HCl, H_2NO_3, etc.) aplicado sobre a rocha ou sedimento é considerado um *palinomorfo*. Estes podem ser grãos de

pólen e esporos, obviamente, mas também esporos de fungo, fragmentos do aparelho bucal de anelídeos, restos de tecido vegetal, cistos de algas, revestimento orgânico de foraminíferos, e o que mais possa ocorrer (Jansonius & McGregor, 1996).

A Palinologia é aplicada como ferramenta para solucionar diferentes problemas geológicos. Pode-se através dela obter informações sobre bioestratigrafia, paleobiogeografia, paleoclimatologia, ambiente deposicional e estágio de maturação termal, por exemplo.

3.2. Análise palinológica neotropical

O registro palinológico das florestas tropicais úmidas é caracterizado pela alta biodiversidade e pela presença de inúmeros táxons polinizados por animais. As espécies anemófilas (polinizadas pelo vento), apesar de serem em menor número, são supra-representadas no registro polínico. Entre elas estão incluídas as gramíneas, ciperáceas e outras ervas, além de algumas árvores típicas da floresta tropical, como certas espécies de Myrtaceae, Moraceae e Ulmaceae (Colinvaux *et al*., 1999).

O sinal polínico das plantas polinizadas por animais registra a comunidade vegetal que cresce dentro dos limites da drenagem local e, por isso, serve de instrumento para uma análise detalhada das associações florestais dentro de uma bacia de sedimentação. Um estudo em maior escala deve ser feito através da combinação de dados de florestas estritamente locais com registros regionais fornecidos pelo grupo de espécies anemófilas. Para uma correta interpretação paleoecológica de diagramas polínicos, é necessário o conhecimento da produção, transporte e deposição atual de grãos de pólen e de esporos, para que se possa comparar a vegetação pretérita com a atual (Colinvaux *et al*., 1999).

3.3. Arcabouços bioestratigráficos

A bioestratigrafia consiste na organização sistemática de estratos de rochas em unidades nomeadas com base no conteúdo e distribuição dos fósseis. Para que um arcabouço bioestratigráfico proposto seja confiável, este deve estar relacionado a biozonas internacionalmente aceitas e de acordo com códigos estratigráficos internacionais. A importância da *palinoestratigrafia* deve-se ao fato de que, por poder ser aplicada tanto para rochas de origem marinha como continental, possibilita a correlação entre depósitos de origens distintas (Christopher & Goodman, 1996).

O Neógeno da região setentrional da América do Sul foi objeto de alguns estudos palinoestratigráficos que estabeleceram zoneamentos cada vez mais detalhados.

A sequência sedimentar costeira da Guiana foi estudada por Van der Hammen & Wijmstra (1964) que estabeleceram um zoneamento bioestratigáfico local englobando o Neo-Cretáceo, Paleógeno e Neógeno. Wijmstra (1971) completou esses estudos com uma reconstituição da história da bacia da Guiana e Suriname durante os mesmos períodos.

Condensando vinte anos de pesquisas palinológicas, Germeraad *et al*. (1968) elaboraram um detalhado estudo bioestratigráfico e paleoambiental dos sedimentos terciários de áreas tropicais da América do Sul (Colômbia, Venezuela, Trinidad e Guianas), África (Nigéria) e Ásia (Bornéo). Este constituiu a base para os trabalhos posteriores feitos na região setentrional da América do Sul.

Em sua tese de doutoramento Regali (1971) estudou o Paleógeno e Neógeno da foz do rio Amazonas, no Brasil. Posteriormente, Regali *et al*. (1974ab) fizeram um biozoneamento englobando os sedimentos meso-cenozóicos de todas as bacias costeiras brasileiras.

Na tentativa de unificar novos dados e os já publicados, Muller *et al*. (1987) elaboraram um zoneamento do Cretáceo ao Recente para norte da América do Sul, incluindo Brasil, Colômbia, Guiana, Suriname, Trindade e Venezuela.

Na Venezuela, Lorente (1986) estudou amostras de trinta poços de três bacias e refinou o arcabouço bioestratigráfico do Neógeno da região. Além disso, fêz uma análise paleoambiental através de estudos estatísticos de dados de palinofácies, palinologia e sedimentologia.

Hoorn (1993), através do estudo de 15 afloramentos e uma perfuração, aplicou o biozoneamento de Lorente (1986) à Formação Solimões no Brasil e Formação Pebas na Colômbia e propôs um biozoneamento palinoestratigráfico com variações locais para essas formações.

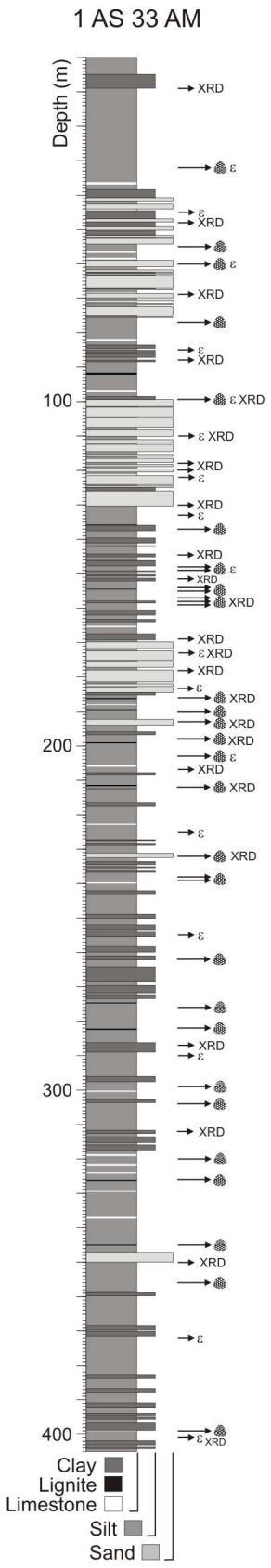
Dentre todos os arcabouços propostos, destacam-se os trabalhos de Germeraad *et al*. (1968), Lorente (1986) e Muller *et al*. (1987) pelo número de poços estudados, pela maior proximidade da área de estudo e por terem contexto geológico semelhante. Estes autores definem o estabelecimento de zonas e subzonas a partir da distribuição estratigráfica de espécies cuja base e/ou topo de ocorrência estão bem definidos. Além disso, os trabalhos de Germeraad *et al*. (1968) e Lorente (1986) correlacionam dados palinológicos com biozonas internacionais baseadas em nanoplancton e foraminíferos possibilitando o estabelecimento de idades de forma mais confiável.

No presente trabalho optou-se por utilizar o arcabouço bioestratigráfico de Lorente (1986), uma vez que a sua aplicabilidade para a Formação Solimões já foi comprovada, e por abranger idades mais jovens que as encontradas por Hoorn (1993).

4. MATERIAL

O material consiste de 74 amostras provenientes do cilindro de sondagem da perfuração 1AS 33AM, das quais apenas 32 apresentaram resíduo palinológico. O poço, perfurado pelo Serviço Geológico do Brasil (CPRM) como parte do Projeto Carvão no Alto Solimões, localiza-se na área do município Atalaia do Norte, no estado do Amazonas, Brasil, nas coordenadas 05°15'S/71°33'W (Figura1).

A coleta de amostra visou principalmente a análise palinológica, mas foram também coletadas outras destinadas a outros métodos (Figura 4). A composição mineralógica de 24 amostras foi determinada por Difração de Raio X. Por fim, foram feitas análises isotópicas de Sm e Nd em 20 amostras. Foram analisados também diversos níveis para obtenção de fósseis carbonáticos. Estes foram analisados separadamente (Do Carmo *et al*., 2005) e serão publicados em breve.



Depth		XRD	ε
8,90		X	
32,00	X		X
45,00			X
47,90		X	
55,00	X		
60,00	X		X
68,90		X	
77,10	X		
85,90			X
87,60		X	
99,80	X	X	X
110,30		X	X
118,00		X	
120,20		X	
122,20			X
131,50		X	
133,30			X
137,00	X		
143,50		X	
148,58	X		
149,40	X		X
151,60		X	
154,70	X		
155,00	X		
157,87	X	X	
158,20	X		
159,75	X		
169,00		X	
173,15		X	X
178,00		X	
183,60			X

Depth		XRD	ε
186,60	X		
187,50		X	
190,70	X		
193,50	X	X	
198,50	X	X	
203,15	X		X
207,70		X	
212,65	X	X	
225,20			X
232,18	X	X	
238,33	X		
239,90	X		
255,00			X
262,00	X		
276,70	X		
282,55	X		
287,35		X	
290,05			X
299,05	X		
304,00			
304,45	X		
312,33		X	
320,25	X		
326,25	X		
345,20	X		
350,50		X	
356,35	X		
372,10			X
399,10	X		
401,00		X	X

Types of sample analysis

	Palynology
XRD	X-ray diffraction
ε	Sm / Nd isotopes

Figura 4: Amostras processadas pelos diferentes métodos: palinologia, difração de raio X e isótopos de SM/Nd.

5. MÉTODOS

5.1. Técnica de preparação de amostras palinológicas:

- Desagregação da amostra com martelo e separação de 10cm^3 de sedimento.
- Adição de pólen exótico (*Kochia escoparia*).
- Eliminação dos carbonatos com ácido clorídrico concentrado, por um período mínimo de duas horas. Controlar a reação com álcool etílico 96 GL.
- Lavagem: centrifugar por 5 minutos a aproximadamente 2500rpm, descartar o ácido e completar o volume com água destilada. Repetir a operação por 3 vezes. Após a centrifugação é aconselhável esperar quinze minutos antes de descartar a água, para evitar que se percam palinomorfos menores ainda não sedimentados no fundo do tubo.
- Eliminação dos silicatos com ácido fluorídrico concentrado, por um período mínimo de doze horas.
- Eliminação dos fluorsilicatos com ácido clorídrico 1:9, em banho-maria até 60°C aproximadamente.
- Lavagem com água destilada por 3 vezes.
- Separação da matéria orgânica. Centrifugar a amostra, descartar completamente a água e adicionar solução de cloreto de zinco (densidade 2), homogeneizando bem o resíduo na solução. Centrifugar por 20 minutos. Conservar o anel sobrenadante e desprezar o precipitado. Diluir a solução com álcool comercial e centrifugar.
- Lavagem com água destilada por 3 vezes.
- Oxidação da matéria orgânica com ácido nítrico concentrado, por um período de 2 a 5 minutos, de acordo com o grau de carbonização do material. Caso a amostra seja de coloração clara, pode-se suprimir essa etapa. Controlar a reação com água destilada.
- Eliminação do excesso de matéria orgânica com hidróxido de potássio 1:9.
- Tamização do resíduo com malha de 6µm, sob água destilada corrente. Conservar a fração retida na peneira.
- Acondicionamento do resíduo em frasco de vidro com tampa. Acrescentar uma gota de fenol para evitar a proliferação de fungos.

Para a montagem de lâminas homogeniza-se uma gota de resíduo sobre a lamínula. Coloca-se a lamínula com o resíduo sobre placa quente, em temperatura média (60-70^{o}C), até formar uma película. Pinga-se 2 a 3 gotas de Entellan sobre uma lâmina e colar a lamínula. É necessário, muitas vezes, pressionar levemente a lamínula com o dedo para retirar o excesso

de Entellan e as bolhas de ar que se formaram. Deixar secar naturalmente e eliminar o excesso de cola sobre a lâmina com o auxílio de uma lâmina de barbear.

5.2. Estudo sistemático

O estudo sistemático foi feito por comparação com paleopalinofloras descritas para o Neógeno do Brasil, de países setentrionais sul-americanos e outros nos quais foram encontradas evidências de floresta tropical úmida durante este período. As identificações estão feitas em nível específico, quando possível, ou em nível genérico, utilizando a classificação de Iversen e Troels-Smith (1950). Alguns palinomorfos foram fotografados em fotomicroscópio com objetiva de 100x para a montagem das estampas.

5.3. Análise quantitativa

A análise quantitativa foi feita com a contagem dos palinomorfos até um mínimo de 300 grãos de pólen em cada amostra. No caso da amostra apresentar uma baixa concentração de pólen foram contados 100 grãos de pólen. Os dados foram processados no programa Excel para a construção dos diagramas de pólen.

Os diagramas polínicos foram feitos com o programa PamPlot da Pangaea PaleoNetwork for Geological and Environmental Data (www.pangaea.de/Software/PanPlot/). Os dados utillizados são de porcentagem de cada espécie em relação à soma total de grãos (pólen e esporos).

As análises estatísticas foram feitas no programa STATISTICA, version 7 (StatSoft, Inc. 2004, www.statsoft.com), usando análise cluster multivariada aplicando os métodos de Ward e 1-Pearson r.

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COMPARISON OF TWO PALYNOLOGICAL METHODS FOR AMAZONIAN NEOGENE SEDIMENTS

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RESUMO

Os métodos de preparação palinológica são de modo geral caracterizados como padrão, porém os resultados diferem de acordo com a técnica e os reagentes empregados. Com o objetivo de checar a compatibilidade dos espectros polínicos obtidos através de diferentes métodos de processamento, quatro amostras de sedimento foram processadas no Instituto de Geociências da Universidade de Brasília (UnB) e no Institute for Biodiversity and Ecosystem Dynamics (IBED) da Universidade de Amsterdã. Os palinomorfos foram identificados, contados até um mínimo de 100 grãos (pólen e esporos) e separados em três frações de tamanho: < 20 μm; ≥ 20 μm / < 30 μm; ≥ 30 μm. Os resultados foram plotados em gráficos e analisados estatisticamente. Apesar das diferenças evidentes, em termos de diversidade ambos os métodos analisados parecem ser eficientes, ou talvez seja melhor dizer igualmente ineficientes. A biodiversidade da Amazônia é tão grande que, mesmo quando a soma de pólen atingiu mais de 500 grãos, menos da metade dos tipos identificados eram comuns aos dois métodos. Isso indica que nenhuma das técnicas oferece um espectro completo da paleovegetação, mas fornece suficiente informação que permite ao palinólogo extrair suas conclusões paleoambientais. As associações palinológicas das quatro amostras são de modo geral similares, correspondendo ao modelo paleoambiental de *sistema fluvial*. Portanto é possível comparar os espectros palinológicos obtidos através de dois métodos diferentes apesar de suas diferenças. O presente trabalho restringiu-se a um caso específico com um número reduzido de amostras e não pretende generalizar, mas indica a necessidade de um estudo mais detalhado com uma maior amostragem.

ABSTRACT

The preparation methods are largely characterized as standard, but the palynological records differ according to the techniques and chemicals used. In order to check the compatibility of spectra obtained through different processing methods, four sediment

samples were processed at the Instituto de Geociencias, University of Brasília (UnB) as well as in the Institute for Biodiversity and Ecosystem Dynamics (IBED), at the University of Amsterdam. The palynomorphs were identified, counted to a minimum of 100 grains (pollen and spores) and separated into three size fractions: < 20 μm; ≥ 20 μm / < 30 μm; ≥ 30 μm. The results were plotted in graphics and subjected to statistical analysis. Although there are evident differences, in terms of diversity both analyzed methods seem to be efficient, or better to say, equally inefficient. The biodiversity of Amazonia is so impressive that even when the pollen sum reached more than 500 grains, less than half of the identified taxa were common to both techniques. It indicates that either method gives a complete spectra of the paleovegetation, but provides enough information that enables the palynologist to draw paleonvironmental conclusions. The palynological associations of the four samples are in general similar, corresponding to the *fluvial system* paleoenvironmental model. Therefore it is possible to compare palynological spectra obtained through the two different methods despite the dissimilarities. The present study is restricted to a specific case with just a few samples and does not intend to generalize the conclusions, but shows the necessity of more detailed analysis with larger sampling.

INTRODUCTION

Palynology is applied to several purposes such as the identification of depositional environments, stratigraphic correlation, biostratigraphy, paleobiogeography and paleoclimatology (Chistopher and Goodman, 1996). A palynological residue is obtained from sediments or rocks after a drastic maceration process and all the organic structures that resist the corrosive chemicals are considered *palynomorphs*. It can be animal and vegetal fragments, algal cysts, different types of spores and pollen grains (Jansonius and McGregor, 1996). Applied to paleonvironmental studies, it is assumed that the palynological spectrum reflects the taxonomic diversity and the proportions of different ecological groups from the surroundings of the depositional site (Colinvaux *et al*., 1999).

The Solimões Formation consists of claystones, siltstones and sandstones intercalated with a few lignite and limestone layers deposited in the Miocene/Pliocene in the northwestern Brazil (Radambrasil, 1977; Maia *et al.*, 1977).

Hoorn (1993, 1994) studied the palynology and sedimentology of one bore hole and many outcrops of the Solimões Formation and presented a paleoenvironmental model for the region during the Miocene. The samples were processed at the Institute for Biodiversity and Ecosystem Dynamics (IBED), at the University of Amsterdam.

A research project of the palynology of the Solimões Formation from another well in the Solimões basin required the comparison of the new data with the previous results. The material was processed at the Instituto de Geociencias, University of Brasília (UnB) according to a different preparation technique (Leite, submitted and Leite *et al.*, submitted).

Although preparation methods are largely characterized as standard, the palynological records differ according to the techniques and chemicals used. So, in order to check the compatibility of spectra obtained through different processing methods, four sediment samples (239,90; 282,55; 326,25 and 345,20 m) were treated at the UnB as well as in the IBED. The palynomorphs were identified, counted to a minimum of 100 grains (pollen and spores) and separated into three size fractions: < 20 μm; ≥ 20 μm / < 30 μm; ≥ 30 μm. The results were plotted in graphics and subjected to statistical analysis.

The present study is restricted to a specific case with just a few samples and does not intend to generalize the conclusions, but it may signalize the necessity of more detained analysis.

DESCRIPTION OF THE METHODS

The standard method at IBED uses 1 cm^3 of sediment, but in this case 2 cm^3 were used. It starts with $Na_4P_2O_7$ 10%, after 8 hours the solution is boiled and sieved with a 250μm mesh to eliminate the large fragments. It proceeds with HCl 10%, acetolysis and separation of organic fraction with bromoform of density 2 g/cm^3. Between different phases the residue is washed and centrifuged at 4500 rpm for 2 minutes. The slides are mounted with jelly and sealed with wax.

The method used at UnB is the result of the personal experience of the author that added or omitted certain steps of the standard method used for pre-Quaternary rocks. 10cm^3 of material is macerated with HCl, HF and HNO_3. $ZnCl_2$ with density 2 g/cm^3 is used for the separation of organic fraction of the residue. Finally it is sieved over a 6μm mesh with KOH 10%. Between the different phases the residue is washed and centrifuged at 2500 rpm for 5 minutes. The slides are mounted with Entellan.

RESULTS

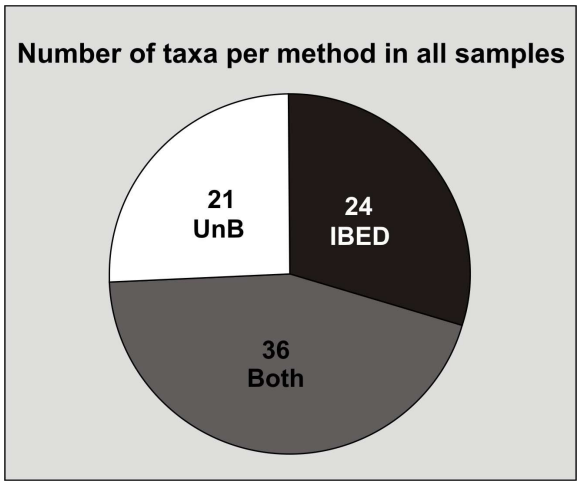
Regarding the general aspect, the analysis of the IBED slide at the microscope is more time consuming than the UnB slide due to the excess of organic debris that made the grains much more sparse. The cleaner aspect of the UnB slide is the result of the 6 μm mesh sieving

with KOH 10%. This step does not seem to cause any loss of material as every recorded grain in both methods is bigger than 10 μm.

Number of taxa

In this study 81 palynomorphs are identified, whenever possible up to specific level. Most of them are pollen grains of angiosperms with 75 types. The spores are very abundant although only seven types are identified (Table 1). The systematic of the palynomorphs mentioned here are presented in Leite (in review), except those identified by a capital letter.

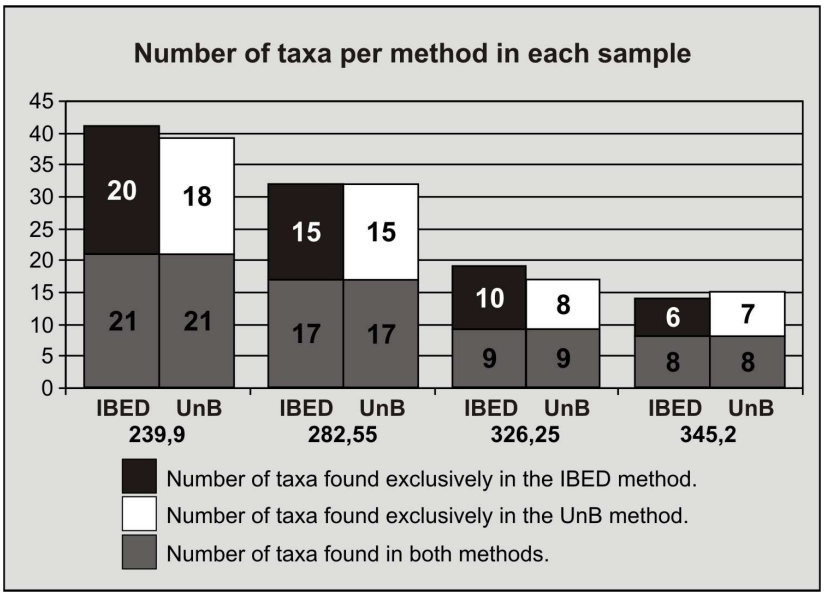
The number of taxa per method is almost the same, around 60 each, but with only 36 in common (Text-Figure 1).



Text-Figure 1: Number of taxa per method in all samples. The total number of taxa per method comprises those restricted to the method and those present in both.

According to Text-Figure 1, both analyzed methods seem to be efficient, or better to say, equally inefficient in terms of diversity as less than half of the identified taxa were common to both.

The diversity is not the same in all samples, but the proportion of taxa present in both and those exclusive to each method remains almost the same (Text-Figure 2).



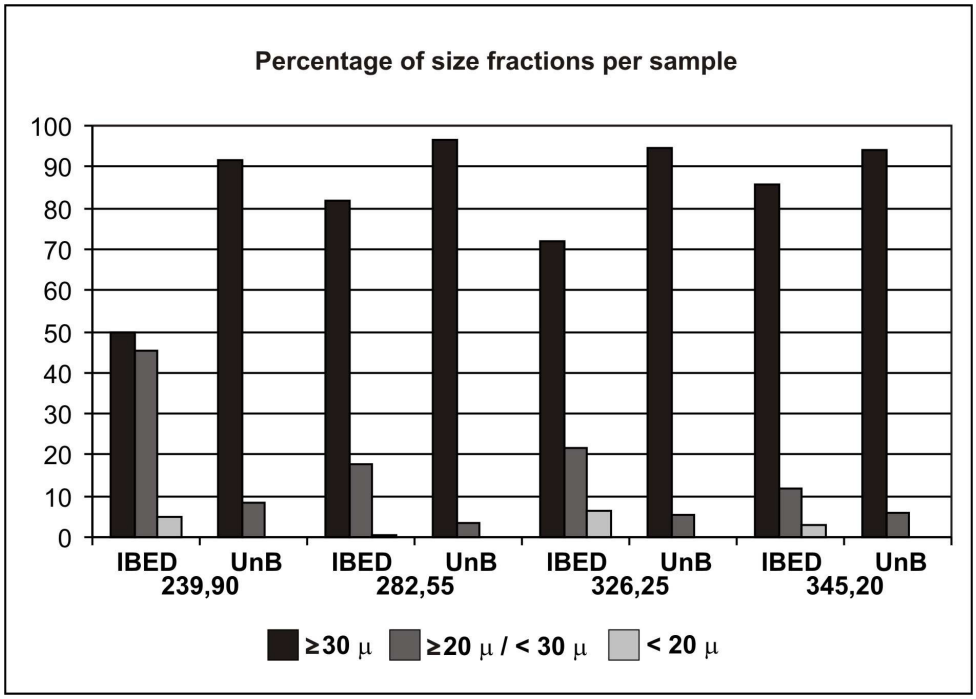
Text-Figure 2: Number of taxa per method in each sample indicating those in common and those found only in one of the methods.

		IBED								UnB							
		ABSOLUTE				PERCENTAGE				ABSOLUTO				PERCENTAGE			
		239,90	282,55	326,25	345,20	239,90	282,55	326,25	345,20	239,90	282,55	326,25	345,20	239,90	282,55	326,25	345,20
≥30 µ	Bombacacidites baculatus	1	0	0	0	0,4	0	0	0	50	0	0	0	9,14	0	0	0
	Bombacacidites bellus	0	2	0	0	0	0,36	0	0	6	88	5	0	1,1	3,84	0,93	0
	Corsinipollenites oculusnoctis	1	3	0	0	0,4	0,54	0	0	2	4	3	1	0,37	0,17	0,56	0,65
	Crassoretitriletes vanraadshoovenii	0	3	4	0	0	0,54	2,88	0	0	188	211	0	0	8,21	39,1	0
	Crototricolpites sp.	0	0	0	0	0	0	0	0	1	24	22	0	0,18	1,05	4,07	0
	Deltoidospora adriennis	1	14	7	0	0,4	2,53	5,04	0	13	56	138	0	2,38	2,44	25,6	0
	Echiperiporites stelae	0	1	0	0	0	0,18	0	0	0	3	1	0	0	0,13	0,19	0
	Echitricolporites maristellae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0,65
	Grimsdalea magnaclavata	7	0	0	0	2,78	0	0	0	120	0	0	0	21,9	0	0	0
	Inaperturopollenites elizabetei	0	0	0	0	0	0	0	0	2	6	0	0	0,37	0,26	0	0
	Inaperturopollenites microechinatus	0	1	0	0	0	0,18	0	0	0	0	0	0	0	0	0	0
	Inaperturopollenites solimoensis	10	10	0	0	3,97	1,81	0	0	1	10	0	0	0,18	0,44	0	0
	Inaperturopollenites spp.	14	8	8	34	5,56	1,45	5,76	23,4	1	0	0	0	0,18	0	0	0
	Laevigatosporites spp.	44	300	38	28	17,5	54,2	27,3	19,3	195	1441	36	55	35,6	62,9	6,67	35,7
	Magnastriatites grandiosus	0	1	2	0	0	0,18	1,44	0	6	19	49	2	1,1	0,83	9,07	1,3
	Margocolporites aff. M. vanwijhei	0	0	0	0	0	0	0	0	0	1	0	1	0	0,04	0	0,65
	Margocolporites vanwijhei	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Mauritiidites franciscoi	1	3	0	0	0,4	0,54	0	0	23	37	13	0	4,2	1,62	2,41	0
	Monoporites annulatus	7	7	2	19	2,78	1,27	1,44	13,1	3	3	0	6	0,55	0,13	0	3,9
	Perinomonoletes sp.	0	0	0	2	0	0	0	1,38	0	0	0	0	0	0	0	0
	Polyadopollenites marileae	0	0	0	0	0	0	0	0	2	0	0	0	0,37	0	0	0
	Polyadopollenites sp.	1	0	0	0	0,4	0	0	0	3	0	0	0	0,55	0	0	0
	Polypodiaceoisporites potoniei	1	0	0	0	0,4	0	0	0	1	0	0	15	0,18	0	0	9,74
	Proxapertites tertiaria	2	0	0	0	0,79	0	0	0	8	7	12	1	1,46	0,31	2,22	0,65
	Psilamonocolpites medius	5	8	1	11	1,98	1,45	0,72	7,59	0	4	2	7	0	0,17	0,37	4,55
	Psilaperiporites sp. A	0	0	0	0	0	0	0	0	0	2	0	0	0	0,09	0	0
	Psilastephanocolporites aff. P. fissilis	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Psilastephanocolporites sp.	0	0	0	0	0	0	0	0	5	0	0	0	0,91	0	0	0
	Psilatricolpites sp. B	1	1	0	0	0,4	0,18	0	0	0	0	0	0	0	0	0	0
	Retimonocolpites fossulatus	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0,74	0
	Retimonocolpites maximus	2	1	14	2	0,79	0,18	10,1	1,38	4	6	2	7	0,73	0,26	0,37	4,55
	Retistephanoporites angelicus	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Retistephanoporites crassiannulatus	1	0	0	0	0,4	0	0	0	7	4	2	0	1,28	0,17	0,37	0
	Retitricolpites cf. R. simplex	5	19	4	21	1,98	3,44	2,88	14,5	3	8	0	48	0,55	0,35	0	31,2
	Retitricolpites conciliatus	0	0	6	3	0	0	4,32	2,07	0	0	0	1	0	0	0	0,65
	Retitricolporites kaarsii	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Retitricolporites sp. D	0	1	0	0	0	0,18	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. E	0	1	0	0	0	0,18	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. I	3	0	2	0	1,19	0	1,44	0	2	0	0	0	0,37	0	0	0
	Scabratricolporites planetensis	0	1	0	0	0	0,18	0	0	0	0	0	0	0	0	0	0
	Striatricolpites catatumbus	0	0	1	0	0	0	0,72	0	5	0	0	0	0,91	0	0	0
	Striatricolporites digitatus	7	0	0	0	2,78	0	0	0	0	0	0	0	0	0	0	0
	Verrucatosporites spp.	12	67	11	4	4,76	12,1	7,91	2,76	34	300	12	0	6,22	13,1	2,22	0
	TOTAL >30 µ	**126**	**452**	**100**	**124**	**50**	**81,7**	**71,9**	**85,5**	**501**	**2211**	**512**	**145**	**91,6**	**96,5**	**94,8**	**94,2**
≥ 20 µ / <30 µ	Costatricolporites reticulatus	0	0	0	0	0	0	0	0	0	2	0	0	0	0,09	0	0
	Echitriletes muellerii	0	0	0	0	0	0	0	0	2	0	0	0	0,37	0	0	0
	Heterocolpites incomptus	2	0	0	0	0,79	0	0	0	0	0	0	0	0	0	0	0
	Myrtaceidites spp.	8	0	0	0	3,17	0	0	0	0	2	0	0	0	0,09	0	0
	Perisyncolporites pokornyi	3	0	1	0	1,19	0	0,72	0	30	10	14	1	5,48	0,44	2,59	0,65
	Psiladiporites minimus	1	0	0	0	0,4	0	0	0	0	0	0	0	0	0	0	0
	Psilatricolpites minutus	1	19	11	1	0,4	3,44	7,91	0,69	1	22	14	5	0,18	0,96	2,59	3,25
	Psilatricolpites sp. A	1	5	0	0	0,4	0,9	0	0	1	0	0	0	0,18	0	0	0
	Psilatricolporites devriesi	0	0	0	0	0	0	0	0	0	2	0	0	0	0,09	0	0
	Psilatricolporites labiatus	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Psilatricolporites operculatus	13	36	1	0	5,16	6,51	0,72	0	0	0	0	0	0	0	0	0
	Psilatricolporites optimus	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Psilatricolporites sp. A	1	4	0	0	0,4	0,72	0	0	0	0	0	0	0	0	0	0
	Psilatricolporites sp. B	1	0	0	0	0,4	0	0	0	1	0	0	0	0,18	0	0	0
	Psilatricolporites sp. C	1	0	0	0	0,4	0	0	0	0	0	0	0	0	0	0	0
	Psilatricolporites sp. D	0	2	0	0	0	0,36	0	0	0	0	0	0	0	0	0	0
	Psilatricolporites vanus	26	13	12	4	10,3	2,35	8,63	2,76	4	27	0	3	0,73	1,18	0	1,95
	Psilatriporites sp. A	29	0	0	0	11,5	0	0	0	0	0	0	0	0	0	0	0
	Retitricolpites sp.A	0	4	0	0	0	0,72	0	0	1	0	0	0	0,18	0	0	0
	Retitricolporites irregularis	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Retitricolporites magnus	0	0	0	0	0	0	0	0	1	0	0	0	0,18	0	0	0
	Retitricolporites medius	3	0	0	0	1,19	0	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. A	1	0	0	10	0,4	0	0	6,9	0	1	0	0	0	0,04	0	0
	Retitricolporites sp. C	0	4	5	0	0	0,72	3,6	0	0	1	0	0	0	0,04	0	0
	Retitricolporites sp. F	0	2	0	0	0	0,36	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. H	0	0	0	2	0	0	0	1,38	0	0	0	0	0	0	0	0
	Retitricolporites sp. K	5	0	0	0	1,98	0	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. L	7	0	0	0	2,78	0	0	0	1	0	0	0	0,18	0	0	0
	Retitricolporites sp.1	1	0	0	0	0,4	0	0	0	0	7	0	0	0	0,31	0	0
	Retitriporites sp. A	8	0	0	0	3,17	0	0	0	0	0	0	0	0	0	0	0
	Striatricolpites tenuissimus	1	0	0	0	0,4	0	0	0	0	0	0	0	0	0	0	0
	Syncolporites incomptus	0	0	0	0	0	0	0	0	0	1	0	0	0	0,04	0	0
	Verrutricolporites sp.	1	10	0	0	0,4	1,81	0	0	0	2	0	0	0	0,09	0	0
	TOTAL >20 µ	**114**	**99**	**30**	**17**	**45,2**	**17,9**	**21,6**	**11,7**	**45**	**77**	**28**	**9**	**8,23**	**3,36**	**5,19**	**5,84**
<20 µ	Psiladiporites sp. A	8	1	0	0	3,17	0,18	0	0	0	0	0	0	0	0	0	0
	Psilatricolporites sp. E	0	0	0	0	0	0	0	0	1	3	0	0	0,18	0,13	0	0
	Retitricolporites sp. B	2	0	0	0	0,79	0	0	0	0	0	0	0	0	0	0	0
	Retitricolporites sp. J	2	0	9	4	0,79	0	6,47	2,76	0	0	0	0	0	0	0	0
	Retitricolporites sp. M	0	1	0	0	0	0,18	0	0	0	0	0	0	0	0	0	0
	TOTAL <20 µ	**12**	**2**	**9**	**4**	**4,76**	**0,36**	**6,47**	**2,76**	**1**	**3**	**0**	**0**	**0,18**	**0,13**	**0**	**0**
	TOTAL SUM	**252**	**553**	**139**	**145**	**100**	**100**	**100**	**100**	**547**	2291	**540**	**154**	**100**	**100**	**100**	**100**

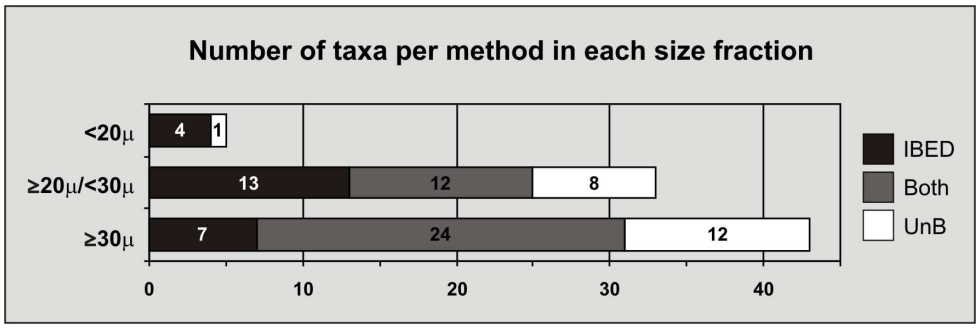
Table 1: Palynological results from four samples prepared in two different methods (IBED and UnB).

Size fractions

The purpose of measuring the grains and quantifying the size fractions was to monitor the possible loss of the smaller grains in the 6 μm mesh sieving step or in the discard during washing in the UnB method. It also intended to evaluate the biostratigraphic and ecological significance of the grains included in each size fraction.



Text-Figure 3: Percentage of size fractions of palynomorphs (< 20 μm; ≥ 20 μm / < 30 μm; ≥ 30 μm) per sample in both methods.



Text-Figure 4: Number of taxa per size fractions of palynomorphs (< 20 μm; ≥ 20 μm / < 30 μm; ≥ 30 μm) indicating those in common and those found only in one of the methods.

The grain size analysis shows that (Text-Figure 3 and 4):

- ≥ 30 μm fraction includes most of the taxa and among them the biostratigraphic markers. It represents the highest percentage in both methods, but it is higher in the UnB.

- ≥20 μm /<30 μm fraction is more representative in IBED than in UnB, especially at 239,90 m sample where it reaches nearly half of the amount. It includes the highest number of taxa restricted to one method (13 in IBED), most of them not formally described.
- <20 μm fraction is smallest in both methods with only five species, none of them common to both. In the IBED method it is present in all samples but in low percentages (less than 10%). Although UnB method had two samples with no element in this fraction(326,25 and 345,20 m), it seems more related to the higher percentage of the larger fractions than to loss of smaller grains. However some may have been lost in the discard water due to the lower centrifuge speed in UnB method.

Ecological significance of the palynological associations

The palynological associations of the four samples prepared in the two different methods are in general similar. Only one sample (326,25 m) presents a totally different association. More than half of the species represent less than 2%. The most abundant taxa in each sample are shown in Table 2. The statistical similarity of the associations can be verified in a cluster analysis graphic (Text-Figure 5).

Spores dominate the palynological association of all samples. In Quaternary Amazonian pollen diagrams spores normally represent low percentages but can be over represented in fern-filled swamps areas. In this case it is suggested to remove them from the pollen sum (Colinvaux *et al*., 1999), however in the pre-Quaternary samples they are included in the sum and used as environmental indicators (Lorente, 1986).

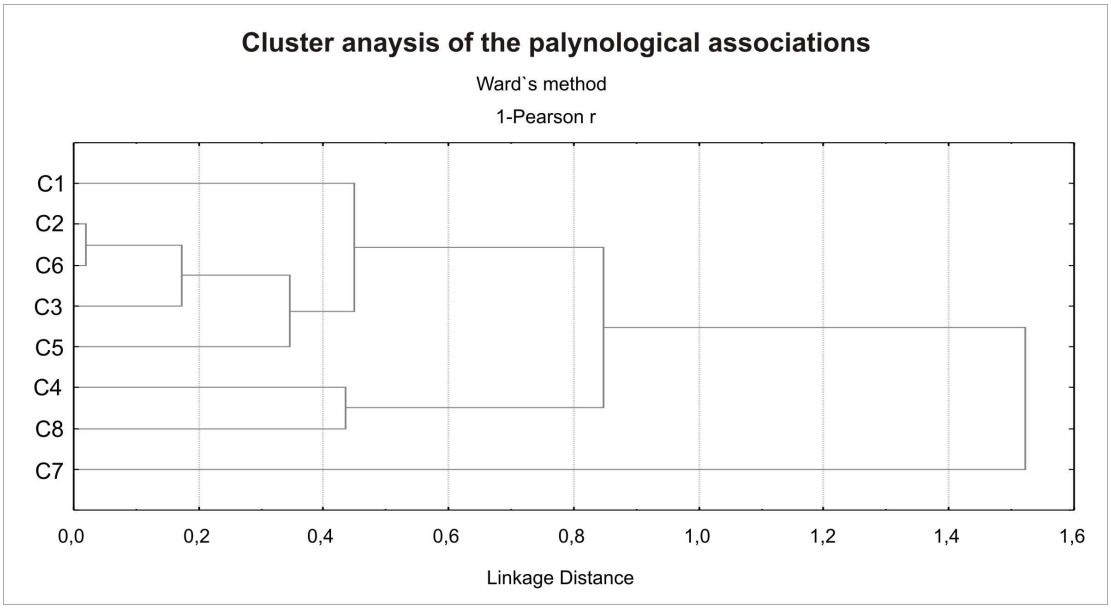
IBED 239,90 - C1	%
Laevigatosporites spp.	17,46
Psiladiporites sp. A	11,51
Psilatricolporites vanus	10,32
Inaperturopollenites spp.	5,56
Psilatricolporites operculatus	5,16
TOTAL	50,00
UnB 239,90 - C5	**%**
Laevigatosporites spp.	35,65
Grimsdalea magnaclavata	21,94
Bombacacidites baculatus	9,14
Verrucatosporites spp.	6,22
Perisyncolporites pokornyi	5,48
TOTAL	78,43

IBED 282,55 - C2	%
Laevigatosporites spp.	54,25
Verrucatosporites spp.	12,12
Psilatricolporites operculatus	6,51
TOTAL	72,88
UnB 282,55 - C6	**%**
Laevigatosporites spp.	62,90
Verrucatosporites spp.	13,09
C. vanraadshoovenii	8,21
TOTAL	84,20

IBED 326,25 - C3	%
Laevigatosporites spp.	27,34
Retimonocolpites maximus	10,07
Psilatricolporites vanus	8,63
Psilatricolpites minutus	7,91
Verrucatosporites spp.	7,91
Retitricolporites sp. J	6,47
Inaperturopollenites spp.	5,76
Deltoidospora adriennis	5,04
TOTAL	79,14
UnB 326,25 - C7	**%**
C. vanraadshoovenii	39,37
Deltoidospora adriennis	25,75
Magnastriatites grandiosus	9,14
Laevigatosporites spp.	6,72
TOTAL	80,97

IBED 345,20 - C4	%
Inaperturopollenites spp.	24,11
Laevigatosporites spp.	19,86
Retitricolpites cf. *R. simplex*	14,89
Monoporites annulatus	13,48
Psilamonocolpites medius	7,80
Retitricolporites sp. A	7,09
TOTAL	87,23
UnB 345,20 - C8	**%**
Laevigatosporites spp.	36,18
Retitricolpites cf. *R. simplex*	30,92
Polypodiaceoisporites potoniei	9,87
TOTAL	76,97

Table 2: Most abundant species (> 5%) found in the four samples prepared in the two different methods. The samples are identified as C1 – C8 in the cluster analysis.

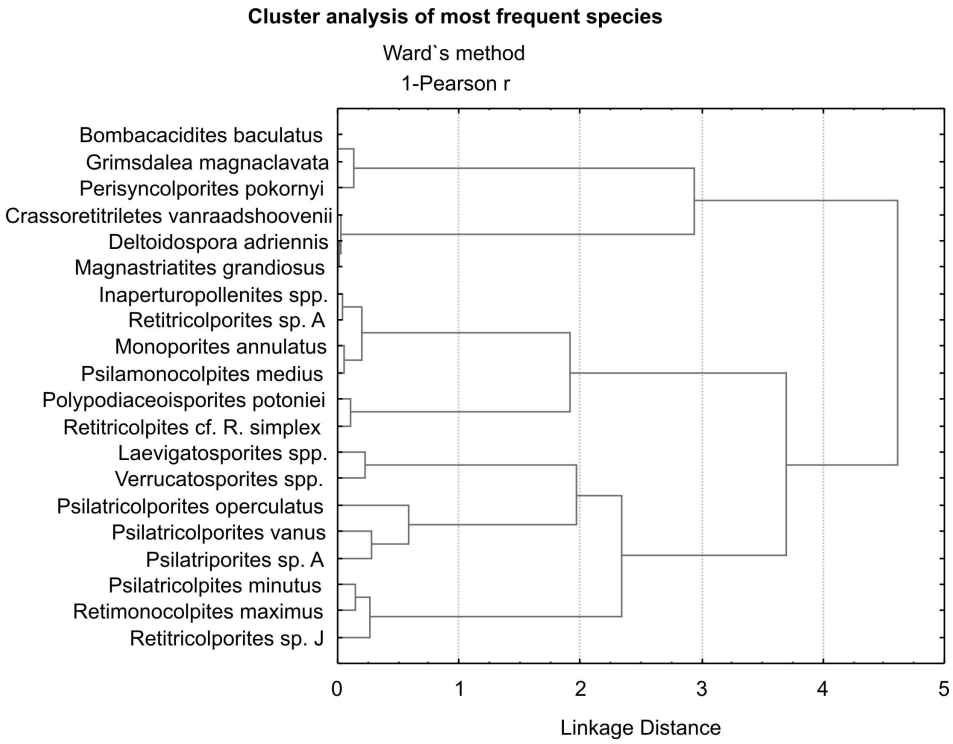


Text-Figure 5: Cluster analysis of the palynological associations found in the samples C1 – C8.

The ecological significance of the palynological associations is centered in the taxonomic affinity and ecology of most abundant species based in Lorente (1986) and Marchant *et al*. (2002) (Table 3). A multivariate cluster analysis of the percentage values groups those with similar occurrence and probably close ecological necessities (Text-Figure 6).

Species	Taxonomic affinity	Ecology
Bombacacidites baculatus	Bombacaceae, *Pachira aquatica*	Tropical wet forests and swamps
C. vanraadshoovenii	Schizaeaceae, *Lygodium*	Tropical swamps
Deltoidospora adriennis	Polypodiaceae, *Acrostichum*	Coastal swamps
Grimsdalea magnaclavata	Possibly Arecaceae	Tropical moist and wet forests
Inaperturopollenites spp.	Rubiaceae, *Psichotria*	Tropical dry, moist and wet forests and swamps
Laevigatosporites spp.	Pteridófita	Tropical dry, moist and wet forests and swamps
Magnastriatites grandiosus	Parkeriaceae, *Ceratopteris*	Wet forests and coastal swamps
Monoporites annulatus	Poaceae	Wide ecology: tropical dry, moist and wet forests (also aquatic) and grasslands
Perisyncolporites pokornyi	Malpighiaceae	Tropical moist and wet forests and swamps
Polypodiaceoisporites potoniei	Pteridóphyte	Tropical dry, moist and wet forests and swamps
Psiladiporites sp. A	Moraceae	Tropical dry, moist and wet forests
Psilamonocolpites medius	Arecaceae	Tropical moist and wet forests
Psilatricolpites minutus	Unknown	
Psilatricolporites operculatus	Euphorbiacea, *Alchornea*	Tropical moist and wet forests
Psilatricolporites vanus	Unknown	
Retimonocolpites maximus	Arecaceae	Tropical moist and wet forests
Retitricolpites cf. *R. simplex*	Possibly Euphorbiaceae	Wide ecology: tropical dry, moist and wet forests and grasslands
Retitricolporites sp. A	Unknown	
Verrucatosporites spp.	Polypodiaceae, *Polypodium*	Tropical dry, moist and wet forests and swamps

Table 3: Taxonomic affinity and ecology of most abundant species found in all samples (Lorente, 1986; Marchant *et al*.,2002).



Text-Figure 6: Cluster analysis of the most abundant species found in all samples.

- **239,90 m**

The most abundant grain in IBED is *Laevigatosporites* sp. followed by two arboreal pollen grains of unknown taxonomic affinity. In general the association is typical of alluvial plain (Lorente, 1986). In UnB, *Laevigatosporites* sp. is also the most abundant grain. Next to it comes *Grimsdalea magnaclavata* that, apart from the biostratigraphic importance, is related to swampy environments together with *Bombacacidites baculatus*.

- **282,55 m**

The association is dominated by *Laevigatosporites* sp. and *Verrutricolporites* sp. in both methods. The next abundant species in IBED is *Psilatricolporites operculatus* that is related to *Alchornea*, a wind pollinated tree commonly found in the Amazonia forest. *Crassoretitriletes vanraadshoovenii* is the next best represented in UnB. It is an important biostratigraphic marker and indicator of wet conditions.

- **326,25 m**

This sample represents a challenge to interpretation. The analysis of the IBED slide at the microscope took longer due to the excess of organic debris that made the grains much more sparse. For this reason the number of grains counted (139), is almost four times smaller than the number of grains counted in the UnB slide (540). In part it could account for the different results, but does not explain it fully. There are eight species in common between the

two methods but with a totally different, almost opposite, numerical importance (Table 4), however the environmental interpretation is in general similar, characteristic of alluvial plain with some evidence of brackish water swamps.

IBED		UnB	
Laevigatosporites spp.	27,34	*C. vanraadshoovenii*	39,07
Retimonocolpites maximus	10,07	*Deltoidospora adriennis*	25,56
Psilatricolpites minutus	7,91	*Magnastriatites grandiosus*	9,07
Verrucatosporites spp.	7,91	*Laevigatosporites spp.*	6,67
Deltoidospora adriennis	5,04	*Perisyncolporites pokornyi*	2,59
C. vanraadshoovenii	2,88	*Psilatricolpites minutus*	2,59
Magnastriatites grandiosus	1,44	*Verrucatosporites spp.*	2,22
Perisyncolporites pokornyi	0,72	*Retimonocolpites maximus*	0,37

Table 4: Species in common between the two processing methods of sample 326,25 with their percentage values.

- **345,20 m**

This sample is not very rich in palynomorphs in neither method. The highest percentage in IBED is of *Inaperturopollenites* spp. that can be trees, shrubs and herbs common in dry and moist forests. The next two are *Laevigatosporites* sp. and *Retitricolporites* cf. *R. simplex* that represent the most abundant grains in UnB. The association is characteristic of alluvial plain.

The age of this sample is determined by the presence of only one grain of the biostratigraphic marker *Echitricolporites maristellae* in UnB. None is present in IBED.

Biostratigraphic significance of the palynological associations

The sediments of the Solimões Formation have been previously dated with palynology by Cruz (1984) and Hoorn (1993). Hoorn (1993) analyzed one well (1 AS 4a AM) and several outcrops in the Solimões basin, applying a framework based in Lorente (1986) but introducing some local variations. The zonation proposed by Hoorn (1993) covers well the early / late Miocene intervals. However in Leite (submitted) and Leite *et al*. (submitted) younger palynozones were found, and thus the original framework of Lorente (1986) was used. As the present work is part of those studies the same framework is applied.

The results presented here are based in the occurrence of biostratigraphic markers in the four samples (239,90; 282,55; 326,25 and 345,20) that enabled the identification of three biozones:

- **239,90 m: *Grimsdalea*** Interval Zone *sensu* Lorente (1986) – middle / late Miocene. This zone was defined by the presence of *Grimsdalea magnaclavata* in both methods.

- **326,25 and 282,55 m:** ***Crassoretitriletes*** Interval Zone *sensu* Lorente (1986) – middle Miocene. This zone was defined by the presence of *Crassoretitriletes vanraadshoovenii* in both methods.
- **345,20 m:** ***Psiladiporites*** Interval Zone *sensu* Lorente (1986) – Early / middle Miocene: This zone was defined by the presence of *Echitricolporites maristellae* in only UnB slide.

CONCLUSIONS

Although there are evident differences, in terms of diversity both analyzed methods seem to be efficient, or better to say, equally inefficient. The biodiversity of Amazonia is so impressive that even when the pollen sum reached more than 500 (282,55) less than half of the identified taxa were common to both. It indicates that either method gives a complete spectra of the paleovegetation, but provides enough information that enables the palynologist to draw paleonvironmental conclusions.

The palynological associations of the four samples prepared in the two different methods are in general similar, corresponding to the *fluvial system* paleoenvironmental model proposed by Lorente (1986) that includes a wide range of geographic and geomorphological units such as alluvial plain, lakes, estuaries and swamps.

Therefore it is possible to compare palynological spectra obtained through the two different methods despite the dissimilarities. However the present study is restricted to a specific case with just four samples and does not intend to generalize the conclusions, but shows the necessity of more detailed analysis with larger sampling.

ACKNOWLEDGMENTS

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6. SISTEMÁTICA

Artigo submetido no peródico *Palynology* da American Association of Stratigraphic Palynologists (AASP):

SYSTEMATICAL PALYNOLOGY OF OF THE SOLIMÕES FORMATION, MIOCENE/PLIOCENE, BRAZIL.

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RESUMO

O presente trabalho consiste nos resultados sistemáticos de uma seção da Formação Solimões no Brasil. Noventa e cinco tipos polínicos foram identificados em nível específico sempre que possível. A maioria deles são grãos de pólen de angiospermas com 85 espécies. Muitos outros foram identificados mas incluídos junto com o grupo de "angiospermas não identificadas" devido ao seu reduzido valor percentual. Apenas uma espécie de gimnosperma foi encontrada e sempre em quantidades reduzidas. De esporos, apesar muito abundantes, somente oito espécies foram identificadas. Sete novas espécies são propostas e formalmente descritas: *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilatricolporites hoornii, Retitricolporites toigoi, Polyadopollenites marileae, Psilatricolporites hoornii, Retitricolporites toigoi*. A ocorrência de marcadores bioestratigráficos ao longo do poço permitiu a identificação de quatro biozonas definidas para o Norte da América do Sul. Intervalo 401 – 300 m: Zona de Intervalo *Psiladiporites* – Eo / Mesomioceno. Essa zona foi definida pela presença de *Echitricolporites maristellae*, *Crototricolpites annemariae* e *Multimarginites vanderhammenii.* A presença de *Psilastephanoporite tesseroporus* também confirma a idade atribuída; Intervalo 326 – 299 m: Zona de Intervalo *Crassoretitriletes* – Mesomioceno. Essa zona foi definida pela presença de *Crassoretitriletes vanraadshoovenii*; Intervalo 299 – 238 m: Zona de Intervalo Asteraceae – Neomioceno. Essa zona foi definida pela presença de *Echitricolporites spinosus* e *Fenestrites spinosus*. *Grimsdalea magnaclavata* foi registrado nesse estudo após a primeira ocorrência de *Fenestrites spinosus*; Intervalo 238 – 32 m: Subzona de Intervalo *Psilatricolporites caribbiensis*– Neomioceno / Plioceno: Essa zona foi definida pela presença de *Psilatricolporites caribbiensis*. *Stephanocolpites evansii*

não foi registrado nesse estudo. A presença de *Multiareolites formosus* também confirma a idade atribuída.

ABSTRACT

The present work consists in the systematic results of a fully cored section of the Solimões Formation in Brazil. Ninety-five palynomorphs were identified, whenever possible up to species level. Most of them were pollen grains of angiosperms with eighty-five types identified and many others included in the group of "undetermined angiosperms" due to their very low percentages. Only one species of gymnosperm was present and always in small quantity. The spores were very abundant although only eight types were identified. Eight new species are proposed and formally described: *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilaperiporites elizabetei, Psilatricolporites hoornii, Retitricolporites toigoi*. The occurrence of biostratigraphic markers throughout the well enabled the identification of four of four biozones described to the northern South America. Interval 399 – 326 m: *Psiladiporites* Interval Zone – Early / middle Miocene. This zone was defined by the presence of *Echitricolporites maristellae*, *Crototricolpites annemariae* and *Multimarginites vanderhammenii.* The presence of *Psilastephanoporite tesseroporus* also confirms the Miocene age attributed to this interval; Interval 326 – 299 m: *Crassoretitriletes* Interval Zone – middle Miocene. This zone was defined by the presence of *Crassoretitriletes vanraadshoovenii*; Interval 299 – 238 m: Asteraceae Interval Zone– late Miocene. This zone was defined by the presence of *Echitricolporites spinosus* and *Fenestrites spinosus*. *Grimsdalea magnaclavata* was recorded in this study after the first occurrence of *Fenestrites spinosus*; Interval 238 – 32 m: *Psilatricolporites caribbiensis* Interval Subzone – late Miocene / Pliocene: This zone was defined by the presence of *Psilatricolporites caribbiensis*. *Stephanocolpites evansii* was not recorded in this study. The presence of *Multiareolites formosus* also confirms the age attributed to this interval.

INTRODUCTION

The size and complexity of the present Amazonia suggests that its past must have been as fascinating as it is now. The number of studies has increased in the last decade but they are still insufficient and sparse to come to a complete picture of the evolution of the system since the uplift of the Andes. The interpretations of the data obtained through different analytical tools are sometimes contradictory as it is well summarized by Westaway (2006).

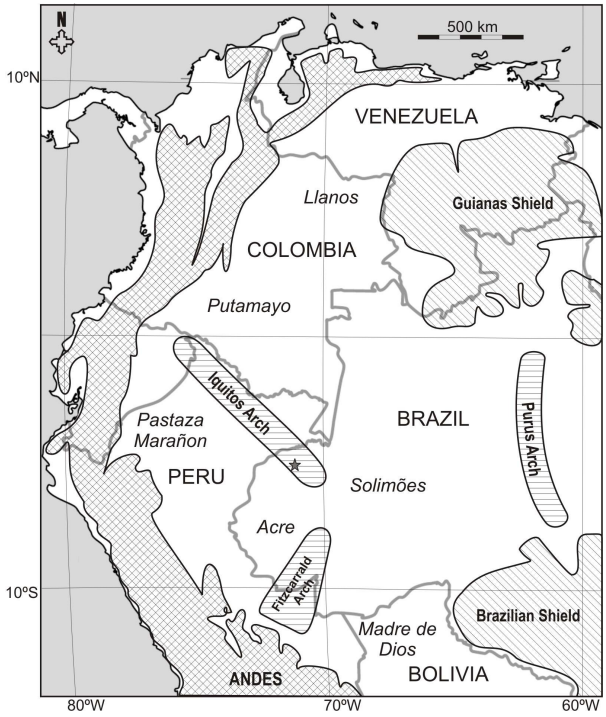
One of the causes for the controversies is the lack of direct dating of the sediments caused by the reduced number of biostratigraphic studies and by the concentration of fossils in certain levels, which hinder an accurate correlation of these Neogene strata.

The Palynology represents an important tool to both paleoenvironmental and biostratigraphic studies as the palynological fossil record, in spite of its limitations, is more easily recovered in different types of depositional environments. The present work consists in the systematic results of a fully cored section of the Solimões Formation in Brazil and the objectives of this study were: 1) to classify and quantify the palynomorphs present in the well 1 AS 33 AM; 2) to identify biostratigraphic markers that enable the placement of the cored interval in one of the palynostratigraphic frameworks proposed to the northern South America; 3) to establish taxonomic affinities of the grains whenever possible in order to make possible a depiction of the evolution of the paleoenvironment in that site.

The paleoenvironmental and palynostratigraphic information presented here is discussed in Leite *et al*. (submitted).

GEOLOGICAL SETTING

The Solimões basin comprises an area of 600.000km^2 limited in the North by the Guiana shield and in the South by the Brazilian shield. The Iquitos arch separates it from the subandean basins in the west and the Purus arch separates it from the Amazonas basin in the east (Text-Figure 1).

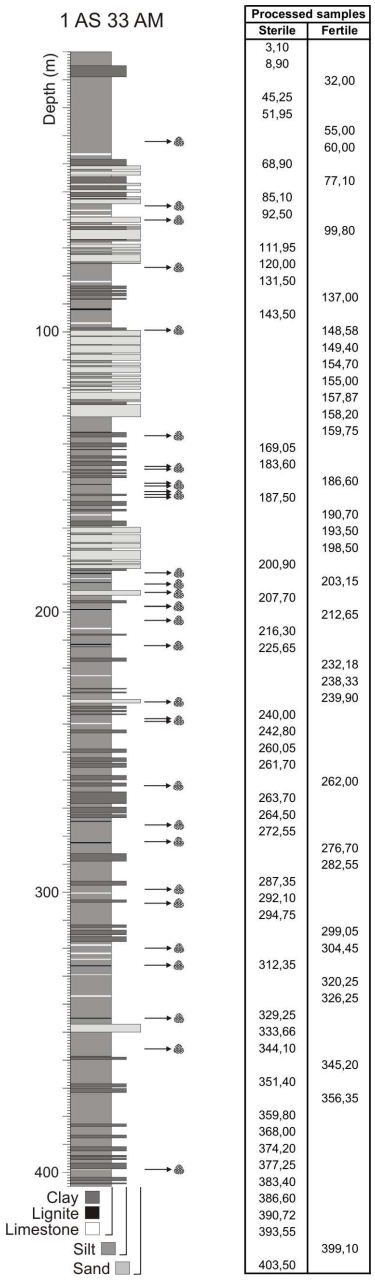


Text-Figure 1: Location map of the Solimões basin, neighbor basins and main structural features in northeastern South America. The names of the basins are in *italic*. Structural data from Caputo (1984), Baby *et al*. (2005), Roddaz *et al*. (2005) and USGS website. ★ Location of the well 1AS 33 AM.

The Solimões Formation consists of claystones, siltstones and sandstones intercalated with a few lignite and limestone layers (Radambrasil, 1977; Hoorn, 1993). The thickness varies reaching up to 600 m according to the paleotopography of the basement (Radambrasil, 1977). It overlays unconformably the Cretaceous Alter do Chão Formation, and is overlain by the unconsolidated white sands of the Pleistocene Içá Formation (Caputo, 1984). In the nearby basins the correlative Neogene sediments were divided into different stratigraphic units as Pebas, Nauta, Ipururo and Madre de Dios Formations (Hoorn, 1993; Campbell *et al*., 2001).

MATERIAL

The present work is the systematic results of the palynological study of 32 samples from the well 1AS 33 AM located at 5º15'S / 71º33'W (Text-Figure 1). It reaches 405 m depth and covers approximately 17 Ma corresponding to middle Miocene/Pliocene interval of the Solimões Formation. Other 42 samples were processed but presented no organic residue (Text-Figure2).



Text-Figure 2: Profile of the well 1 AS 33 AM with the depth of the processed samples.

ANALYTICAL METHODS

The palynological samples were processed in the Palynology Laboratory at the University of Brasília. The method consisted of disaggregation of 10cm^3 of the material, introduction of exotic pollen, elimination of the carbonates with HCl, elimination of silicates with HF, separation of organic fraction with $ZnCl_2$ with density 2 g/cm^3, and elimination of the excess of organic debris with solution of KOH 10%. The slides were mounted with Entellan.

The systematic study was done by comparison with the Neogene palynofloras of northern South America and the taxonomic affinities found by comparison with modern pollen atlas (Huang, 1972; Roubik & Moreno, 1991; Colinvaux *et al.*, 1999) and reference slide collections. The photographs were taken with digital camera attached to the microscope with 100X objective lens.

The palynomorphs were counted up to a minimum of 300 pollen grains, except in the samples that had very low pollen concentration. The original data were processed in the Excel 2000 software to produce the percentage table that were plotted in a pollen diagram made with the computer program PamPlot of Pangaea PaleoNetwork for Geological and Environmental Data (www.pangaea.de/Software/PanPlot/). The statistic analysis was done by the software system STATISTICA, version 7 (StatSoft, Inc. 2004, www.statsoft.com.), using the multivariate cluster analysis applying Ward's and 1-Pearson r methods.

SYSTEMATIC PALYNOLOGY

In this study ninety-five palynomorphs were identified, whenever possible up to species level. Most of them were pollen grains of angiosperms with eighty-five types classified and many others included in the group of "undetermined angiosperms" due to their very low percentages. Only one species of gymnosperm was present and always in small quantity. The spores were very abundant although only eight types were identified. The systematic of all the palynomorphs follows mostly the class level subdivisions of Iversen & Troels-Smith (1950).

Seven new species are proposed and formally described mainly according the terminology used in Colinvaux *et al.* (1999): *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilatricolporites hoornii, Retitricolporites toigoi*. The holotypes and paratypes and all illustrated material are kept at the Museum of Geosciences of the University of Brasília, Brazil, in the research collection. The reference numbers appear next to the figure number under the generic/specific names.

The pollen diagram presents the pollen and spores in order of appearance with the percentage of each species in relation to the sum of all the palynomorphs per sample. A list in alphabetical order provides the position of each species in the diagram (Appendix).

The occurrence of biostratigraphic markers throughout the well enabled the identification of four of four biozones (Leite, in review) described by Lorente (1986) to the northern South America.

▪ **Interval 399 – 326 m:** *Psiladiporites* Interval Zone – Early / middle Miocene. This zone was defined by the presence of *Echitricolporites maristellae*, *Crototricolpites annemariae* and *Multimarginites vanderhammenii.* The presence of *Psilastephanoporite tesseroporus* also confirms the Miocene age attributed to this interval (Regali *et al*., 1974ab);

▪ **Interval 326 – 299 m:** *Crassoretitriletes* Interval Zone – middle Miocene. This zone was defined by the presence of *Crassoretitriletes vanraadshoovenii*;

▪ **Interval 299 – 238 m:** Asteraceae Interval Zone– late Miocene. This zone was defined by the presence of *Echitricolporites spinosus* and *Fenestrites spinosus*. *Grimsdalea magnaclavata* was recorded in this study after the first occurrence of *Fenestrites spinosus*;

▪ **Interval 238 – 32 m:** *Psilatricolporites caribbiensis* Interval Subzone – late Miocene / Pliocene: This zone was defined by the presence of *Psilatricolporites caribbiensis*. *Stephanocolpites evansii* was not recorded in this study. The presence of *Multiareolites formosus* also confirms the age attributed to this interval (Muller *et al*., 1987).

DIVISION SPORITES H. Potonié, 1893

CLASS TRILETES (Reinsch, 1881) Potonié & Kremp, 1954

Genus ***Crassoretitriletes*** Germeraad *et al.*, 1968

Crassoretitriletes vanraadshoovenii Germeraad *et al.*, 1968

Plate 1, fig.1 - CP-218

Stratigraphic range: early Miocene (Germeraad *et al.*, 1968); middle Miocene (Muller *et al.*, 1987); middle Miocene – Pleistocene (Lorente, 1986). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Schizaeaceae, *Lygodium* (Lorente, 1986).

Genus ***Deltoidospora*** Miner, 1935

Deltoidospora adriennis (Potonié & Gelletich, 1933) Frederiksen, 1983

Plate 1, fig.2 - CP-219

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Polypodiaceae, *Acrostichum aureum* (Lorente, 1986 and Hoorn, 1993).

Genus ***Echitriletes*** Potonié, 1956

Echitriletes muellerii Regali *et al.*, 1974

Plate 1, fig. 3 - CP-220

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Selaginellaceae, *Selaginella.*

Genus ***Magnastriatites*** Germeraad *et al.*, 1968

Magnastriatites grandiosus (Kedves & Sole de Porta, 1963) Dueñas, 1980

Plate 1, fig. 4, 5 - CP-222

Stratigraphic range: Oligocene – Pleistocene (Germeraad *et al.*, 1968 and Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Parkeriaceae, *Ceratopteris* (Germeraad *et al.*, 1968).

Genus ***Polypodiaceoisporites*** R. Potonié, 1951 *ex* Potonié, 1956

Polypodiaceoisporites potoniei Kedves, 1961

Plate 1, fig. 5 - CP-223

Stratigraphic range: Campanian – Pleistocene (Muller *et al.*, 1987). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Polypodiaceae, *Pteris* (Lorente, 1986).

CLASS MONOLETES Ibrahim, 1933

Genus ***Laevigatosporites*** Ibrahim, 1933

Laevigatosporites spp.

Plate 1, fig. 6 - CP-224

Description: Group of psilate, monolete spores.

Stratigraphic range: Eocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Polypodiaceae.

Genus ***Perinomonoletes*** Krutzsch, 1967

Perinomonoletes sp.

Plate 1, fig. 7 - CP-225

Description: Monolete spore, sculptured perine, rugulate process sometimes ending in spines, subcircular outline.

Stratigraphic range: Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Polypodiaceae.

Genus ***Verrucatosporites*** (Plfug, 1952) R. Potonié

Verrucatosporites spp.

Plate 1, fig. 8 - CP-226

Description: Group of verrucate, monolete spores.

Stratigraphic range: *5. usmensis*, Eocene - Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Polypodiaceae, *Microgramma, Nephrolepis* and *Polypodium* (Lorente, 1986).

DIVISION POLLENITES H. Potonié, 1893

CLASS INAPERTURATAE Iversen & Troels-Smith, 1950

Genus ***Grimsdalea*** Germeraad *et al.*, 1968

Grimsdalea magnaclavata Germeraad *et al.*, 1968

Plate 2, fig. 10 - CP-227

Stratigraphic range: middle Miocene – Pliocene (Lorente, 1986). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown, probably an extinct palm species (Germeraad *et al.*, 1968).

Genus ***Inaperturopollenites*** Nilsson, 1958

Inaperturopollenites elizabetei nov. sp.

Plate 2, figs. 11-12ab

Derivatio nominis: Named in honor of the Brazilian palynologist Elizabete Pedrão Ferreira.

Holotype: slide 276,70 (1); coordinates 35,5/100,8 **-** CP**-**228.

Paratype: slide 326,25 (1); coordinates 43,9/106,9 **-** CP**-**229.

Locus tipicus: Well 1AS-33-AM; 276,70 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Single grain, inaperturate, spheroidal, reticulate, tectate, larger columellae under the junctions of the reticulum, homobrochate, asymmetric lumina.

Dimensions: 38 - 48 μm; exine 0,8 - 1 μm; lumina 2 - 4 μm; muri 0,5 μm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Rubiaceae?

Inaperturopollenites microechinatus nov. sp.

Plate 2, figs. 13-14ab

Derivatio nominis: Named derived from the microechinate ornamentation.

Holotype: slide 155,00 (6); coordinates 51,4/107,4 **-** CP**-**230.

Paratype: slide 198,50 (1);.coordinates 26,8/107,9 **-** CP**-**231.

Locus tipicus: Well 1AS-33-AM; 155,00 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Single grain, inaperturate, spheroidal, apolar, echinate, very small spines uniformly spread around the grain.

Dimensions: 25 - 32 μm; exine 1 μm; spines 0,5 – 1 μm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Lauraceae?

Inaperturopollenites solimoensis nov. sp.

Plate 2, fig. 15, 16

Derivatio nominis: Named derived from the Solimões Formation.

Holotype: slide 276,70 (3); coordinates 37,9/109,0 **-** CP**-**232.

Paratype: slide 304,45 (1); coordinates 52,5/108,7 **-** CP**-**233.

Locus tipicus: Well 1AS-33-AM; 276,70 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Single grain, inaperturate, spheroidal to subprolate, reticulate, homobrochate.

Dimensions: 23 - 39 μm; exine 1,5 μm; lumina 1 - 2 μm; muri 0,5 μm.

Stratigraphic range: Present through the entire stratigraphic interval included in this study.

Comparison: This species differs from *I. elizabetei* because of the pattern of the reticulum and tectum.

Taxonomic affinity: Rubiaceae, *Psychotria.*

Inaperturopollenites spp.

Plate 2, fig. 17 - CP-234

Description: Single grain, inaperturate, spheroidal to subprolate, scabrate or microreticulate.

Dimensions: 24 - 32 μm; exine 1 - 1,5 μm.

Stratigraphic range: Present through the entire stratigraphic interval included in this study.

Comparison: This species differs from *I. solimoensis* because of the microreticulate ornamentation.

Taxonomic affinity: Rubiaceae, *Psychotria.*

CLASS MONOPORATAE Iversen & Troels-Smith, 1950

Genus ***Monoporites*** Cookson, 1947

Monoporites annulatus Van der Hammen, 1954

Plate 2, fig. 18 - CP-235

Stratigraphic range: Middle Eocene – Pleistocene (Germeraad *et al.*, 1968); Paleocene – Pleistocene (Muller *et al.*, 1987 and Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Poaceae (Lorente, 1986).

Monoporites annuloides Gonzalez-Guzmán, 1967

Plate 2, fig. 19 - CP-236

Comment: These grains are monoporate, annulate, but the exine is rougher and thicker than in *M. annulatus*.

Stratigraphic range: Middle Eocene (Gonzalez-Guzmán, 1967). Present in this study from the Subzone *Psilatricolporites caribbiensis* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Poaceae.

CLASS MONOCOLPATAE Iversen & Troels-Smith, 1950

Genus ***Mauritiidites*** Van Hoeken-Klinkenberg, 1964

Mauritiidites franciscoi (Van der Hammen, 1956) Van Hoeken-Klinkenberg, 1964

Plate 2, fig. 20 - CP-237

Stratigraphic range: Paleocene – Pleistocene (Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Arecaceae, *Mauritia* (Lorente, 1986).

Genus ***Proxapertites*** Van der Hammen,1956

Proxapertites tertiaria Van der Hammen & García de Mutis, 1965

Plate 2, fig. 21 - CP-238

Stratigraphic range: Paleocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Annonaceae, *Crematosperma* (Lorente, 1986).

Genus ***Psilamonocolpites*** Van der Hammen & García de Mutis, 1965

Psilamonocolpites medius Van der Hammen & García de Mutis, 1965

Plate 2, fig. 22 - CP-239

Stratigraphic range: Cretaceous – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Several genera of Arecaceae (Lorente, 1986).

Genus ***Retimonocolpites*** Pierce, 1961

Retimonocolpites maximus Hoorn, 1993

Plate 2, fig. 23 - CP-240

Stratigraphic range: Miocene – Pleistocene (Hoorn, 1993). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Arecaceae (Hoorn, 1993).

CLASS DIPORATAE Iversen & Troels-Smith, 1950

Genus ***Psiladiporites*** Varma & Rawat, 1963

Psiladiporites minimus Van der Hammen & Wijmstra, 1964

Plate 3, fig. 24 - CP-241

Stratigraphic range: early Miocene – Pleistocene (Germeraad *et al.*, 1968; Lorente, 1986; Muller *et al.*, 1987). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Moraceae (Germeraad *et al.*, 1968).

CLASS TRIPORATAE Iversen & Troels-Smith, 1950

Genus ***Corsinipollenites*** Nakoman, 1965

Corsinipollenites oculusnoctis (Thiergart,1940) Nakoman, 1965

Plate 3, fig. 25 - CP-242

Stratigraphic range: Maestrichtian – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Onagraceae, *Ludwigia* (Hoorn, 1994b).

Genus ***Echitriporites*** Iversen & Troels-Smith, 1950

Echitriporites sp.

Plate 3, fig. 26, 27 - CP-243

Description: Single grain, oblate, isopolar, triporate, annulate pore, echinate exine, echini with dilated basis supported by columellae.

Dimensions: 32 - 44 µm; spines 4 - 5 µm.

Stratigraphic range: Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Malvaceae, *Abutilon*?

Genus ***Proteacidites*** (Cookson, 1950) Couper, 1953

Proteacidites triangulatus Lorente, 1986

Plate 3, fig. 28 - CP-244

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present in this study in the Subzone *Psilatricolporites caribbiensis.*

Taxonomic affinity: Proteaceae (Lorente, 1986).

Genus ***Retitriporites*** (Van der Hammen, 1956) Gonzalez-Guzmán, 1967

Retitriporites dubiosus Gonzalez-Guzmán, 1967

Plate 3, fig. 29 - CP-245

Comments: These grains present 3 or 4 pores.

Stratigraphic range: Early Eocene (Gonzalez-Guzmán, 1967). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Rubiaceae, *Psychotria* / *Alibertia*.

CLASS STEPHANOPORATAE Iversen & Troels-Smith, 1950

Genus ***Malvacipollis*** Harris, 1965

Malvacipollis aff. ***M. spinulosa*** Frederiksen, 1983

Plate 3, fig. 30 - CP-246

Description: Single grain, stephanoporate (5 to 6 pores), sometimes the pores are indistinct, echinate, spheroidal, isopolar, radially symmetric.

Comments: The grains observed are much smaller than the one described in Lorente (1986).

Stratigraphic range: *M. spinulosa,* Oligocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Euphorbiaceae (Frederiksen, 1983).

Genus ***Psilastephanoporites*** (Regali *et al*.,1974) Hoorn, 1993

Psilastephanoporites tesseroporus Regali *et al*.,1974

Plate 3, fig. 31 - CP-247

Stratigraphic range: Miocene – Pleistocene (Regali *et al*.,1974). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Apocynaceae, *Prestonia*?

Genus ***Retistephanoporites*** Gonzalez-Guzmán, 1967

Retistephanoporites crassiannulatus Lorente, 1986

Plate 3, fig. 32 - CP-248

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Bombacaceae, *Quararibea* (Lorente, 1986)

CLASS PERIPORATAE Iversen & Troels-Smith, 1950

Genus ***Echiperiporites*** Van der Hammen & Wijmstra, 1964

Echiperiporites stelae Germeraad *et al.*, 1968

Plate 3, fig. 33 - CP-249

Comments: This species contains different types of echiperiporate grains according to the original description.

Stratigraphic range: Early Eocene – Pleistocene (Muller *et al.*, 1987). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Malvaceae, *Thespesia* or *Hibiscus*, or Convolvulaceae, *Ipomoea* (Germeraad *et al.*, 1968).

Genus ***Psilaperiporites*** Regali *et al.*, 1974

Psilaperiporites sp.

Plate 3, fig. 34 - CP-250

Description: Single grain, periporate, 6 - 7 circular pores, spheroidal, psilate.

Stratigraphic range: Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Malpighiaceae.

CLASS FENESTRATAE Iversen & Troels-Smith, 1950

Genus ***Fenestrites*** (Van der Hammen, 1956) Germeraad *et al.*, 1968

Fenestrites garciae nov. sp.

Plate 3, figs. 35ab

Derivatio nominis: Named in honor of the Brazilian palynologist Maria Judite Garcia.

Holotype: slide 276,70 (2);.coordinates 39,2/100,7 **-** CP**-**251.

Paratype: slide 299,05 (1);.coordinates 53,0/98,1 **-** CP**-**252.

Locus tipicus: Well 1AS-33-AM; 276,70 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Single grain, lopho-reticulate, spheroidal, asymmetric lophae, muri simplibaculate.

Dimensions: 27 - 30 µm; lophae 2 - 8 µm; muri 1- 1,5 µm; exine 5 µm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Comparison: This species differs from *Fenestrites spinosus* (Van der Hammen, 1956) Germeraad *et al.*, 1968 because of the lack of spines and the asymmetry of the lophae.

Taxonomic affinity: Amaranthaceae, *Gomphrena.*

Fenestrites spinosus (Van der Hammen, 1956) Germeraad *et al.*, 1968

Plate 3, fig. 36 - CP-253

Stratigraphic range: late Miocene – Pleistocene (Germeraad *et al.*, 1968; Lorente, 1986). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Asteraceae (Germeraad *et al.*, 1968)

CLASS TRICOLPATAE Iversen & Troels-Smith, 1950

Genus ***Crototricolpites*** Leidelmeyer, 1966

Crototricolpites sp.

Plate 4, fig. 37 - CP-254

Description: Single grain, spheroidal, indistinct apertures, circular to subcircular outline, clavate exine in *Croton* pattern.

Stratigraphic range: early Miocene – Pleistocene (Lorente, 1986; Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Probably Euphorbiaceae (Lorente, 1986).

Genus ***Perfotricolpites*** Gonzalez-Guzmán, 1967

Perfotricolpites digitatus Gonzalez-Guzmán, 1967

Plate 4, fig. 38 - CP-255

Stratigraphic range: Middle Eocene – Pleistocene (Germeraad *et al.*, 1968); Early Eocene – Pleistocene (Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Convolvulaceae, *Merremia* (Lorente, 1986).

Genus ***Psilatricolpites*** (Van der Hammen, 1956) Van der Hammen & Wijmstra, 1964

Psilatricolpites minutus Gonzalez-Guzmán, 1967

Plate 4, fig. 42 - CP-256

Stratigraphic range: Middle Eocene (Gonzalez-Guzmán, 1967). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Several families present this type of pollen.

Genus ***Retibrevitricolpites*** Van Hoeken-Klinkenberg, 1964

Retibrevitricolpites cf. ***R. catatumbus*** Gonzalez-Guzmán, 1967

Plate 4, fig. 43 - CP-257

Description: Single grain, prolate, tricolporate, colpi short, reticulate, homobrochate.

Comments: It was not possible to observe the "colpi transversales" mentioned in the original description.

Stratigraphic range: Eocene (Gonzalez-Guzmán, 1967). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown

Genus ***Retitricolpites*** Van der Hammen & Wijmstra, 1964

Retitricolpites conciliatus Gonzalez-Guzmán, 1967

Plate 4, fig. 39 - CP-258

Stratigraphic range: Early – Middle Eocene (Gonzalez-Guzmán, 1967). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Bignoniaceae?

Retitricolpites florentinus Gonzalez-Guzmán, 1967

Plate 4, fig. 41 - CP-259

Stratigraphic range: Early – Middle Eocene (Gonzalez-Guzmán, 1967). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Possibly Tiliaceae, but there are no distinct pores.

Retitricolpites perforatus Gonzalez-Guzmán, 1967

Stratigraphic range: Middle Eocene (Gonzalez-Guzmán, 1967). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown.

Retitricolpites cf. ***R. amapaensis*** Regali *et al.*, 1974

Plate 4, fig. 40 - CP-260

Description: Single grain, oblate, isopolar, radially symmetric, colpi indistinct, coarsely reticulate, simplibaculate, sinuous muri.

Comments: The grains observed are smaller than the original description.

Stratigraphic range: *R. amapaensis*, Oligocene – Pleistocene (Lorente, 1986); Early Eocene – middle Miocene (Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Bignoniaceae, *Pithecoctenium*?

Retitricolpites cf. ***R. simplex*** Gonzalez-Guzmán, 1967

Plate 4, fig. 44 - CP-261

Description: Single grain, prolate, isopolar, radially symmetric, tricolpate or tricolporate, fossaperturate, microreticulate.

Comments: The grains observed are smaller than the original description.

Stratigraphic range: *R. simplex*, Oligocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Euphorbiaceae?

Genus ***Striatricolpites*** (Van der Hammen, 1956b) Gonzalez-Guzmán, 1967

Striatricolpites catatumbus Gonzalez-Guzmán, 1967

Plate 4, fig. 45 - CP-262

Stratigraphic range: Early Eocene – Pleistocene (Germeraad *et al*., 1968 and Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Comments: The grains observed are smaller than the original description.

Taxonomic affinity: Caesalpinaceae, *Macrolobium*/*Isorbelina* (Hoorn, 1994a) or Fabaceae, *Crudia*.(Germeraad *et al*., 1968).

CLASS DICOLPORATAE Iversen & Troels-Smith, 1950

Genus ***Multiareolites*** Germeraad *et al*., 1968

Multiareolites formosus Germeraad *et al*., 1968

Plate 4, fig. 46 - CP-263

Stratigraphic range: early Miocene – Pleistocene (Germeraad *et al*., 1968); Pliocene – Pleistocene (Muller *et al.*, 1987). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Comments: In Germeraad *et al.* (1968) this species appears in the early Miocene in the general diagram (which includes the Caribbean, Nigeria and Borneo), but in the diagram of the well Paria 1, in Venezuela, it occurs only in the Pliocene. This well is used by Muller *et al.* (1987) as a reference section for the Pliocene of the Northern South America. Lorente (1986) registers this species only in the Pleistocene.

Taxonomic affinity: Acanthaceae, several genera (Germeraad *et al*., 1968).

Genus ***Multimarginites*** Germeraad *et al*., 1968

Multimarginites vanderhammeni Germeraad *et al*., 1968

Plate 4, fig. 47 - CP-264

Stratigraphic range: middle Miocene – Pleistocene (Germeraad *et al*., 1968 and Muller *et al.*, 1987); Early/middle Miocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Acanthaceae, *Sanchezia, Trichantera* and *Bravaisia* (Germeraad *et al*., 1968).

CLASS TRICOLPORATAE Iversen & Troels-Smith, 1950

Genus ***Bombacacidites*** Couper, 1960

Bombacacidites baculatus Muller *et al.*, 1987

Plate 4, fig. 48 - CP-265

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986); middle Miocene – Pleistocene (Muller *et al.*, 1987). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Bombacaceae, *Pachira aquatica* (Lorente, 1986).

Bombacacidites bellus Frederiksen, 1983

Plate 4, fig. 49 - CP-266

Stratigraphic range: Eocene – Pliocene (Lorente, 1986); Early Eocene – Late Eocene (Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Bombacaceae, *Pseudobombax* / *Bombax* (Lorente, 1986).

Genus ***Costatricolporites*** Wijmstra,1971

Costatricolporites reticulatus Wijmstra,1971

Plate 4, fig. 50 - CP-267

Stratigraphic range: Eocene (Wijmstra,1971). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Burseraceae?

Genus ***Crassiectoapertites*** Dueñas, 1980

Crassiectoapertites colombianus (Dueñas, 1980) Lorente, 1986

Plate 4, fig. 51 - CP-268

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Fabaceae, *Canavalia* / *Dioclea* (Lorente, 1986).

Genus ***Echitricolporites*** Van der Hammen, 1956b

Echitricolporites maristellae Muller *et al.*, 1987

Plate 4, fig. 52 - CP-269

Stratigraphic range: early Miocene – Pleistocene (Lorente, 1986 and Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Malvaceae / Bombacaceae (Lorente, 1986).

Echitricolporites spinosus (Van der Hammen, 1956) Germeraad *et al.*, 1968

Plate 5, fig. 53 - CP-270

Stratigraphic range: late Miocene – Pleistocene (Germeraad *et al.*, 1968; Lorente, 1986 and Muller *et al.*, 1987). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Asteraceae (Lorente, 1986).

Echitricolporites sp.

Plate 5, fig. 54 - CP-271

Description: Single grain, tricolporate, microechinate, subspheroidal, isopolar, radially symmetric.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Asteraceae?

Genus ***Foveotricolporites*** Pierce, 1961

Foveotricolporites caldensis Gonzalez-Guzmán, 1967

Plate 5, fig. 55 - CP-272

Stratigraphic range: Early Eocene (Gonzalez-Guzmán, 1967). Present in this study in the Subzone *Psilatricolporites caribbiensis.*

Taxonomic affinity: Connaraceae?

Foveotricolporites florschutzi (Van der Hammen, 1954) Van der Hammen & Wijmstra,1964

Plate 5, fig. 56 - CP-273

Stratigraphic range: Maestrichtian (Van der Hammen & Wijmstra,1964). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown.

Genus ***Ilexpollenites*** (Thiergart, 1937) Potonié, 1960

Ilexpollenites sp.

Plate 5, fig. 57 - CP-274

Stratigraphic range: Maestrichtian – Pleistocene (Muller *et al.*, 1987). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Aquifoliaceae, *Ilex*

Genus ***Margocolporites*** Germeraad *et al.*, 1968

Margocolporites vanwijhei Germeraad *et al.*, 1968

Plate 5, fig. 58 - CP-275

Stratigraphic range: Early Eocene – Pleistocene (Muller *et al.*, 1987). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Caesalpinaceae, *Caesalpinia* (Germeraad *et al.*, 1968).

Margocolporites aff. ***M. vanwijhei*** Germeraad *et al.*, 1968

Plate 5, fig. 59 - CP-276

Description: Close resemblance with *Margocolporites vanwijhei* but with a less marked change in the ornamental pattern.

Stratigraphic range: Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Caesalpinaceae.

Genus ***Psilatricolporites*** (Van der Hammen, 1956) Van der Hammen & Wijmstra, 1964

Psilatricolporites caribbiensis Muller *et al*., 1986

Plate 5, fig. 60 - CP-277

Stratigraphic range: late Miocene – Pleistocene (Lorente, 1986), Pliocene – Pleistocene (Muller *et al.*, 1987). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Euphorbiaceae, *Sapium* ?

Psilatricolporites hoornii nov. sp.

Plate 5, fig. 61, 62

Derivatio nominis: Named in honor of the Dutch palynologist Carina Hoorn.

Holotype: slide 203,15(2); coordinates 43,1/108,2 – CP-278.

Paratype: slide 190,70(1); coordinates 30,5/102,9 – CP-279.

Locus tipicus: Well 1AS-33-AM; 203,15 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Single grain, oblate, isopolar, radially symmetric, angular to subcircular outline, tricolporate, colpi short with thick margo, pores circular, psilate, exine with crest along the colpi.

Dimensions: 30 – 35 µm; pore 3 – 6 µm; polar area ~ 10 µm; exine 1 µm; exine between the crest and margo < 1 µm; margo and crest 2 – 3 µm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Apocinaceae, *Rauwolfia.*

Psilatricolporites labiatus Hoorn, 1993

Plate 5, fig. 63 - CP-280

Stratigraphic range: Miocene (Hoorn, 1993). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Sapotaceae, *Pouteria* (Hoorn, 1993).

Psilatricolporites operculatus Van der Hammen & Wijmstra, 1964

Plate 5, fig. 64 - CP-281

Stratigraphic range: Middle Eocene – Pleistocene (Germeraad *et al.*, 1968 and Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Euphorbiaceae, *Alchornea* (Germeraad *et al.*, 1968).

Psilatricolporites silvaticus Hoorn, 1993

Stratigraphic range: Miocene (Hoorn, 1993). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Burseraceae / Sapotaceae (Hoorn, 1993).

Psilatricolporites vanus Gonzalez-Guzmán, 1967

Plate 5, fig. 65 - CP-282

Stratigraphic range: Eocene (Gonzalez-Guzmán, 1967). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Several families present this type of pollen.

Psilatricolporites sp.

Plate 5, fig. 66 - CP-283

Description: Single grain, oblate, isopolar, radially symmetric, angular to subcircular outline, tricolporate, colpi long, psilate, exine thinner near the colpi.

Stratigraphic range: Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown.

Genus ***Retibrevitricolporites*** Van Hoeken-Klinkenberg, 1964

Retibrevitricolporites cf. ***R. grandis*** Jaramillo & Dilcher, 2001

Plate 5, fig. 67 - CP-284

Comments: The grains observed correspond apparently with the original description but are not well preserved.

Stratigraphic range: *R. grandis,* Paleocene – Eocene (Jaramillo & Dilcher, 2001). Present in this study in the Subzone *Psilatricolporites caribbiensis.*

Taxonomic affinity: Unknown.

Retibrevitricolporites speciosus Jaramillo & Dilcher, 2001

Plate 5, fig. 68 - CP-285

Stratigraphic range: Paleocene – Eocene (Jaramillo & Dilcher, 2001). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Bombacaceae?

Genus ***Retitricolporites*** (Van der Hammen, 1956) Van der Hammen & Wijmstra, 1964

Retitricolporites finitus Gonzalez-Guzmán, 1967

Plate 5, fig. 69 - CP-286

Stratigraphic range: Early – Middle Eocene (Gonzalez-Guzmán, 1967). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

Retitricolporites guianensis Van der Hammen & Wijmstra, 1964

Plate 5, fig. 70 - CP-287

Stratigraphic range: Middle Eocene – Pleistocene (Germeraad *et al.*, 1968, Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Sterculiaceae (Germeraad *et al.*, 1968).

Retitricolporites hispidus Van der Hammen & Wijmstra, 1964

Plate 5, fig. 71 - CP-288

Stratigraphic range: Oligocene – Miocene (Van der Hammen & Wijmstra, 1964). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

Retitricolporites irregularis Van der Hammen & Wijmstra, 1964

Plate 5, fig. 72 - CP-289

Stratigraphic range: Early Eocene – Pleistocene (Germeraad *et al.*, 1968 and Muller *et al.*, 1987).

Taxonomic affinity: Euphorbiaceae, *Amanoa oblongifolia* (Germeraad *et al.*, 1968).

Retitricolporites aff. ***R. magnus*** Gonzalez-Guzmán, 1967

Plate 5, fig. 74 - CP-290

Description: Single grain, oblate, isopolar, radially symmetric, tricolporate, coarsely reticulate, heterobrochate, simplibaculate.

Comments: The grains observed are smaller than the original description and present pores.

Stratigraphic range: *R. magnus,* Middle Eocene (Gonzalez-Guzmán, 1967). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Unknown

Retitricolporites medius Gonzalez-Guzmán, 1967

Plate 5, fig. 73 - CP-291

Stratigraphic range: Early – Middle Eocene (Gonzalez-Guzmán, 1967). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Several families present this type of pollen.

Retitricolporites cf. ***R. perpusillus*** Regali *et al*., 1974

Plate 6, fig. 75 - CP-292

Description: Single grain, oblate, isopolar, radially symmetric, tricolporate, reticulate, heterobrochate.

Comments: The grains observed are smaller than the original description.

Stratigraphic range: *R. perpusillus*, Paleocene – Early Eocene (Regali *et al*., 1974). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Caesalpinaceae?

Retitricolporites squarrosus Van der Hammen & Wijmstra, 1964

Plate 6, fig. 76 - CP-293

Stratigraphic range: Oligocene – Miocene (Van der Hammen & Wijmstra, 1964). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

Retitricolporites ticuneorum Hoorn, 1993

Stratigraphic range: middle Miocene (Hoorn, 1993). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown.

Retitricolporites toigoi nov. sp.

Plate 6, figs. 77ab-78ab

Derivatio nominis: Named in memory of the Brazilian palynologist Marleni Toigo.

Holotype: slide 155,00(6); coordinates 52,6/102,9 – CP-294.

Paratype: slide 157,87(1); coordinates 42,2/92,1 – CP-295.

Locus tipicus: Well 1AS-33-AM; 155,00 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene.

Description: Single grain, spheroidal, tricolporate, colpi very thin, sometimes indistinct, pores lalongate, exine reticulate, tectate, larger columellae under the junctions of the reticulum, heterobrochate, asymmetric lumina.

Dimensions: 34 – 44 µm; colpi 11 µm; pore 10 – 11 µm; exine 1,5 µm; muri 1 µm; lumina 1 – 2,5 µm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Rubiaceae?

***Retitricolporites* sp.1**

Plate 6, fig. 80 - CP-296

Description: Single grain, prolate, isopolar, radially symmetric, tricolporate, microreticulate, homobrochate.

Stratigraphic range: Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Several families present this type of pollen.

***Retitricolporites* sp.2**

Plate 6, fig. 79 - CP-297

Description: Single grain, suboblate to subprolate, isopolar, radially symmetric, tricolporate, reticulate.

Stratigraphic range: Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

***Retitricolporites* sp.3**

Plate 6, fig. 81 - CP-298

Description: Single grain, prolate, isopolar, radially symmetric, tricolporate, pores circular and large without annulus, microreticulate, homobrochate.

Stratigraphic range: Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

Genus ***Rugotricolporites*** Germeraad *et al.*, 1968

Rugotricolporites arcus Hoorn, 1993

Plate 6, fig. 83 - CP-299

Stratigraphic range: Miocene (Hoorn, 1993). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Chrysobalanaceae, *Licania* (Hoorn, 1993).

Scabratricolporites (Van der Hammen, 1956) Ramanujan, 1966

Scabratricolporites planetensis Dueñas, 1980

Stratigraphic range: Oligocene – Miocene (Dueñas, 1980). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Several families present this type of pollen.

Genus ***Striatricolporites*** Leidelmeyer, 1966

Striatricolporites digitatus Jaramillo & Dilcher, 2001

Plate 6, fig. 82 - CP-300

Stratigraphic range: Late Paleocene – Middle Eocene (Jaramillo & Dilcher, 2001). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Caesalpinaceae? Solanaceae?

Striatricolporites tenuissimus Dueñas, 1980

Plate 6, fig. 84 - CP-301

Stratigraphic range: Oligocene – Miocene (Dueñas, 1980). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Caesalpinaceae?

Genus ***Verrutricolporites*** Van der Hammen & Wijmstra, 1964

Verrutricolporites sp.

Plate 6, fig. 85 - CP-302

Description: Single grain, subprolate, isopolar, radially symmetric, tricolporate, verrucate.

Stratigraphic range: late Miocene – Pliocene. Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Unknown.

Genus ***Zonocostites*** Germeraad *et al.*, 1968

Zonocostites cf. ***Z. ramonae*** Germeraad *et al.*, 1968

Plate 4, fig. 86 - CP-303

Stratigraphic range: Late Eocene – Pleistocene (Germeraad *et al.*, 1968); Early Eocene – Pleistocene (Muller *et al.*, 1987). Present in this study in the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Rhizophoraceae, *Rhizophora* / *Bruquiera* (Germeraad *et al.*, 1968).

CLASS STEPHANOCOLPORATAE Iversen & Troels-Smith, 1950

Genus ***Jandufouria*** Germeraad *et al.*, 1968

Jandufouria seamrogiformis Germeraad *et al.*, 1968

Plate 4, fig. 87 - CP-304

Stratigraphic range: Oligocene – Pleistocene (Muller *et al.*, 1987). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Bombacaceae, *Catostema* (Germeraad *et al.*, 1968).

Genus ***Psilastephanocolporites*** Leidelmeyer, 1966

Psilastephanocolporites aff. ***P. fissilis*** Plate 4, fig. 87

Plate 4, fig. 88 - CP-305

Description: Single grain, subprolate, isopolar, radially symmetric, stephanocolporate (12 – 13 colpores), circular outline, psilate, foveolate on the poles.

Comments: The grains observed are smaller and with more colpores than the original description.

Stratigraphic range: *P. fissilis*, Eocene – Pleistocene (Lorente, 1986). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Polygalaceae

***Psilastephanocolporites* sp.**

Plate 4, fig. 89 - CP-306

Description: Single grain, subprolate, isopolar, radially symmetric, stephanocolporate (5 – 6 colpores), circular outline, psilate.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Meliaceae.

CLASS PERICOLPORATAE Iversen & Troels-Smith, 1950

Genus ***Perisyncolporites*** Germeraad *et al.*, 1968

Perisyncolporites pokornyi Germeraad *et al.*, 1968

Plate 4, fig. 90 - CP-307

Stratigraphic range: Middle Eocene – Pleistocene (Muller *et al.*, 1987). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Malpighiaceae (Germeraad *et al.*, 1968).

CLASS SYNCOLPORATAE Iversen & Troels-Smith, 1950

Genus ***Myrtaceidites*** Cookson & Pike, 1954

Myrtaceidites spp.

Plate 4, fig. 91 - CP-308

Description: Single grain, oblate, isopolar, radially symmetric, tricolporate, long colpi, small polar area, subtriangular outline, exine scabrate.

Stratigraphic range: Oligocene – Pleistocene (Lorente, 1986). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Myrtaceae, *Eugenia* / *Myrcia* (Lorente, 1986).

Genus ***Syncolporites*** Van der Hammen, 1954

Syncolporites incomptus Van Hoeken-Klinkenberg, 1964

Stratigraphic range: Miocene (Hoorn, 1993). Present through the entire stratigraphic interval included in this study.

Taxonomic affinity: Loranthaceae (Hoorn, 1993).

CLASS HETEROCOLPATES Iversen & Troels-Smith, 1950

Heterocolpites (Van der Hammen, 1956) Van der Hammen & García de Mutis, 1965

Heterocolpites incomptus (Van der Hammen, 1956) Hoorn, 1993

Plate 4, fig. 92 - CP-309

Stratigraphic range: Miocene (Hoorn, 1993). Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Melastomataceae, *Miconia* (Hoorn, 1993).

CLASS POLYADEAE Iversen & Troels-Smith, 1950

Genus ***Polyadopollenites*** Thompson & Pflug, 1953

Polyadopollenites mariae Dueñas, 1980

Plate 7, fig. 93 - CP-310

Stratigraphic range: Oligo – Miocene (Lorente, 1986). Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Mimosaceae, *Acacia* (Dueñas, 1980).

Polyadopollenites marileae nov. sp.

Plate 7, figs. 94ab-95

Derivatio nominis: Named in honor of the Brazilian palynologist Maria Lea Salgado-Labouriau.

Holotype: slide 232,18(1); coordinates 35,5/107,9 – CP-311.

Paratype: slide 232,18(1); coordinates 29,59106,7 – CP-312.

Locus tipicus: Well 1AS-33-AM; 232,18 m; Amazonas State, Brazil.

Stratum tipicum: Solimões Formation, Miocene / Pliocene

Description: Polyad of 16 grains, subcircular, symmetric arrangement, individual grains apolar and asymmetric, apparently inaperturate, exine verrucate.

Dimensions: 62 – 68 µm; individual grains 25 – 27 µm; exine 1,5 – 2,5 µm; verruca 3 – 7 µm.

Stratigraphic range: Present in this study from the Zone Asteraceae to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Mimosaceae.

CLASS VESICULATAE Iversen & Troels-Smith, 1950

Genus ***Podocarpidites*** (Cookson, 1947) Couper, 1953

Podocarpidites sp.

Plate 7, fig. 97 - CP-313

Stratigraphic range: Present in this study from the Zone *Crassoretitriletes* to the Subzone *Psilatricolporites caribbiensis*.

Taxonomic affinity: Podocarpaceae, *Podocarpus* (Lorente, 1986).

DIVISION CHLOROPHYTAE

CLASS CHLOROPHYCEAE

Genus ***Pediastrum***

Pediastrum sp.

Comments: Although not normally included in the pollen sum, *Pediastrum* sp. was counted due to its abundance reaching up to 70% of the total.

Stratigraphic range: It appeared in only one sample (55,00 m) in the Subzone *Psilatricolporites caribbiensis*.

DIVISION CHRYSOPHYTA

CLASS DINOPHYCEAE

Dinoflagelate cyst

Plate 7, fig. 96 - CP-314

Description: Proximate cyst not well preserved missing identifying features.

Stratigraphic range: Only one specimen appeared in one sample (154,70 m) in the Subzone *Psilatricolporites caribbiensis*.

ACKNOWLEDGMENTS

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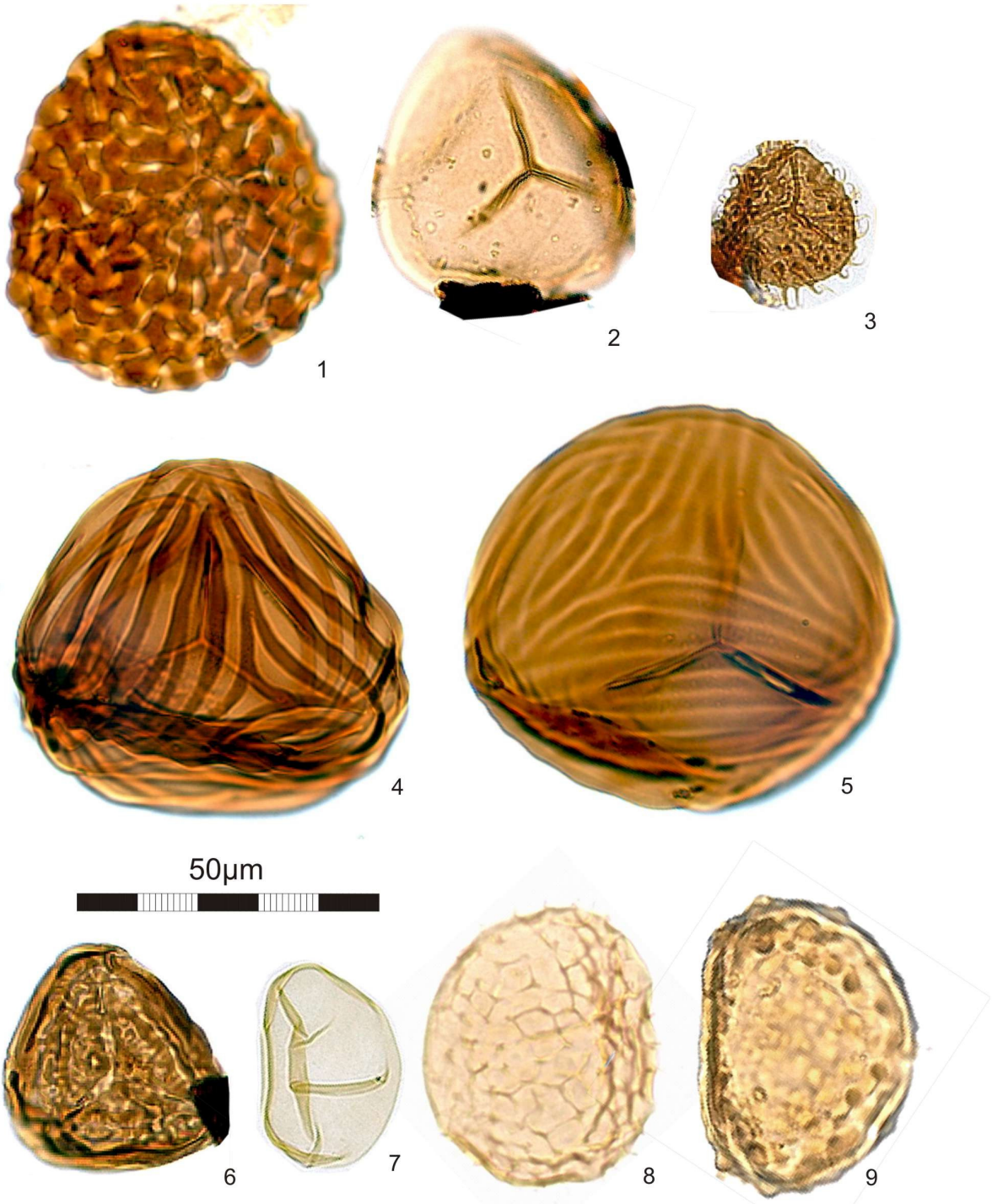
APENDIX

Species list in alphabetical order.

The number at the right corresponds to the occurrence order displayed in the Pollen Diagram.

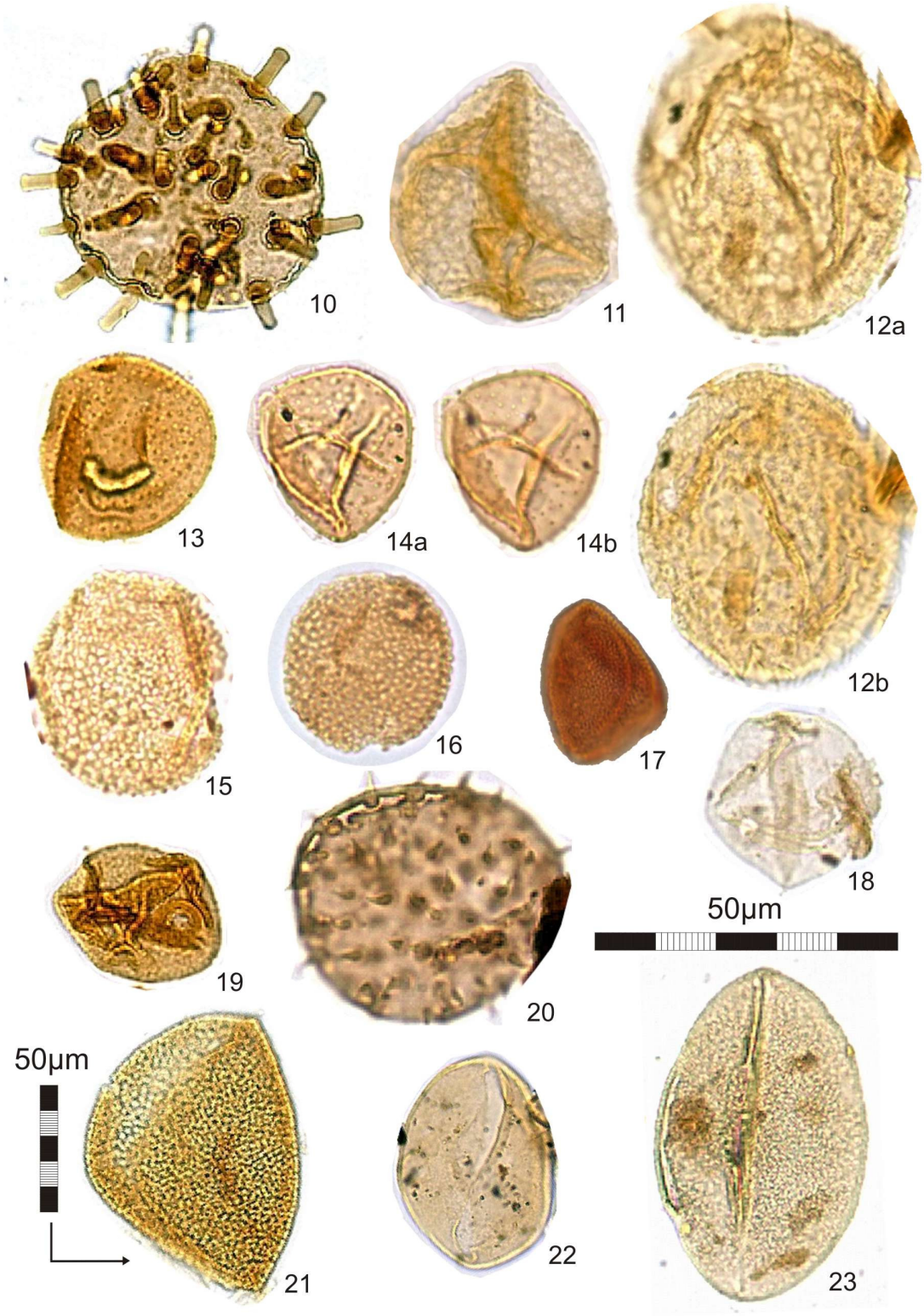
Bombacacidites baculatus
Bombacacidites bellus
Corsinipollenites oculusnoctis
Costatricolporites reticulatus
Crassiectoapertites colombianus
Crassoretitriletes vanraadshoovenii
Crototricolpites sp.
Deltoidospora adriennis
Echiperiporites stelae
Echitricolporites maristellae
Echitricolporites sp.
Echitricolporites spinosus
Echitriletes muellerii
Echitriporites sp.
Fenestrites garciae
Fenestrites spinosus
Foveotricolporites caldensis
Foveotricolporites florschutzi
Grimsdalea magnaclavata
Heterocolpites incomptus
Ilexpollenites sp.
Inaperturopollenites elizabetei
Inaperturopollenites microechinatus
Inaperturopollenites solimoensis
Inaperturopollenites sp.*p*
Jandufouria seamrogiformis
Laevigatosporites spp.
Magnastriatites grandiosus
Malvacipollis cf M spinulosa
Margocolporites aff M vanwijhei
Margocolporites vanwijhei
Mauritiidites franciscoi
Monoporites annulatus
Monoporites annuloides
Multiareolites formosus
Multimarginites vanderhammeni
Myrtaceidites spp.
Perfotricolpites digitatus
Perinomonoletes sp.
Perisyncolporites pokornyi
Podocarpidites sp.
Polyadopollenites mariae
Polyadopollenites marileae
Polypodiaceoisporites potoniei
Proteacidites triangulatus
Proxapertites tertiaria
Psiladiporites minimus
Psilamonocolpites medius
Psilaperiporites sp.
Psilastephanocolporites aff P fissilis
Psilastephanocolporites marinamensis
Psilastephanoporites tesseroporus
Psilatricolpites hoornii
Psilatricolpites minutus
Psilatricolporites caribbiensis
Psilatricolporites labiatus
Psilatricolporites operculatus
Psilatricolporites silvaticus
Psilatricolporites sp.
Psilatricolporites vanus
Retibrevitricolporites cf R catatumbus
Retibrevitricolporites cf R grandis
Retibrevitricolporites speciosus
Retimonocolpites maximus
Retistephanoporites crassiannulatus
Retitricolpites amapaensis
Retitricolpites cf R simplex
Retitricolpites conciliatus
Retitricolpites florentinus
Retitricolpites perforatus
Retitricolporites finitus
Retitricolporites guianensis
Retitricolporites hispidus
Retitricolporites irregularis
Retitricolporites magnus
Retitricolporites medius
Retitricolporites perpusillus
Retitricolporites sp.1
Retitricolporites sp.2
Retitricolporites sp.3
Retitricolporites squarrosus
Retitricolporites ticuneorum
Retitricolporites toigoi
Retitriporites dubiosus
Rugotricolporite arcus
Scabratricolporites planetensis
Striatricolpites catatumbus
Striatricolpites tenuissimus
Striatricolporites digitatus
Syncolporites incomptus
Verrucatosporites spp
Verrutricolporites sp
Zonocostites cf Z. ramonae

PLATE 1



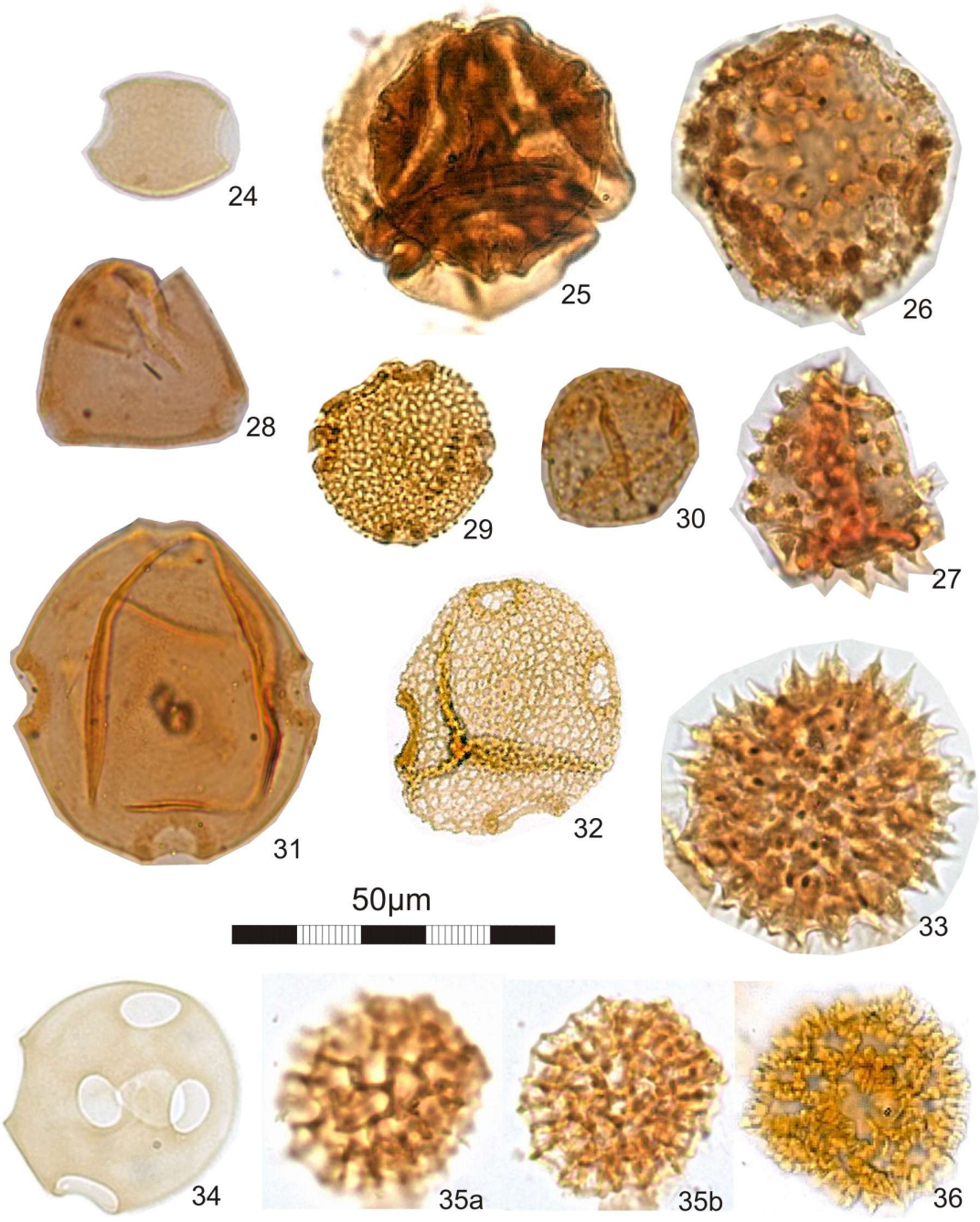
1: *Crassoretitriletes vanraadshoovenii;* 2: *Deltoidospora adriennis;* 3: *Echitriletes muellerii;* 4, *5*: *Magnastriatites grandiosus;* 6: *Polypodiaceoisporites potoniei;* 7: *Laevigatosporites* spp.; 8: *Perinomonoletes* sp.; 9: *Verrucatosporites* spp.

PLATE 2



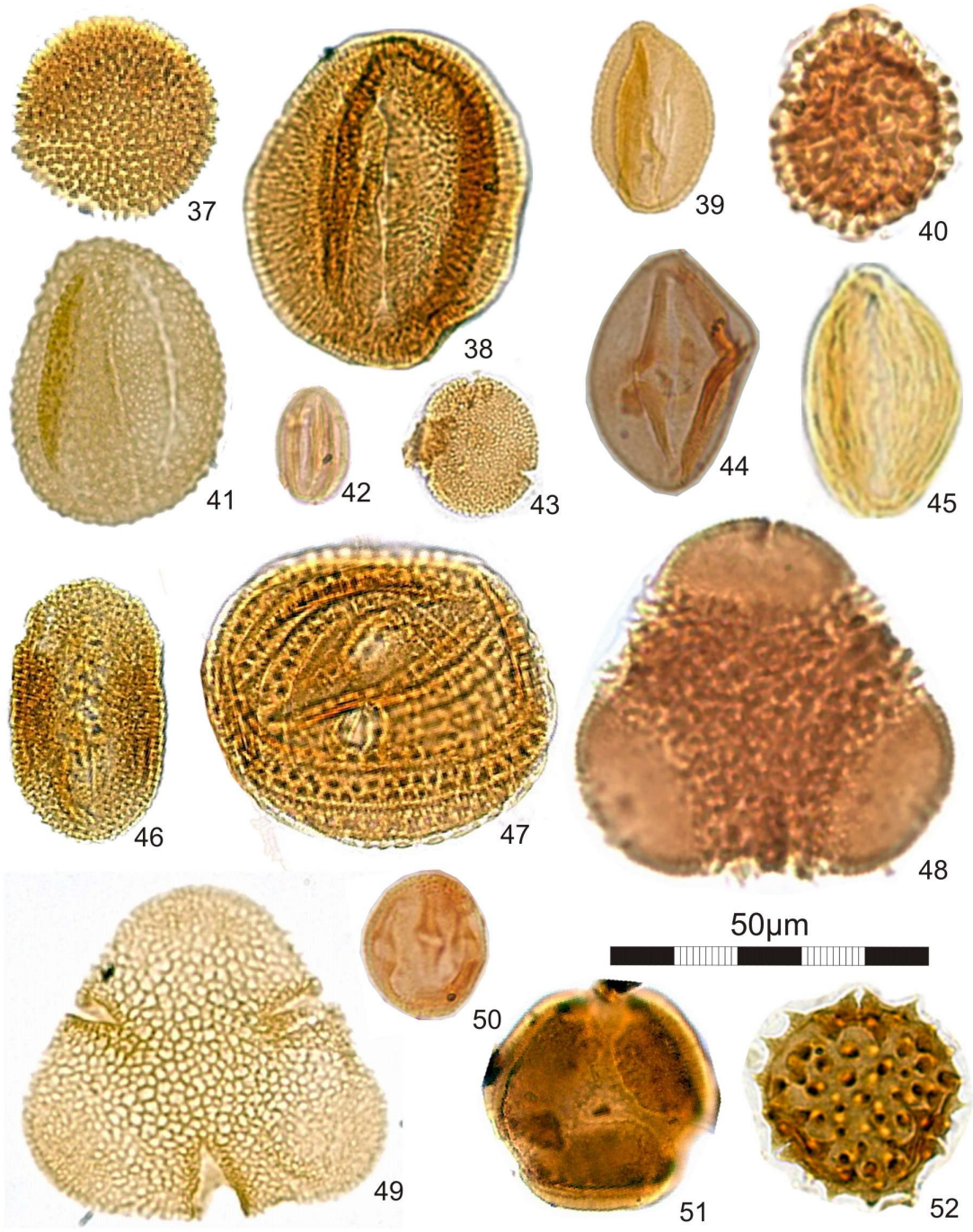
10: *Grimsdalea magnaclavata*; 11 (paratype), 12ab (holotype): *Inaperturopollenites elizabetei*; 13 (holotype), 14ab (paratype): *Inaperturopollenites microechinatus* ; 15 (paratype), 16 (holotype): *Inaperturopollenites solimoensis* ; 17: *Inaperturopollenites* sp.; 18: *Monoporites annulatus*; 19: *Monoporites annuloides*; 20: *Mauritiidites franciscoi*; 21: *Proxapertites tertiaria* (40 X); 22: *Psilamonocolpites medius*; 23: *Retimonocolpites maximus.*

PLATE 3



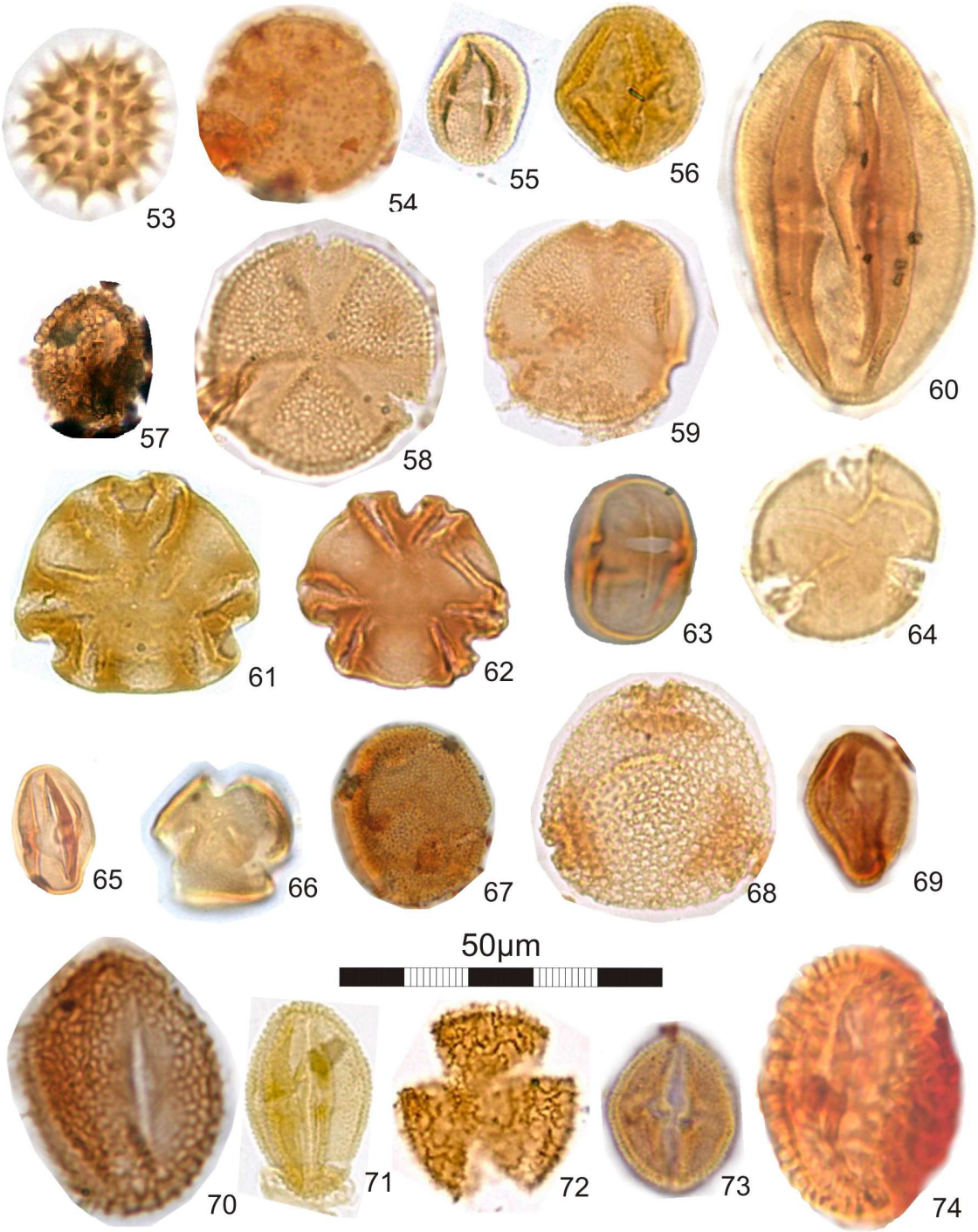
24: *Psiladiporites minimus*; 25:*Corsinipollenites oculusnoctis* (tétrade); 26, 27: *Echitriporites* sp.1; 28: *Proteacidites triangulatus*; 29: *Retitriporites dubiosus*; 30:. *Malvacipollis* aff. *M. spinulosa*; 31: *Psilastephanoporites tesseroporus*; 32: *Retistephanoporites crassiannulatus*; 33: *Echiperiporites stelae* ; 34: *Psilaperiporites sp.*; 35ab: *Fenestrites garciae* ; 36: *Fenestrites spinosus*.

PLATE 4



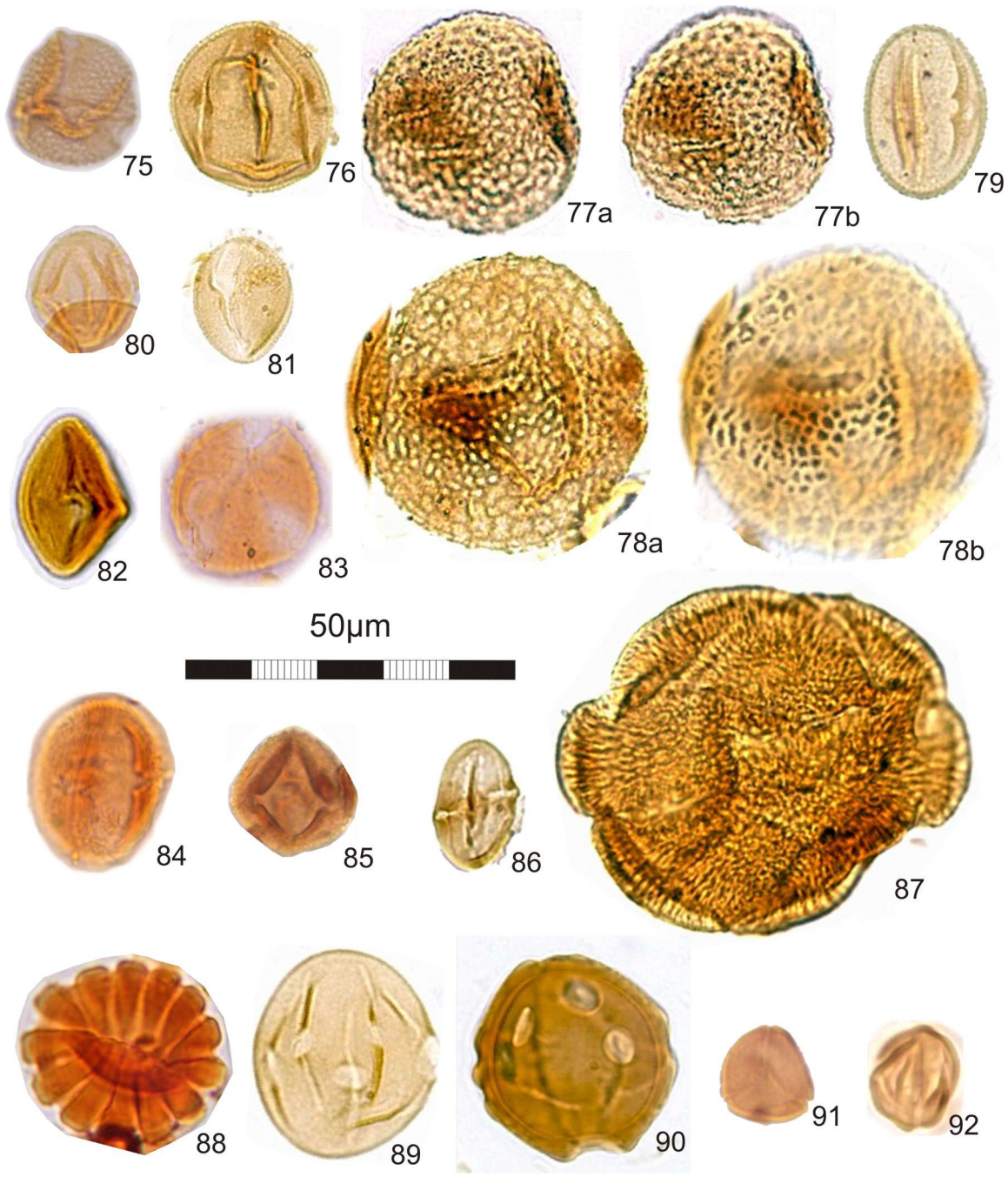
37: *Crototricolpites* sp.; 38: *Perfotricolpites digitatus*; 39: *Retitricolpites conciliatus*; 40: *Retitricolpites* cf. *R. amapaensis* ; 41: *Retitricolpites florentinus*; 42: *Psilatricolpites minutus*; 43: *Retibrevitricolpites* cf. *R. catatumbus;* 44: *Retitricolpites* cf. *R. simplex*; 45: *Striatricolpites catatumbus*; 46: *Multiareolites formosus*; 47: *Multimarginites vanderhammeni*; 48: *Bombacacidites baculatus*; 49: *Bombacacidites bellus*; 50: *Costatricolporites reticulatus*; 51: *Crassiectoapertites colombianus*; 52: *Echitricolporites maristellae.*

PLATE 5



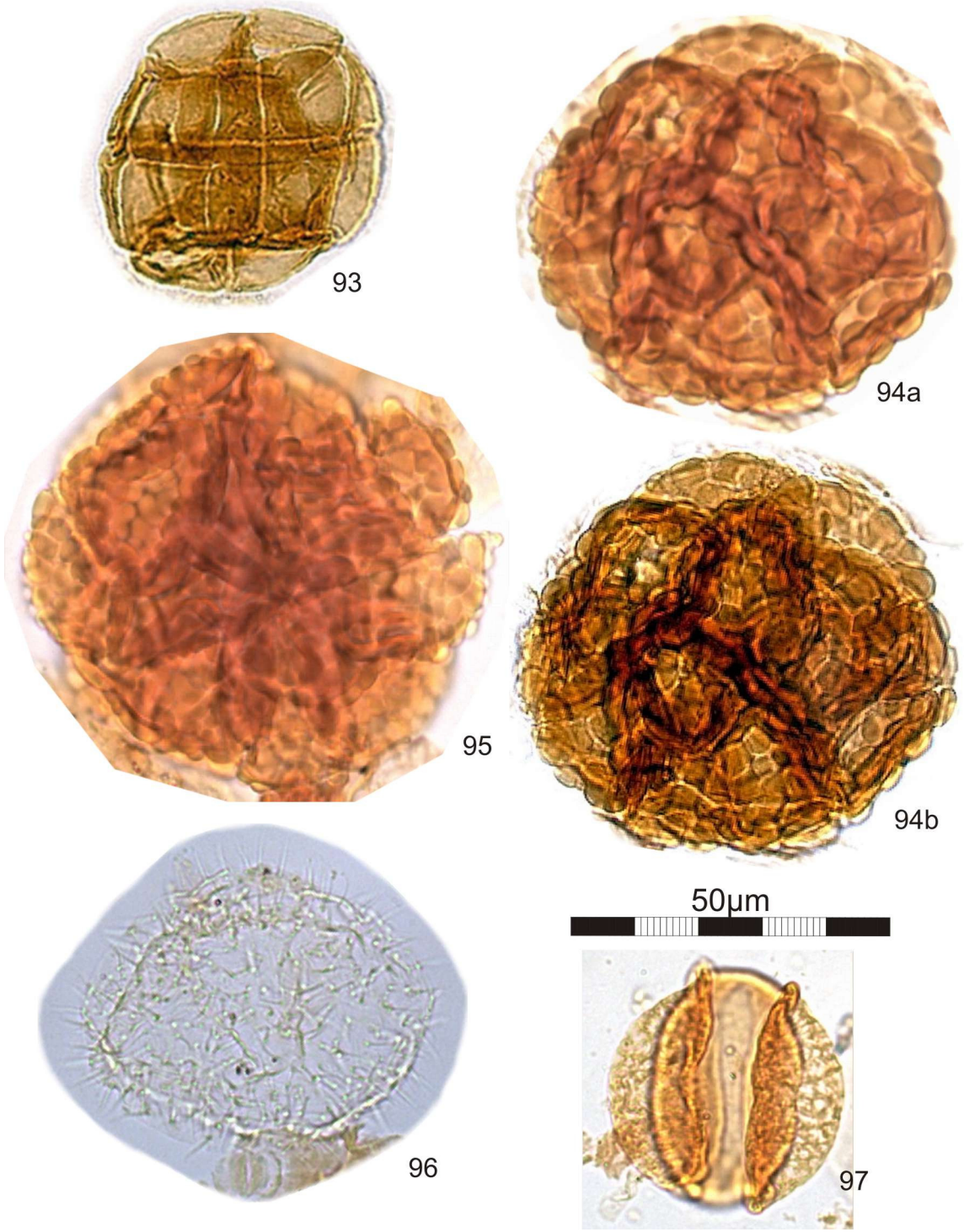
53: *Echitricolporites spinosus*; 54: *Echitricolporites* sp.; 55: *Foveotricolporites caldensis*; 56: *Foveotricolporites florschutzi*; 57: *Ilexpollenites* sp.; 58: *Margocolporites vanwijhe*i; 59: *Margocolporites* aff. *M. vanwijhe*i; 60: *Psilatricolporites caribbiensis*; 61 (paratype), 62 (holotype): *Psilatricolporites hoornii*; 63: *Psilatricolporites labiatus*; 64: *Psilatricolporites operculatus*; 65: *Psilatricolporites vanus*; 66: *Psilatricolporites* sp.; 67: *Retibrevitricolporites* cf. *R. grandis*; 68: *Retibrevitricolporites speciosus*; 69: *Retitricolporites finitus*; 70: *Retitricolporites guianensis*; 71: *Retitricolporites hispidus*; 72: *Retitricolporites irregularis*; 73: *Retitricolporites medius*; 74: *Retitricolporites* aff. *R. magnus*.

PLATE 6



75: *Retitricolporites* cf. *R. perpusillus*;76: *Retitricolporites squarrosus*; 77ab (paratype), 78ab (holotype) *Retitricolporites toigoi*; 79: *Retitricolporites* sp.2; 80: *Retitricolporites* sp.1; 81: *Retitricolporites* sp.3; 82: *Striatricolporites digitatus*; 83: *Rugotricolporites arcus*; 84: *Striatricolporites tenuissimus*; 85: *Verrutricolporites* sp.; 86: *Zonocostites* cf. *Z. ramonae*; 87: *Jandufouria seamrogiformis*; 88: *Psilastephanocolporites* aff. *P. fissilis*; 89: *Psilastephanocolporites* sp.; 90: *Perisyncolporites pokornyi*; 91: *Myrtaceidites* spp.; 92: *Heterocolpites incomptus*.

PLATE 7



93: *Polyadopollenites mariae*; 94ab (holotype), 95 (paratype): *Polyadopollenites marileae*; 96: Dinoflagelate cyst; 97: *Podocarpidites* sp.

Pollen diagram

7. BIOESTRATIGRAFIA, PALEOECOLOGIA E CORRELAÇÃO ESTRATIGRÁFICA.

Artigo submetido no peródico *Palynology* da American Association of Stratigraphic Palynologists (AASP):

MIOCENE-PLIOCENE PALYNOLOGY, MINERALOGY AND ISOTOPE GEOCHEMISTRY OF THE SOLIMÕES FORMATION, IQUITOS ARCH, BRAZIL.

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RESUMO

O arco de Iquitos influenciou a paisagem da região noroeste da América do Sul desde o Mioceno tardio. Reflexos da sua dinâmica de soerguimento, antes vistos apenas em afloramentos, podem também ser observados em sub-superfície. O estudo de palinologia, mineralogia e geoquímica de isótopos de uma seção da Formação Solimões possibilitou a sua correlação com as formações Pebas e Nauta da região de Iquitos. Essa correlação possibilita a aplicação direta de um arcabouço palinostratigráfico nos sedimentos. O intervalo 401 – 300 m do poço 1 AS 33 AM (Mioceno inferior / médio), depositado em ambiente principalmente de água doce com alguma influência marinha, corresponde à Formação Pebas. O intervalo seguinte 300 – 185 m (Mioceno superior / Plioceno) corresponde à camada superior da Formação Pebas, designada na literatura como 'Uppermost Pebas'. Na seção estudada esta camada recobre discordantemente a Formação Pebas, assim como em algumas localidades no Peru. É sugerido aqui um diacronismo para essa unidade uma vez que a idade atribuída a ela é mais jovem que a descrita na literatura. A porção inferior desse intervalo (299,05 – 238,33 m) está na zona de intervalo Asteraceae e a porção superior (238,33 – 185,00m) está na subzona de intervalo *Psilatricolporites caribbiensis*. Não foi observada nenhuma discordância entre as duas biozonas. O último intervalo de *ca.* 185 m até a superfície é formado por depósitos típicos de sistema fluvial e é correlacionado aqui com a Formação Nauta. É considerado Plioceno por corresponder à parte superior da subzona de intervalo *Psilatricolporites caribbiensis*, idade mais jovem que a proposta anteriormente.

ABSTRACT

The Iquitos arch influenced significantly the landscape since its uplift in the late Miocene and it is possible to verify the forebulge dynamics, originally observed in outcrops, in the sub-surface sediments. This study presents the palynology and associated minerals and isotopes of a Miocene / Pliocene cored section in Brazil. Considering the approximate age, depositional environment and sediment provenance, it is possible to correlate the Solimões Formation with the Pebas and Nauta formations near the Iquitos arch in Peru, now with the advantage of a biostratigraphic framework that enable a direct dating for the sediments. The interval between 401 m and 300 m (early / middle Miocene) deposited under a mainly fresh water environment with some marine influence corresponds to the Pebas Formation. The following interval between 300 m and 185 m corresponds to the 'Uppermost Pebas' Formation. Since the Uppermost Pebas Formation may unconformably overlie the Pebas Formation in Peru it is suggested here that the top of the Pebas Formation in Brazil is younger then it is in Peruvian Amazonia, and thus diachronic. The lower part of the interval (299,05 – 238,33 m) is in the Asteraceae Interval Zone and the upper part (238,33 – 185,00) is in the *Psilatricolporites caribbiensis* Interval Subzone. It was not observed any evidence of discontinuity between both biozones. The last interval from *ca.*185,00 m to the surface is a typical fluvial system deposit and is correlated here to the Nauta Formation. It is considered Pliocene, corresponding to the upper part of the *Psilatricolporites caribbiensis* Interval Subzone, a younger age than the originally proposed to it.

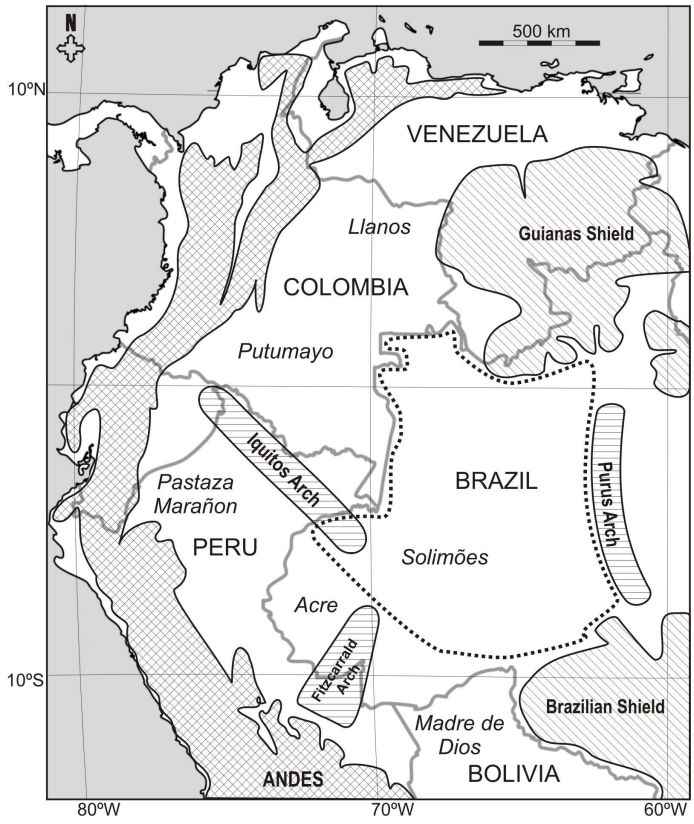
INTRODUCTION

The Iquitos arch is a structural high that separates the Solimões and Acre basins in western Amazonia in Brazil, however its exact location has shifted in various publications over the past decades (Wesselingh *et al.* 2006b). According to Caputo & Silva (1990), it was formed in the Early Cretaceous due to the Andean orogeny that overloaded the continental margin causing peripheral uplift and erosion of older sediments until the exposure of the basement that was afterwards covered by Cretaceous and Cenozoic sediments. Later, Roddaz *et al*. (2005ab) presented a more detailed flexural model and a stratigraphic background proposing a late Miocene origin for the forebulge, but could not find suitable fossils for a direct dating of the sediments. According to them the Iquitos arch changed the landscape significantly since its uplift in the late Miocene and consequently influenced the paleoenvironment in the area.

The objectives of this study are: 1) to correlate the palynological data and associated mineralogical and isotopic information of the sediments from a well located on the eastern end of the Iquitos arch in Brazil; 2) to compare it with the stratigraphic units described in the region in order to correlate the strata; 3) and, considering previous palynological studies, apply a biostratigraphic framework to these sediments and contribute to the understanding of the Neogene paleoenvironment evolution in western Amazon.

GEOLOGICAL SETTING

The Solimões basin comprises an area of 600.000km^2 limited in the North by the Guiana shield and in the South by the Brazilian shield. The Iquitos arch separates it from the subandean basins in the west and the Purus arch separates it from the Amazonas basin in the east (Text-Figure 1).



Text-Figure 1: Location map of the Solimões basin, neighbor basins and main structural features in northeastern South America (modified from Leite *et al.*, submitted). The names of the basins are in *italic*. Structural data from Caputo (1984), Baby *et al*. (2005), Roddaz *et al*. (2005a) and USGS website.

The sedimentary infill reaches up to 3500 m of thickness. The Paleozoic sequence represents most of the sedimentary succession but can only be observed in boreholes. The Mesozoic-Cenozoic sequences can crop out, especially along the rivers (Caputo, 1984; Caputo & Silva, 1990; Hoorn, 1993; Eiras *et al.*, 1994).

The Solimões Formation consists of claystones, siltstones and sandstones intercalated with a few lignite and limestone layers (Radambrasil, 1977; Hoorn, 1993). The thickness varies reaching up to 600 m according to the paleotopography of the basement (Radambrasil, 1977). It overlies unconformably the Cretaceous Alter do Chão Formation, and it is overlay by the unconsolidated white sands of the Pleistocene Içá Formation (Caputo, 1984). In the nearby basins the correlative Neogene sediments were divided into different stratigraphic units as Pebas, Nauta, Ipururo, Marañon and Madre de Dios Formations (Hoorn, 1993; Campbell *et al*., 2001, Wesselingh *et al*., 2006a). However, in Brazil the sedimentological and faciological differences observed in these strata were not registered so far and the Neogene deposits of the Solimões basin were all included in the Solimões Formation.

The paleoenvironmental interpretations of the data obtained through different analytical tools for these Neogene units are sometimes contradictory as it is well summarized by Westaway (2006). In Brazil, Rego (1930 *apud* Caputo, 1984) formalized the Solimões Formation describing it as Miocene estuarine deposit. Later this unit was reinterpreted as being deposited in a fluvial-lacustrine environment during the Miocene / Pliocene (Caputo, 1984, Radambrasil, 1977; Cruz, 1984).

Studying samples from several drill cores along the Solimões River, Purper (1977, 1979) and Purper & Ornellas (1991) registered a mesohaline water ostracod fauna, restarting the discussion about the depositional environment.

The mollusks from many outcrops in western Amazonia were studied by Nuttal (1990) that proposed a dynamic environment formed by rivers, swamps and lakes of varying salinity, under the influence of the Caribbean Sea. Hoorn (1993, 1994) and Hoorn *et al.* (1995) studied the palynology and sedimentology of one bore hole and many outcrops in the same region and concluded that the Solimões/Pebas Formation was deposited in a fluvial/lacustrine environment with episodic marine incursions caused by the sea level rises in the Miocene. According Hoorn *et al.* (1995) the uplift of the Eastern Cordillera, the Santander massif and the Merida Andes in the late Miocene induced the development of the transcontinental Amazonas river and closed the Amazonian/Caribbean connection.

The report of tidal deposits in the Acre basin dated ~10 Ma by Räsänen *et al.* (1995) presented the possibility that the seaway connecting the Caribbean to the South Atlantic postulated by Von Ihering (1927 *apud* Monsch, 1998) would have remained until the end of the Miocene. They interpreted the occurrence of sand-mud couplets as semidiurnal tidal deposits with a mesotidal range of 2 – 4 m. Hoorn (1996) and Paxton & Crampton (1996) in comments to this study pointed out that the palynology and fish fossils did not indicate a

marine environment, but only sporadic incursions, and that by the late Miocene the connection to the Caribbean Sea was already closed. Later, Westaway (2006) reanalyzed these sediments and interpreted them as flood and slack water deposits.

Alvarenga & Guilherme (2003) described the first fossil bird yet found in the Acre deposits, the *Macranhinga ranzii*, commonly known as anhinga, darter or snakebird. These birds are considered good palaeoenvironmental indicators because they are typical of forested borders of fresh and clear water lakes and meandering rivers. The authors compared the paleoenvironment with the present Brazilian "Pantanal".

Stable isotopes of mollusk shells from the Pebas Formation in western Peru confirmed the existence of a fresh water system during the middle – late Miocene with at least one marine incursion occurred ~11Ma (Vonhof *et al*., 1998, 2003). Analyzing the ictiofauna of these sediments Monsch (1998) found marine, brackish and fresh water fish remains and reinforced the riverine/lacustrine model with a marginal marine sporadic influence. Still in the same region Gingras *et al.* (2002) described deposits similar to the ones found by Räsänen *et al.* (1995) and interpreted them as marginal marine with a stratified water column. They tried to conciliate these conclusions with the previous isotope studies suggesting that the isotopic database reflected the most extreme non-marine conditions in the system.

A multidisciplinary study presented by Wesselingh *et al.* (2002) combined all the so far available data and proposed that the Pebas Formation was deposited in a "paramarine megalake", that is a freshwater tidal basin with occasional marine incursions.

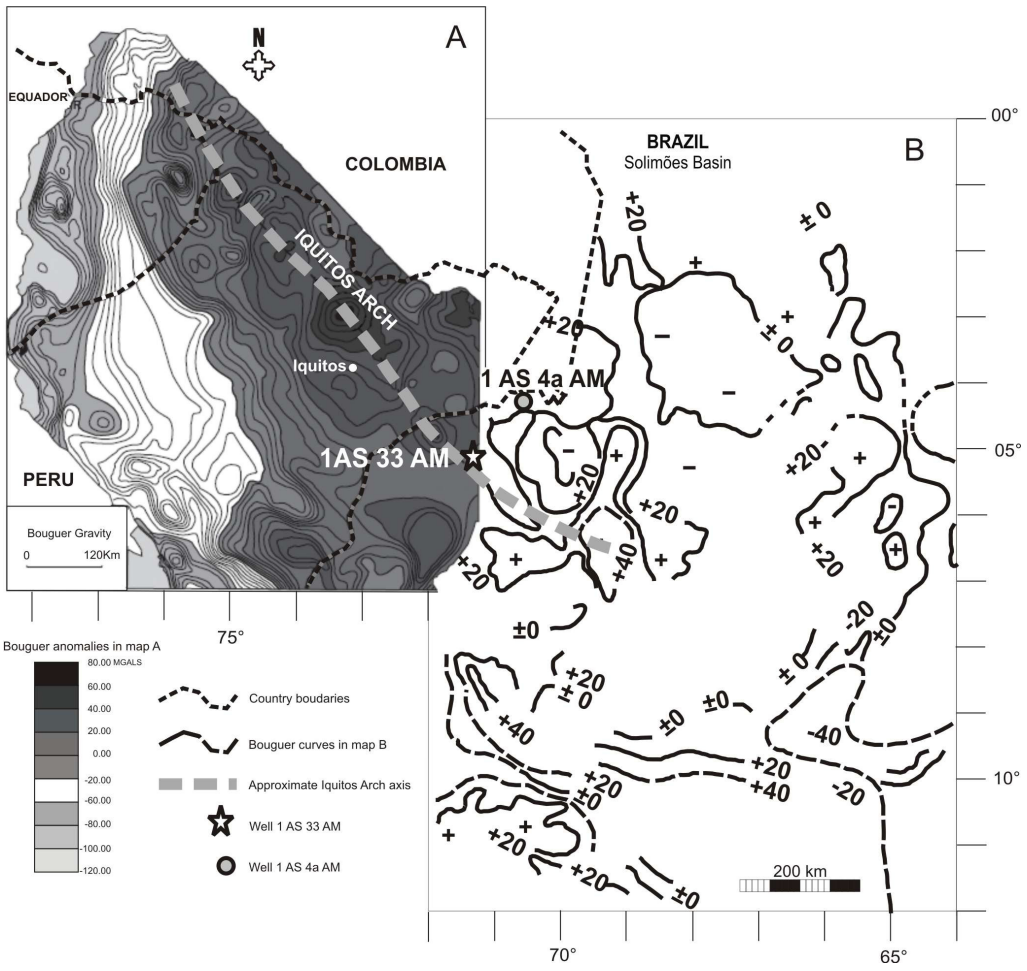
The Iquitos arch

The Iquitos arch corresponds to the elongated band of positive anomalies (20-60 mgals) that can be observed in two associated Bouguer anomaly maps from Peru and Brazil (Text-Figure 2). There are authors that argue that the term "arch" should be abandoned as it covers a variety of geological and geomorphological features (Wesselingh and Salo, 2006), but since this question is not decided, the term will be used in the present study.

Roddaz *et al*. (2005ab) recognized four sedimentary units in the region near the cities of Iquitos and Nauta in Peru: Pebas, Nauta, White Sands and Amazonas formations. They proposed that in the late Miocene/Pliocene the Iquitos forebulge acted as a drainage divide. The paleoenvironment changed from the tidal influenced lake that deposited the Pebas Formation (Wesselingh *et al*., 2002) to a fluvial plain that originated the Nauta Formation. In the Pliocene the overfilling of the foreland basin and an orogenic pulse in the Andes resulted

in the burying of the forebulge and its later incision by transverse rivers issued from the Andes.

In the same region, Rebata *et al.* (2006ab) individualized a level at the top of the Pebas Formation, called 'Uppermost Pebas'. It is characterized by the lack of fossil mollusks and low organic content. They dated this interval as Late Miocene by the presence of a palynological association characteristic of the Asteraceae interval zone *sensu* Lorente(1986). According to the authors, the Geological Survey of Peru – INGEMMET considered it as the Ipururo Formation, separated from the underlying Pebas Formation by a regional unconformity. However, Rebata *et al.* (2006a) did not observe this discontinuity and described it as a gradual transition between the Pebas and Nauta formations. The Nauta Formation was separated into several stratigraphic facies characteristic of ebb-dominated channels and inactive portions of delta plains around shallow brackish water embayment.



Text-Figure 2: Compound Bouguer anomaly map of the region around the Iquitos arch in Brazil and Peru with the location of the wells 1 AS 33 AM (this study) and 1 AS 4a AM (Hoorn, 1993). A: modified from Roddaz *et al.* (2005a). B: modified from Caputo (1984).

MATERIAL

The Solimões and Acre basins were the object of two major drilling projects carried out for scientific and economic purposes. The Brazilian Geological Survey (CPRM) developed an extensive geological research that produced 37 fully cored wells and a detailed report on the geology of the area (Maia *et al.* 1977). The preliminary palynological results of these wells were presented by Cruz (1984) that interpreted the Solimões Formation as Miocene / Pliocene fluvial deposits. Some of these results are now available at the PALEO data base (http://www.cprm.gov.br/bases/novapale/paleind.php).

The present work is the study of the palynology and associated minerals of the well 1AS 33 AM located at 5º15'S / 71º33'W (Text-Figure 2). It reaches 405 m depth and covers approximately 17 Ma corresponding to middle Miocene/Pliocene interval of the Solimões Formation.

The palynological results were compared with Hoorn (1993) that proposed a palynostratigraphic framework for the Solimões Formation for the well 1AS 4a AM (4º23'S / 70º55'W) drilled by the same project (Text-Figure 2).

The sampling aimed mainly the palynology but other samples were collected for other methods. It was possible to obtain organic residue in 32 palynological samples out of the 74 that were prepared. The mineralogical composition of 24 samples was determined by X-ray diffraction. Sm and Nd isotopic analyses were done in 20 samples.

Apart from the present work at least two more papers will be published with this material, one on the palynological systematic results (Leite, submitted) and another on the carbonatic fossils.

ANALYTICAL METHODS

The palynological samples were processed in the Palynology Laboratory at the University of Brasília. The method consisted of disaggregation of 10cm^3 of the material, introduction of exotic pollen, elimination of the carbonates with HCl, elimination of silicates with HF, separation of organic fraction with $ZnCl_2$ with density 2 g/cm^3, and elimination of the excess of organic debris with solution of KOH 10%. The slides were mounted with Entellan. The pollen diagrams were made using the computer program PamPlot of Pangaea PaleoNetwork for Geological and Environmental Data (www.pangaea.de/Software/PanPlot/). The statistic analysis was done by the software system STATISTICA, version 7 (StatSoft, Inc. 2004, www.statsoft.com), using the multivariate cluster analysis applying Ward's and 1-Pearson r methods.

The X-ray analysis was done at the X-ray Laboratory of the University of Brasília. The samples were disaggregated and ground with agate mortar and the slides were fixed with back loading technique. The analysis was performed in a diffractometer Rigaku D/MAX – 2 A/C with copper tube and Ni filter, operating with 40kV and 20 mA. The samples were under a scanning of 2 to 70º 2θ, with continuous speed of 2º/min. The characterization of the sedimentary facies was based on macroscopical and thin sections observation of core samples in optical microscope.

Sm and Nd isotopic analyses were performed in the Geochronology Laboratory of the University of Brasília. Approximately 60 mg of powdered rock samples were dissolved for Sm and Nd extraction in successive acid attacks with concentrated HF, HNO_3, and HCl. A mixed ^{149}Sm–^{150}Nd spike was added to the solution before the first acid attack. Subsequently, Sm and Nd were extracted by reverse-phase chromatography in columns packed with HDEHP (di-2-ethyl-hexyl phosphoric acid) supported with Teflon powder. Sm and Nd aliquots were loaded onto double reevaporation filaments, and the isotopic measurements were carried out on a multi-collector Finnigan MAT-262 mass spectrometer in static mode. For Sm/Nd and $^{143}Nd/^{144}Nd$ ratios, the uncertainties are lower than 0.1% (2σ) and 0.003% (2σ) respectively, according to repeated analyses of international rock standards BCR-1 and BHVO-1. The $^{143}Nd/^{144}Nd$ ratios were normalized to a $^{146}Nd/^{144}Nd$ ratio of 0.7219. Nd procedure blank was less than 150 pg.

RESULTS

Palynology

The palynological content of the samples from the well 1 AS 33 AM consists of ninety-five palynomorphs. Most of them were pollen grains of angiosperms with eighty-five types classified and many others included in the group of "undetermined angiosperms" due to their very low percentages. Only one species of gymnosperm was present and always in small quantity. The systematic of these palynomorphs are presented in Leite (submitted).

The paleoenvironmental interpretation was mainly centered in the taxonomic affinity and ecology of most abundant species (Pollen diagram). A multivariate cluster analysis of the percentage values grouped those species with similar occurrence and probably close ecological necessities (Text-Figure 3; Table 1).

Considering the percentage results of all species in each sample, seven associations were defined (Table 2). These assemblages correspond in general to the *fluvial system*

paleoenvironmental model proposed by Lorente (1986) that includes a wide range of geographic and geomorphological units such as alluvial plain, lakes, estuaries and swamps.

The identified associations are:

▪ **Lake 1**: This association is present in only one sample (55,00m). It is characterized by the absolute dominance of *Pediastum* sp. *Magnastriatites grandiosus* occurs in subordinate amount. *Pediastrum* is a chlorophyte typical of tropical hard water eutrophic lakes (Tyson, 1995).

▪ **Lake 2**: It is also present in only one sample (137,00 m). It is characterized by the absolute dominance of *Monoporites annulatus* and small quantities of *Echitricolporites maristellae* and *Laevigatosporites* spp. A common habitat for grasses (*Monoporites* spp.) in Amazon lowlands is the floating mats in shallow lakes and rivers (Colinvaux *et al.*, 1999). *Echitricolporites maristellae* is related to *Camptostemon* (Lorente, 1986), a Bombacaceae that grows in coastal swamps and lakes.

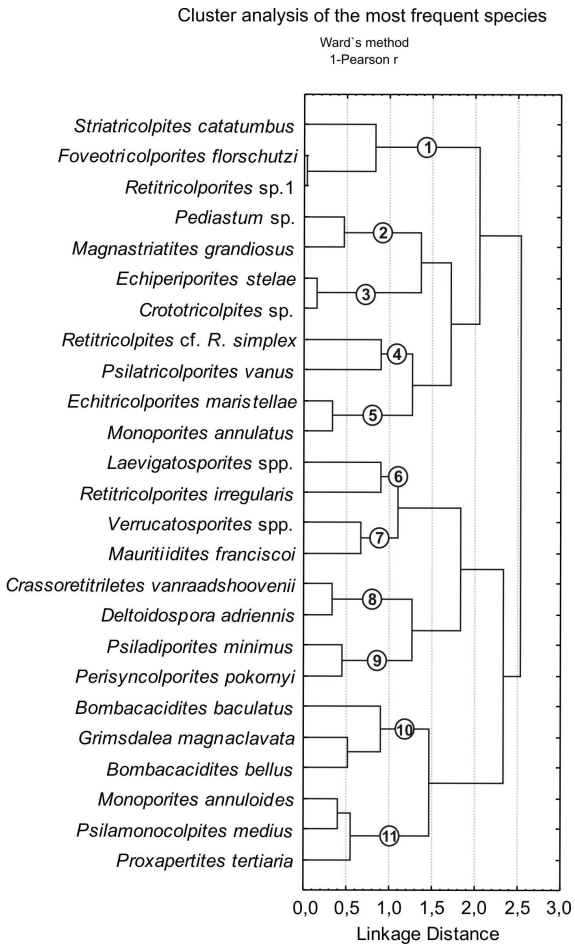
▪ **Alluvial Plain 1**: This association is found in four samples and groups a varied assemblage of arboreal pollen grains with moderate percentages of *Retitricolpites* cf. *R. simplex* and *Laevigatosporites* spp.

▪ **Alluvial Plain 2**: It is present in four samples and is characterized by moderate percentages of *Mauritiidites franciscoi*, *Laevigatosporites* spp., and *Verrucatosporites* spp. and subordinate amounts of *Perisyncolporites pokornyi. Mauritia* (*Mauritiidites franciscoi*) is a palmae commonly found in tropical swamps and alluvial plains (Lorente, 1986).

▪ **Swamp 1**: It groups three samples with subordinate amounts of *Magnastriatites grandiosus* and *Deltoidospora adriennis,* two of them dominated by high percentages of *Echiperiporites stelae* and the other by *Crassoretitriletes vanraadshoovenii. Echiperiporites stelae* is the fossil name of several Malvaceae genus, including *Thespesia*, typical of coastal swamps. *Acrostichum aureum* (*Deltoidospora adriennis*) grows in mangroves near the fresh water swamps and *Lygodium* (*Crassoretitriletes vanraadshoovenii*) is found in tropical swamps (Lorente, 1986).

▪ **Swamp 2**: This association is found in ten samples and is characterized by moderate percentages of *Laevigatosporites* spp. and *Grimsdalea magnaclavata.* Fern-filled swamps are widely spread in Amazon forest (Colinvaux *et al.*, 1999).

▪ **Swamp 3**: This association, found in nine samples, is characterized by the absolute dominance of *Laevigatosporites* spp., moderate percentages of *Verrucatosporites* spp and a great variety of species present in small quantities.



Text-Figure 3: Cluster graphic of most frequent species with nine small clusters corresponding to close occurrence association.

	Species	Taxonomic affinity*	Ecology
1	*Striatricolpites catatumbus*	Caesalpinoideae, *Crudia* , *Macrolobium*	Tropical dry, moist and wet forests
	Foveotricolporites florschutzi	Unknown	
	Retitricolporites sp.1	Unknown	
2	*Pediastum* sp.		Tropical eutrophic low salinity lakes
	Magnastriatites grandiosus	Parkeriaceae, *Ceratopteris*	Wet forests and coastal swamps
3	*Echiperiporites stelae*	Malvaceae	Wide ecology: tropical dry, moist and wet forests and coastal habitat
	Crototricolpites sp.	Euphorbiaceae, *Croton*	Tropical dry, moist and wet forests
4	*Retitricolpites* cf. *R. simplex*	Possibly Euphorbiaceae	Wide ecology: tropical dry, moist and wet forests and grasslands
	Psilatricolporites vanus	Unknown	
5	*Echitricolporites maristellae*	Bombacaceae, *Camptostemon*	Coastal swamps
	Monoporites annulatus	Poaceae	Wide ecology: tropical dry, moist and wet forests and grasslands (also aquatic)
6	*Laevigatosporites* spp.	Pteridófita	Tropical dry, moist and wet forests and swamps
	Retitricolporites irregularis	Euphorbiaceae, *Amanoa*	Tropical moist and wet forests and swamps
7	*Verrucatosporites* spp.	Polypodiaceae, *Polypodium*	Tropical dry, moist and wet forests and swamps
	Mauritiidites franciscoi	Arecaceae, *Mauritia*	Tropical moist and wet forests and swamps
8	*Crassoretitriletes vanraadshoovenii*	Schizaeaceae, *Lygodium microphyllum*	Tropical swamps
	Deltoidospora adriennis	Polypodiaceae, *Acrostichum*	Coastal swamps
9	*Psiladiporites minimus*	Moraceae	Tropical dry, moist and wet forests
	Perisyncolporites pokornyi	Malpighiaceae	Tropical moist and wet forests and swamps
10	*Bombacacidites baculatus*	Bombacaceae, *Pachira aquatica*	Tropical wet forests and swamps
	Grimsdalea magnaclavata	Possibly Arecaceae	
	Bombacacidites bellus	Bombacaceae, *Pseudobombax*	Tropical dry, moist and wet forests
11	*Monoporites annuloides*	Poaceae	Wide ecology: tropical dry, moist and wet forests and grasslands (also aquatic)
	Psilamonocolpites medius	Arecaceae	Tropical moist and wet forests
	Proxapertites tertiaria	Anonaceae, *Crematosperma*	Tropical dry, moist and wet forests

Table 1: Most frequent species in the palynological assemblage separated in nine clusters with their taxonomic affinities and ecology. * The references for the taxonomic affinities are in Leite (submitted).

LAKE 1	
55,00	**%**
Pediastum sp.	71,0
Magnastriatites grandiosus	21,5
TOTAL	92,5

LAKE 2	
137,00	**%**
Monoporites annulatus	54,0
Echitricolporites maristellae	5,0
Laevigatosporites spp.	4,7
TOTAL	63,6

ALLUVIAL PLAIN 1	
R.* cf. *simplex	
***Laevigatosporites* spp.**	
154,70	**%**
Retitricolporites sp.1	13,2
F. florschutzi	12,3
Retitricolporites sp.3	7,8
Laevigatosporites spp.	6,6
Striatricolpites tenuissimus	5,7
TOTAL	45,5
232,18	**%**
Perinomonoletes sp.	17,6
Psilatricolporites vanus	13,3
Laevigatosporites spp.	8,9
R. cf. *simplex*	4,8
TOTAL	44,6
345,20	**%**
Laevigatosporites spp.	32,0
R. cf. *simplex*	27,3
P. potoniei	8,7
TOTAL	68,0
399,10	**%**
R. cf. *simplex*	26,9
Magnastriatites grandiosus	19,4
Laevigatosporites spp.	7,1
Echitricolporites maristellae	4,7
M. cf. *spinulosa*	4,7
TOTAL	62,8

ALLUVIAL PLAIN 2	
Mauritiidites franciscoi	
***Laevigatosporites* spp.**	
***Verrucatosporites* spp.**	
Perisyncolporites pokornyi	
157,87	**%**
Laevigatosporites spp.	16,3
Mauritiidites franciscoi	15,1
Retitricolporites irregularis	8,7
Magnastriatites grandiosus	7,0
Verrucatosporites spp.	6,8
Perisyncolporites pokornyi	5,5
Monoporites annulatus	4,9
TOTAL	64,3
304,45	**%**
Mauritiidites franciscoi	17,9
Deltoidospora adriennis	14,1
Laevigatosporites spp.	11,8
Psiladiporites minimus	11,3
Perisyncolporites pokornyi	9,6
Verrucatosporites spp.	5,3
TOTAL	70,1
320,25	**%**
Verrucatosporites spp.	46,9
Mauritiidites franciscoi	19,5
Laevigatosporites spp.	6,3
Perisyncolporites pokornyi	5,2
TOTAL	77,9
356,35	**%**
Laevigatosporites spp.	41,7
Mauritiidites franciscoi	38,4
Verrucatosporites spp.	8,3
TOTAL	88,5

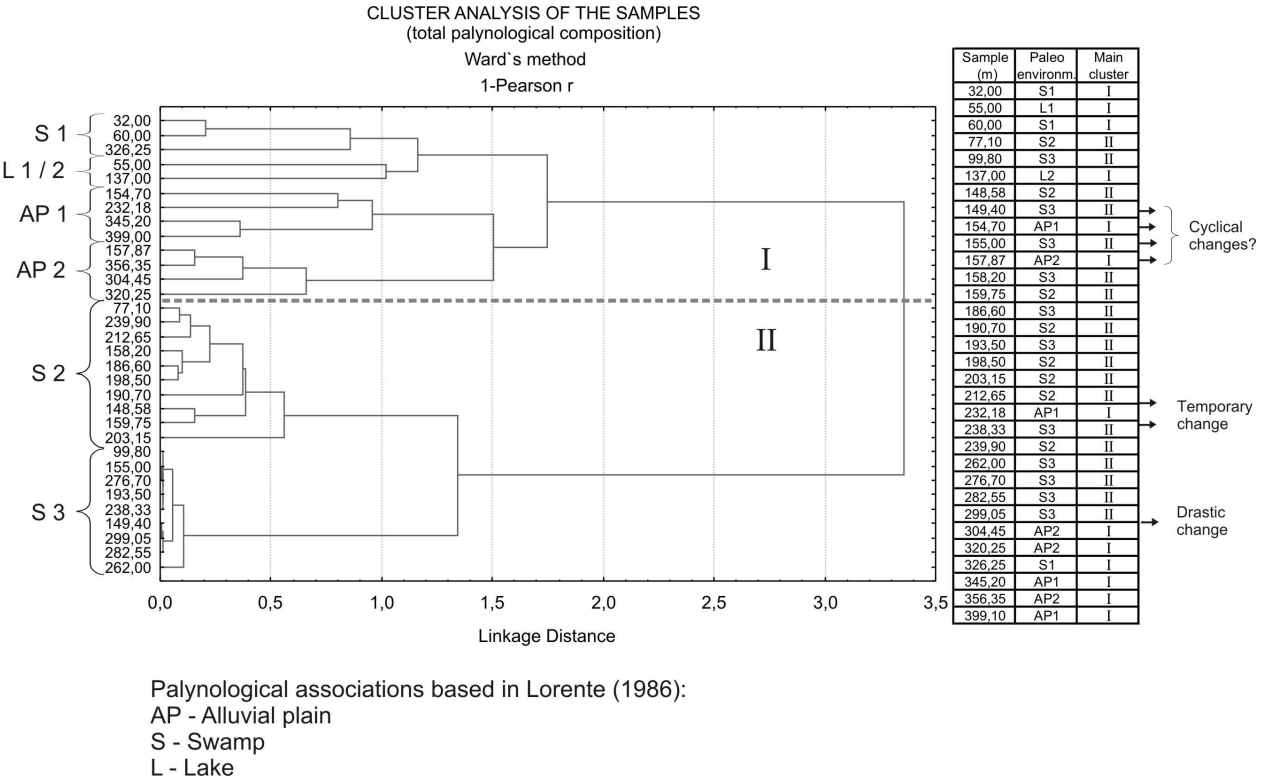
SWAMP 1	
Echiperiporites stelae	
Magnastriatites grandiosus	
Deltoidospora adriennis	
32,00	**%**
Echiperiporites stelae	22,0
Magnastriatites grandiosus	17,3
Crototricolpites sp.	12,4
Deltoidospora adriennis	7,9
TOTAL	59,6
60,00	**%**
Echiperiporites stelae	17,3
Deltoidospora adriennis	14,9
Grimsdalea magnaclavata	13,7
Magnastriatites grandiosus	11,3
Crototricolpites sp.	6,0
Laevigatosporites spp.	5,2
Verrucatosporites spp.	5,2
TOTAL	73,8
326,25	**%**
C. vanraadshoovenii	38,3
Deltoidospora adriennis	25,0
Magnastriatites grandiosus	8,9
Laevigatosporites spp.	6,5
TOTAL	78,8

SWAMP 2			
***Laevigatosporites* spp.**			
Grimsdalea magnaclavata			
77,10	**%**	**190,70**	**%**
Laevigatosporites spp.	24,4	*Laevigatosporites* spp.	17,6
Grimsdalea magnaclavata	16,6	*Grimsdalea magnaclavata*	14,9
Verrucatosporites spp.	7,5	*Magnastriatites grandiosus*	13,4
Magnastriatites grandiosus	6,2	*Deltoidospora adriennis*	12,0
Bombacacidites bellus	6,0	*Bombacacidites bellus*	7,3
Echiperiporites stelae	5,2	*Perisyncolporites pokornyi*	6,9
Monoporites annulatus	5,0	TOTAL	72,1
TOTAL	71,0	**198,50**	**%**
148,58	**%**	*Laevigatosporites* spp.	19,6
Grimsdalea magnaclavata	22,6	*Grimsdalea magnaclavata*	10,1
Laevigatosporites spp.	17,2	*Verrucatosporites* spp.	9,3
Mauritiidites franciscoi	12,9	*Perisyncolporites pokornyi*	4,8
Verrucatosporites spp.	11,3	*Psilatricolporites vanus*	4,6
Psilatricolporites vanus	9,1	TOTAL	48,5
TOTAL	73,1	**203,15**	**%**
158,20	**%**	*Monoporites annuloides*	16,4
Laevigatosporites spp.	23,7	*Laevigatosporites* spp.	16,2
Verrucatosporites spp.	9,9	*Grimsdalea magnaclavata*	12,1
Proxapertites tertiaria	6,4	*Psilamonocolpites medius*	7,1
Grimsdalea magnaclavata	5,4	*Proxapertites tertiaria*	6,3
Perisyncolporites pokornyi	4,9	*Mauritiidites franciscoi*	4,7
TOTAL	50,3	TOTAL	62,7
159,75	**%**	**212,65**	**%**
Laevigatosporites spp.	15,9	*Laevigatosporites* spp.	28,5
Grimsdalea magnaclavata	12,5	*Grimsdalea magnaclavata*	11,4
Striatricolpites catatumbus	10,2	*Bombacacidites bellus*	9,3
Verrucatosporites spp.	8,2	*Psilamonocolpites medius*	5,2
Mauritiidites franciscoi	7,3	*Psilatricolporites vanus*	5,2
TOTAL	54,1	*Foveotricolporites caldensis*	5,2
186,60	**%**	*TOTAL*	64,7
Laevigatosporites spp.	33,6	**239,90**	**%**
Verrucatosporites spp.	17,1	*Laevigatosporites* spp.	34,0
Deltoidospora adriennis	10,3	*Grimsdalea magnaclavata*	20,9
Grimsdalea magnaclavata	9,3	*Bombacacidites baculatus*	8,7
Psilamonocolpites medius	5,1	*Verrucatosporites* spp.	5,9
TOTAL	75,4	*Perisyncolporites pokornyi*	5,2
		TOTAL	74,7

SWAMP 3			
***Laevigatosporites* spp.**			
***Verrucatosporites* spp.**			
99,80	**%**	**262,00**	**%**
Laevigatosporites spp.	58,7	*Laevigatosporites* spp.	51,8
Perisyncolporites pokornyi	6,1	*Retitricolporites irregularis*	17,6
Verrucatosporites spp.	5,1	*Verrucatosporites* spp.	13,5
Deltoidospora adriennis	4,9	*Mauritiidites franciscoi*	4,1
TOTAL	74,8	TOTAL	87,0
149,40	**%**	**276,70**	**%**
Laevigatosporites spp.	66,6	*Laevigatosporites* spp.	77,9
Verrucatosporites spp.	18,7	*Verrucatosporites* spp.	2,8
Grimsdalea magnaclavata	4,4	*C. vanraadshoovenii*	2,5
TOTAL	89,7	*Echitricolporites maristellae*	1,2
155,00	**%**	TOTAL	84,4
Laevigatosporites spp.	71,4	**282,55**	**%**
Verrucatosporites spp.	7,0	*Laevigatosporites* spp.	61,9
Proxapertites tertiaria	2,8	*Verrucatosporites* spp.	12,9
TOTAL	81,2	*C. vanraadshoovenii*	8,1
193,50	**%**	*Bombacacidites bellus*	3,8
Laevigatosporites spp.	51,6	*TOTAL*	86,6
Verrucatosporites spp.	5,6	**299,05**	**%**
Deltoidospora adriennis	3,6	*Laevigatosporites* spp.	64,6
I. solimoensis	3,1	*Verrucatosporites* spp.	17,5
TOTAL	63,8	*Mauritiidites franciscoi*	4,5
238,33	**%**	TOTAL	86,6
Laevigatosporites spp.	56,3		
Verrucatosporites spp.	9,7		
Mauritiidites franciscoi	4,1		
TOTAL	65,9		

Table 2: Palynological associations established according to the most frequent palynomorphs. The environmental interpretation is based in Lorente (1986). The associations are characterized by the presence of the following species:
Lake 1: Pediastum sp. and Magnastriatites grandiosus
Lake 2: Monoporites annulatus, Echitricolporites maristellae and Laevigatosporites spp.
Alluvial Plain 1: Retitricolpites cf. R. simplex and Laevigatosporites spp.
Alluvial Plain 2: Mauritiidites franciscoi, Laevigatosporites spp., Verrucatosporites spp. and Perisyncolporites pokornyi
Swamp 1: Echiperiporites stelae, Magnastriatites grandiosus and Deltoidospora adriennis
Swamp 2: Laevigatosporites spp. and Grimsdalea magnaclavata
Swamp 3: Laevigatosporites spp. and Verrucatosporites spp.

These groups with similar palynological association were also recognized in a cluster graphic of samples considering the total palynological content. Two main clusters (I and II) were individualized with a linkage distance higher than three indicating a very different palynological composition (Text-Figure 4). The main clusters were separated into smaller units correlated with the palynological associations.



Text-Figure 4: Cluster analysis of the samples considering the total palynological composition.
Two main clusters (I and II) are separated into smaller units correlated with the palynological associations. The chart shows the sample sequence with the cluster changes.
L – Lake 1 and 2; AP - Alluvial plain 1 and 2; S - Swamp 1, 2 and 3

According to these palynological results of the well 1 AS 33 AM it is possible to propose an evolution of the paleoenvironment in that site.

From the base to 304, 45 m the association is characteristic of alluvial plain with *Mauritiidites franciscoi, Perisyncolporites pokornyi, Retitricolpites* cf. *R. simplex* and other trees, ferns and grasses. An indication of a possible marine influence can be observed at 399,10 m by the presence of *Echitricolporites maristellae* (4,7%), and at 326,25 m and 320,25 m by moderate percentages of *Deltoidospora adriennis* (14-25%) both related to coastal environments.

Between 304,45 m 299,05 m there is a change not so much in the type of environment as in the composition of the flora. There are different elements in each and those in common

present a striking contrast in importance. These two assemblages were identified in the cluster analysis as I and II.

From 299,05 m to 238,33 m the palynoflora is typical of fresh water swampy environments characterized by high percentages of *Laevigatosporites* sp. (28-78%). *Grimsdalea magnaclavata* appears for the first time at 239,90 m representing 20% of the total sum but drops to 2,5% in the next sample (238,33 m).

The sample 232,18 m is a break in this swampy pattern, with moderate percentage of a different fern spore (*Perinomonoletes* sp., 17,6%) and an arboreal pollen grain (*Psilatricolporites vanus*, 13,3%). At 212,65 m the amounts of *Laevigatosporites* sp. and *Grimsdalea magnaclavata* increase again keeping a relative stability until 158,20 m despite the greater contribution of sands in the profile (185-170 m) indicating a change in the deposition dynamics. Upwards the palynological association changes frequently. In five samples distributed in around ten meters (158,20-149,80 m) it is possible to observe an oscillation between assemblages I and II. The amounts *Laevigatosporites* sp. varies significantly.

At 154,70 m different arboreal pollen grains, *Retitricolporites* sp.1 and *Foveotricolporites florschutzi*, assume an unprecedented importance. Although the vegetation does not indicate a marine influence, it is registered the only dinoflagelate cyst found in the well. It is a proximate cyst, but as the specimen is broken it was not possible to identify it to a generic level. This fact seems to indicate it was reworked rather than deposited *in situ*, however it could also be the result of tidal influence in an upper delta.

The swampy conditions return with *Laevigatosporites* sp. and *Grimsdalea magnaclavata* again as the most representative palynomorphs at 149,49 and 148,58 m respectively.

Ten meters above (137 m) the scenario changes completely into an absolute dominance of *Monoporites anulatus* (54%) and low amounts of *Echitricolporites maristellae* (5%). Apparently it is the deposits of an ox bow lake with low salinity water, and the successive sand beds above it (130-100 m) represent the riverbanks of a fluvial system. The vegetation of the surrounding poorly drained alluvial plain continued same as before at 99,80 and 77,10 m, which is followed by 15 m of riverbank sands.

At 60 m succeeds a different association dominated by *Echiperiporites estelae*, *Crototricolpotrites* sp. and *Magnastriatites grandiosus*. At 55 m another lake deposit is registered but with a distinct assemblage composed basically by *Pediastrum* sp. with

subordinate amounts of *Magnastriatites grandiosus*. Finally at 32 m the conditions return to the previous one.

Palynostratigraphy

There are three main biostratigraphic frameworks for the Neogene of western Amazonia: Germeraad *et al*. (1968), Lorente (1986) and Muller *et al*. (1987). These frameworks are based in the stratigraphic distribution of species that have their base and top occurrences well defined for the establishment of the zones and subzones. The first two works correlate the palynological zonation with international planktonic zones that enable precise age determination.

The sediments of the Solimões Formation have been previously dated by palynology by Cruz (1984) and Hoorn (1993). Hoorn (1993) analyzed one well (1 AS 4a AM) and several outcrops in the Solimões basin, applying a framework based in Lorente (1986) but introducing some local variations. The zonation proposed by Hoorn (1993) covers well the early / late Miocene intervals. However in the current study younger palynozones were found, and thus the original framework of Lorente (1986) was used.

Lorente(1986) described the following biozones for the Neogene:

▪ ***Psiladiporites*** Interval Zone: The base of this zone is defined by the first occurrence of *Psiladiporites minimus.* In western Venezuela the first occurrence of *Echitricolporites maristellae* is also characteristic of the base of this zone. The top of the zone is defined just below the first occurrence of *Crassoretitriletes vanraadshoovenii. Crototricolpites annemariae* has its first regular occurrence at the base of the zone, while *Multimarginites vanderhammenii* has its first occurrence within the zone. *Bombacacidites zuatensis* and *Venezualenites planetensis* have their last occurrences at the top of this zone. Age: early / middle Miocene. The first occurrence of *Psiladiporites minimus* is not precise, but happens between the nannoplankton zones NN2 and NN4.

▪ ***Crassoretitriletes*** Interval Zone: The base is defined by the first occurrence of *C. vanraadshoovenii* and *Trichotomocolpites* sp. The top is defined just below first occurrence of *Grimsdalea magnaclavata*. The last regular occurrence of *Scabratricolporites planetensis* is found at the top of the zone. Age: middle Miocene. The first occurrence of *Crassoretitriletes vanraadshoovenii* is in the middle of the nannoplankton zone NN5.

▪ ***Grimsdalea*** Interval Zone: The base is defined by the first occurrence of *Grimsdalea magnaclavata*. The top is defined just below of the first occurrence of *Echitricolporites*

spinosus, *Fenestrites spinosus* or *Fenestrites longispinosus*. Age: middle / late Miocene. The first occurrence of *Grimsdalea magnaclavata* is in the nannoplankton zone NN7.

▪ **Asteraceae** Interval Zone: The base is defined by the first occurrence of *Echitricolporites spinosus*. *Fenestrites spinosus, Fenestrites longispinosus, Cyatheacidites annulatus* and *Maravenites polyoratus* also have their first occurrence in the zone. The top is just below the first occurrence of *Stephanocolpites evansii.* Age: late Miocene. The first occurrence of Asteraceae happens between the nannoplankton zones NN9 and NN10.

▪ ***Fenestrites longispinosus*** Interval Zone: The base is defined by the first occurrence of *Stephanocolpites evansii*. The top is just below of the first occurrence of *Alnipollenites verus. Fenestrites longispinosus* is present through the entire interval.

Three subzones may be recognized in this zone:

▪ ***Stephanocolpites evansii*** Interval Subzone: The base is the base of the zone and the top of the subzone is just below of the first occurrence of *Psilatricolporites caribbiensis*. Age: late Miocene. The first occurrence of *Stephanocolpites evansii* is in the nannoplankton zone NN11.

▪ ***Psilatricolporites caribiensis*** Interval Subzone: The base is defined by the first occurrence of *Psilatricolporites caribiensis.* The top is just below of the first occurrence of *Echitricolporites mcneillyi.* Age: late Miocene/ Pliocene. The first occurrence of *Psilatricolporites caribiensis* happens between the nannoplankton zones NN12 and NN15.

▪ ***Echitricolporites – Alnipollenites*** Interval Subzone: The base is defined by the first occurrence of *Echitricolporites mcneillyi.* The top is just below of the first occurrence of *Alnipollenites verus.* Age: Pliocene.

The occurrence of biostratigraphic markers throughout the well 1 AS 33 AM enabled the identification of four of the biozones described above (Text-Figure 5).

▪ **Interval 399 – 326 m → *Psiladiporites*** Interval Zone *sensu* Lorente (1986) – Early / middle Miocene: This zone was defined by the presence of *Echitricolporites maristellae*, *Crototricolpites annemariae* and *Multimarginites vanderhammenii.* The presence of *Psilastephanoporite tesseroporus* also confirms the Miocene age attributed to this interval (Regali *et al*., 1974ab).

▪ **Interval 326 – 299 m → *Crassoretitriletes*** Interval Zone *sensu* Lorente (1986) – middle Miocene: This zone was defined by the presence of *Crassoretitriletes vanraadshoovenii.*

▪ **Interval 299 – 238 m → Asteraceae** Interval Zone *sensu* Lorente (1986) – late Miocene: This zone was defined by the presence of *Echitricolporites spinosus* and *Fenestrites spinosus*.

Grimsdalea magnaclavata was recorded in this study after the first occurrence of *Fenestrites spinosus.*

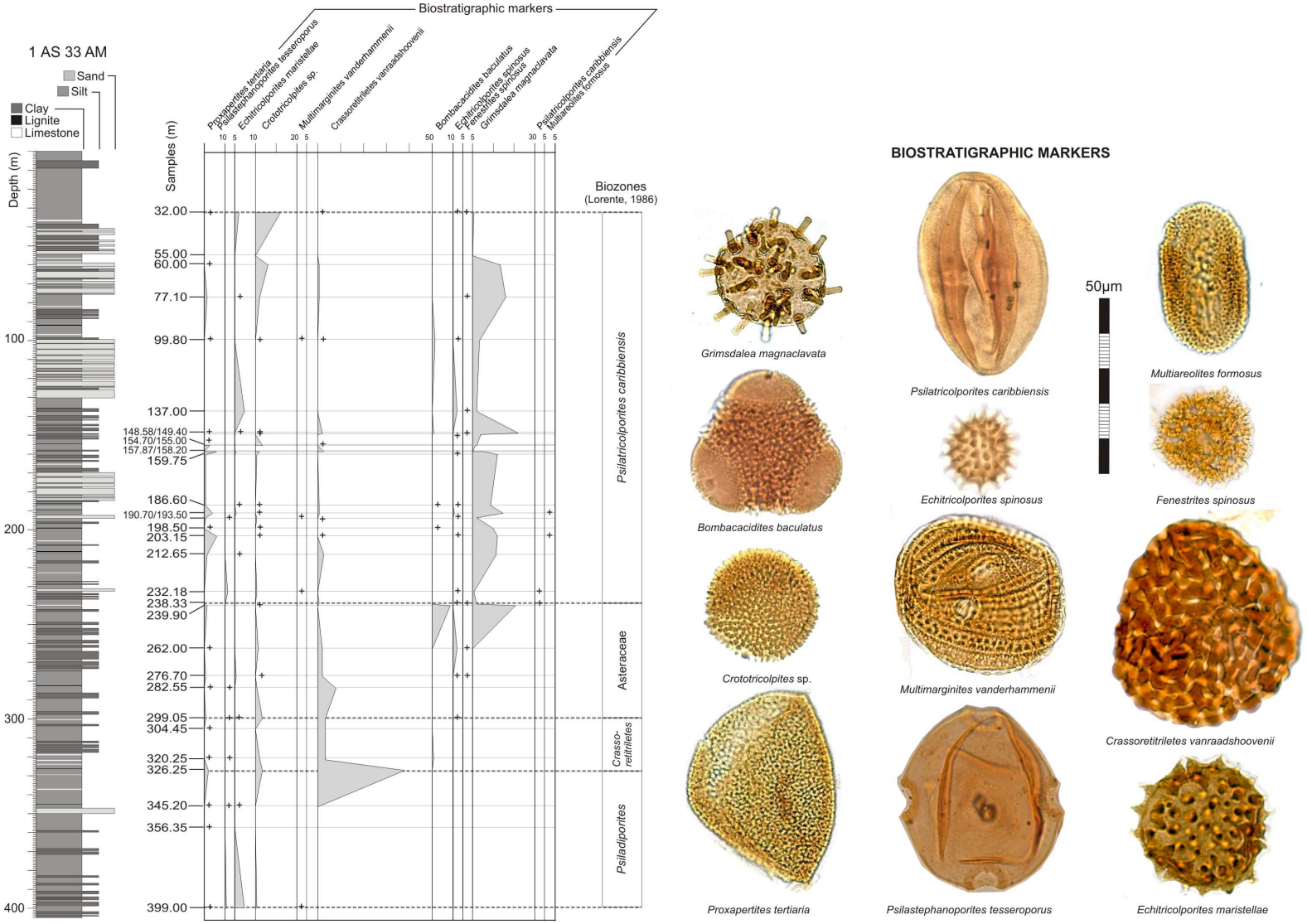
▪ **Interval 238 – 32 m → *Psilatricolporites caribbiensis*** Interval Subzone *sensu* Lorente (1986) – late Miocene / Pliocene: This zone was defined by the presence of *Psilatricolporites caribbiensis*. *Stephanocolpites evansii* was not recorded in this study. The presence of *Multiareolites formosus* also confirms the age attributed to this interval (Muller *et al*., 1987).

In order to compare the biostratigraphy, we applied the same zonation criteria (Lorente, 1986) for the well 1AS 4a AM (Hoorn, 1993). The analysis of both wells in a same framework provides a sequential register of the sub-soil strata over the Iquitos arch in Brazil (Text-Figure 6). However, the sequence in the well 1 AS 33 AM presents two biostratigraphic hiatus (Gap 1 and 2). Gap 1 corresponds to the zone *Grimsdalea* and Gap 2 to the Subzone *Stephanocolpites evansii.*

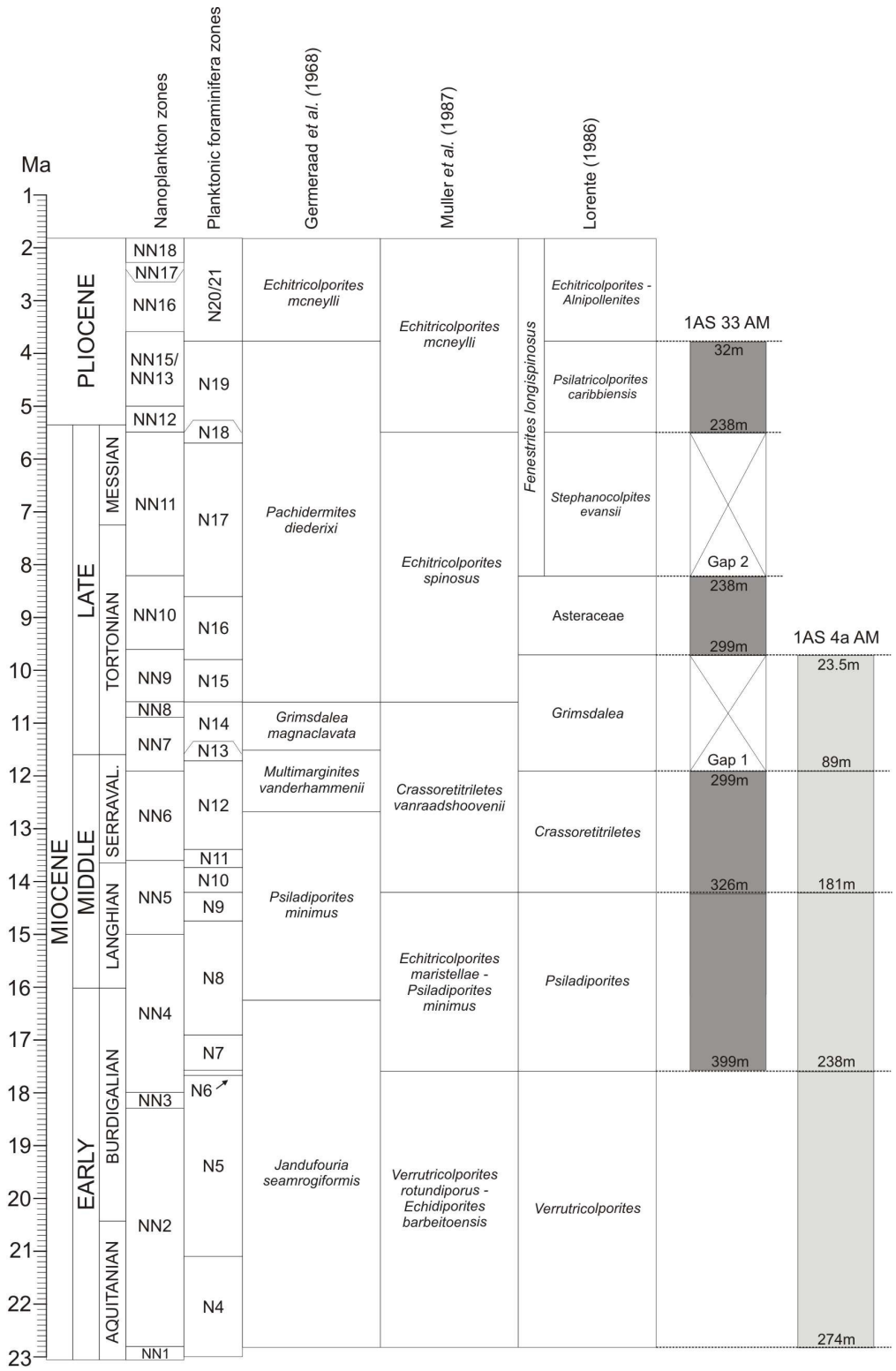
A biostratigraphical hiatus does not necessarily mean a depositional discontinuity, as the absence of a guide fossil can be the result of environmental constrains. Nonetheless it should be carefully observed if the general palynological assemblage presents any abrupt change that indicates any break in a natural vegetational succession.

The reason for an anomalous result as this could be analytical. In this case there was no possibility of contaminating the samples from the well 1AS 33 AM with another fossil material as they were the only ones being prepared in the laboratory and all measures of safety were taken during the process to avoid cross contamination.

In any case, as this well was drilled around 30 years ago, cross contamination of the samples could have happened in storage. However the palynology of the well 1 AS 33 AM was described while the drilling project was developed by CPRM. In the report *Fesnestrites spinosus* was registered at 92,70 and 60m; *Multiareolites formosus* at 214,28 m; and *Grimsdalea magnaclavata* was not found (Table 4). The palynological content of the well is available at the PALEO data base (http://www.cprm.gov.br/bases/novapale/paleind.php).



Text-Figure 5: Percentage diagram with the identified biozones according to the palynostratigraphic framework of Lorente (1986) and pictures of the main biostratigraphic markers throughout the well 1AS 33 AM (modified from Leite, submitted).



Text-Figure 6: Three main palynostratigraphic frameworks for the northern South America (Germeraad *et al.*, 1968; Muller *et al.*, 1987 and Lorente, 1986) and their correspondence to the international planktonic zones and Neogene time scale according to Lourens *et al.* (2004).
It is possible to correlate the wells 1AS 33 AM (this study) and 1AS 4a AM (Hoorn, 1993) with the framework proposed by Lorente (1986). The sequence of biozones identified in the well 1AS 33 AM (this study) presents two biostratigraphic hiatus (Gap 1 and 2).

	Palynomorphs										
Depth	*Zonocostites ramonae*	*Echitricolporites spinosus*	*Psilaperiporites minimus*	*Verrucatosporites usmensis*	*Clavatricolpites daemoni*	*Magnastriatites howardi*	*Pachydermites diederixi*	*Crassoretitriletes vanraadshooveni*	*Cyatheacidites annulatus*	*Multiareolites formosus*	*Fenestrites spinosus*
60,00					*				*		*
92,70			*			*			*		*
214,28	*						*			*	
327,05					*	*	*	*	*		
342,58	*			*	*	*	*				
356,35	*	*	*	*							

Table 3: Palynological content of well 1 AS 33AM available at the PALEO data base (http://www.cprm.gov.br/bases/novapale/paleind.php).

Another possibility is the base occurrence of *Fesnestrites spinosus* and *Psilatricolporites caribbiensis* being misplaced. However this can only be proved examining more wells in the Solimões basin as the stratigraphic position of these fossils was based in the analysis of at least 30 wells (Germeraad *et al*., 1968; Lorente, 1986; Muller *et al*., 1987).

The multivariate cluster analysis of the palynological content used to establish the paleoenvironment (Text-Figure 4), helped to check the significance of these missing biostratigraphic intervals. The statistical results indicate a drastic change in the palynological assemblage in the samples separated by Gap 1. The level above it corresponds to the Asteraceae Interval Zone *sensu* Lorente (1986), the same of the 'Uppermost Pebas' that unconformably overlies the Pebas Formation in some areas in Peru (Rebata *et al.,* 2006a). Campbell *et al.* (2001) also registered in the Madre de Dios basin a regional erosive surface, the so called Ucayali discontinuity, 4 m below a bed of volcanic ashes dated 9,01 Ma by $^{40}Ar/^{39}Ar$. Finally, the age of the missing *Grimsdalea* zone (middle / late Miocene) corresponds in part to the period of uplift of the Iquitos arch – late Miocene (Roddaz *et al.,* 2005a). Therefore, Gap 1 possibly represents a depositional unconformity, maybe the Ucayali discontinuity, between the samples 304 m and 299 m. However, the period comprehended by this hiatus is unknown.

Gap 2 apparently does not indicate a discontinuity. There is a shift at 212 m, but as it returns to the previous pattern it can be interpreted as a temporary environmental change. There seems to be another important change in the palynological succession from 157,87 m upwards as it was mentioned above in the paleoenvironmental interpretation, but it was not

possible to identify any palynomorph that could indicate a different biozone and age for the interval above it.

Mineralogical characterization

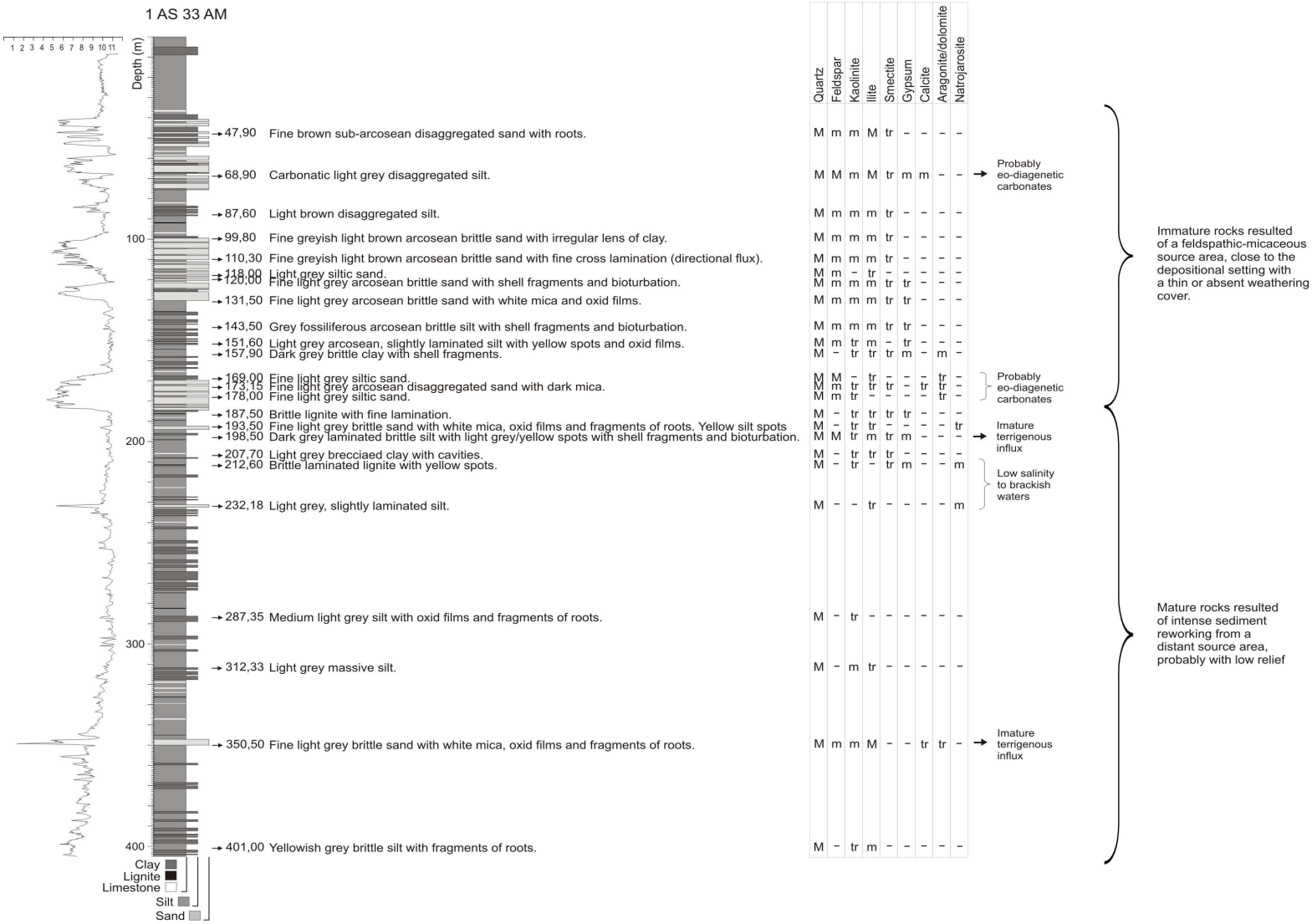
In the well 1AS 33 AM, the Solimões Formation is constituted predominantly of clastic sedimentary rocks of fine textures - fine sandstones, siltstones, claystones – indicatives of low energy environments, and contains also some thin levels of lignite and limestones.

It is possible to individualize two distinct groups of samples based in the mineralogical composition of 24 samples determined by XRD (Text-Figure 7 and 8).

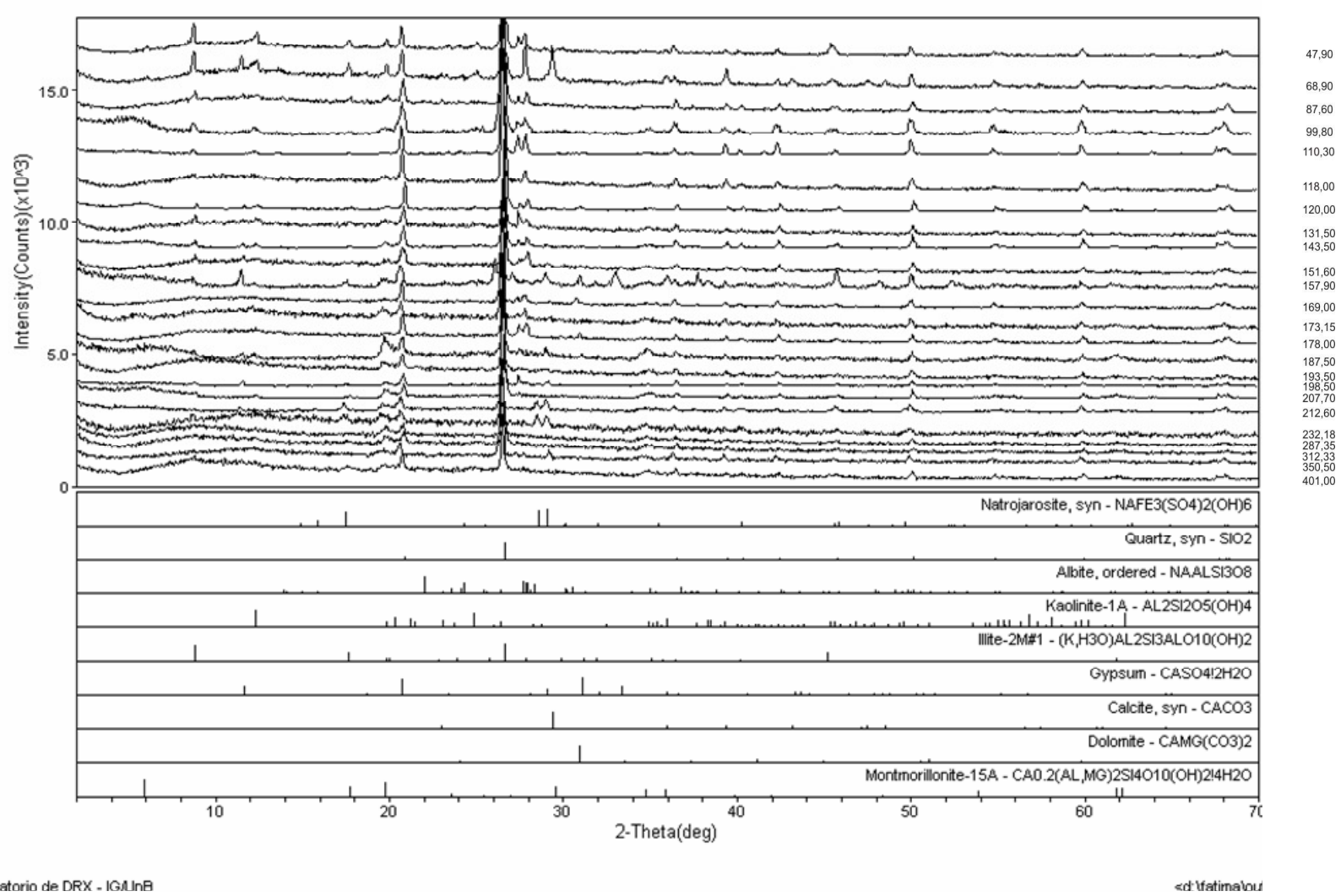
The first includes the samples from the base to 187,50 m where very fine grains of quartz are the main clastic constituent. The absence of unstable minerals gives this sandstones and siltstones a mature character that results of intense sediment reworking and a distant source area, probably with low relief. The low quantity of clay minerals even considering the fine grain size indicates thin weathering cover, while minor content in disordered kaolinite is accepted as a diagenetic product of precipitated ions dissolved in sub-surface water flux. In the sulphate rich levels (312,33; 212,60 and 193,50 m), gypsum and natrojarosite associated with fine quartz sand indicate low salinity to brackish waters, in a low energy setting, under high rate of evaporation. However, detrital feldspar and mica are registered in 312,33 and 198,50 m, indicating at least two minor event of immature terrigenous apport of sediments.

The second group is formed by the samples from 178,50 m upwards, which contain quartz, feldspar and mica/illite as a minor/major constituents. These immature rocks indicate a feldspathic-micaceous source area, close to the depositional setting with a thin or absent weathering cover, indicated also by the kaolinite as a trace constituent.

In rich carbonate levels (157m and 68m) terrigenous sediments – quartz, feldspar and mica – are the major constituents, indicating the probably eo-diagenetic, origin of calcite and dolomite. Associated gypsum probably results of the evaporation of alkaline sub-surface waters within the sediments.



Text-Figure 7: Profile, gama ray, rock description and main constituents identified by XRD present in the samples of the well 1 AS 33 AM (this study).
M: Major constituent; m: minor; tr: trace.



Text-Figure 8: X-ray diffractogram of 24 samples of the well 1 AS 33 AM (this study).

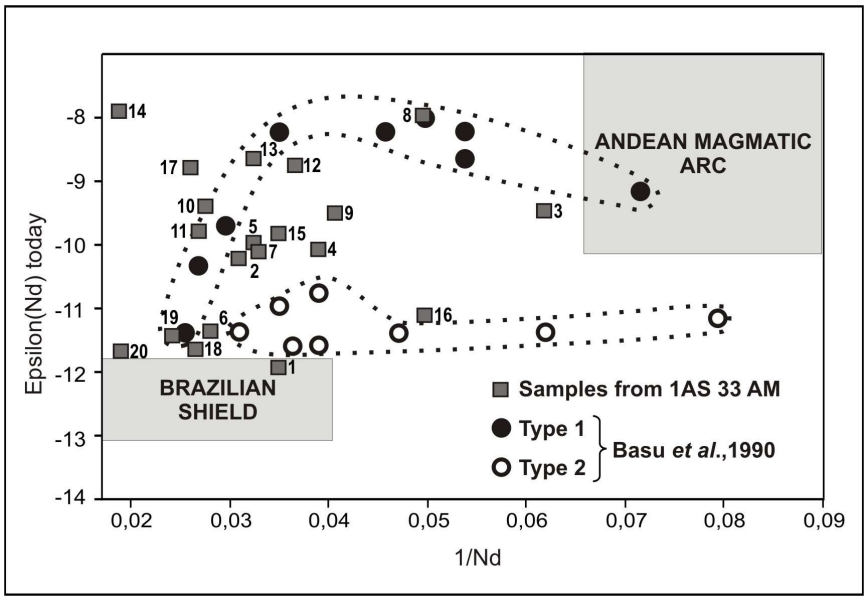
Nd isotopes

According to Basu *et al.* (1990) the main Andean orogeny in the Neogene was accompanied by the development of the subandean fold-thrust belt and continued arc magmatism. This phase was characterized by pluton intrusion and extrusion of associated volcanics. The modern fluvial sediments deposited in the Madre de Dios foreland basin (Peru and Bolivia) are the result of a mechanical mixing of sands proceeding from the metasediments from the fold thrust belt derived from the Brazilian Shield and two distinct volcanic rock suites from the Andes with a mean age of 1,46 Ga, approximately equal to the Brazilian shield. They established a twofold classification of the sands (types 1 and 2) distinguished from each other by the εNd(0) signatures according to the level of contamination of the magmatic arc that originated them. Type 2 sand has an older arc component which is heavily contaminated by Paleozoic sedimentary rocks, and presents isotopic values between -10,70/-11,80. Type 1 shows a less negative signature (-7,26/-10,32) and hence more mantle derived magmatic components.

The samples from the well 1AS 33 AM present εNd(0) values varying from –7.89 to –11.69 and a mean age of 1,45 Ga that correspond in general to the sand types described by Basu *et al.* (1990). These data indicate an Andean provenance for the sediments and an evolution correlated to the Madre de Dios basin. Type 1 is predominant through out the well and type 2 characterizes samples at the base and just three others above (Table 5, Text-Figure 9).

	Sample depth (m)	Sm(ppm)	Nd(ppm)	147Sm/144Nd	143Nd/144Nd ± 2SE	TDM (Ga)	ε(o)	Sand types*
1	10,00	5,499	28,659	0,1160	0,512027+/-13	1,57	-11,92	2
2	32,00	5,615	32,392	0,1048	0,512113+/-7	1,29	-10,23	1
3	45,00	3,323	16,18	0,1241	0,512154+/-6	1,5	-9,45	1
4	60,00	4,998	25,697	0,1176	0,512122+/-12	1,45	-10,06	1
5	75,00	6,032	30,822	0,1183	0,512127+/-6	1,45	-9,97	1
6	85,90	6,938	35,542	0,118	0,512056+/-7	1,56	-11,36	2
7	99,80	5,934	30,314	0,1183	0,512121+/-5	1,46	-10,09	1
8	110,30	3,965	20,209	0,1186	0,512230+/-6	1,29	-7,96	1
9	122,20	4,825	24,568	0,1187	0,512151+/-14	1,42	-9,5	1
10	133,30	7,185	36,371	0,1194	0,512156+/-10	1,42	-9,41	1
11	149,40	7,18	37,186	0,1167	0,512136+/-15	1,42	-9,8	1
12	173,15	5,568	27,348	0,1231	0,512189+/-8	1,42	-8,75	1
13	183,60	6,31	30,787	0,1239	0,512196+/-6	1,43	-8,63	1
14	203,15	12,159	53,143	0,1383	0,512233+/-12	1,62	-7,89	1
15	225,20	5,556	28,67	0,1171	0,512135+/-12	1,42	-9,81	1
16	255,00	3,428	20,136	0,1029	0,512068+/-10	1,33	-11,12	2
17	290,05	7,71	38,499	0,1211	0,512187+/-24	1,4	-8,79	1
18	333,60	6,374	37,680	0,1023	0,512041+/-8	1,36	-11,65	2
19	372,10	7,914	41,352	0,1157	0,512052+/-6	1,53	-11,43	2
20	401,00	10,382	52,438	0,1197	0,512039+/-24	1,61	-11,68	2

Table 4: Data of Sm and Nd isotopes from samples of well 1AS 33 AM (this study).
* The sand types correspond to the twofold classification of Basu *et al.* (1990) for the fluvial sediments of the Madre de Dios basin.



Text-Figure 9: Graphic of the εNd (0) versus the inverted Nd concentrations(modified from Basu *et al*., 1990). The results of the samples from the well 1 AS 33 AM (this study) indicated in gray squares. Also shown the values of Basu *et al*. (1990) for the sand Type 1 (black dots) and Type 2 (white dots) and two possible end-member compositions: the western Brazilian shield and the Andean Magmatic Arc.

These values are also similar to the results presented by Roddaz *et al.* (2005b) for the Pebas and Nauta Formations that crop out above the Iquitos forebulge, making possible a correlation of the stratigraphic units in both areas.

DISCUSSION

Integrating all the results presented in this study it is possible to recognize three phases in the deposition of the sediments of the Solimões Formation in the well 1 AS 33 AM (Text-Figure 10).

▪ **PHASE 1:** Corresponds to the interval between 401 m and 300 m. It is formed by mature rocks resulted of intense sediment reworking from a distant source area, probably with low relief. The type 2 isotopic sand signatures indicate an Andean older source. The age attributed to this interval is early / middle Miocene based in the two palynological biozones identified (Lorente, 1986): Psiladiporites Interval Zone (399,10 – 326,25 m) and Crassoretitriletes Interval Zone (326,25 – 299,05 m). The palynological association (cluster I) is characteristic of alluvial plain. An indication of a possible marine influence can be observed at 399,10; 326,25 and 320,25 m by moderate percentages of elements related to coastal environments.

This phase is supposed to be separated from next by a depositional unconformity, maybe the Ucayali discontinuity (Campbell *et al.*, 2001), caused by the uplift of the Iquitos arch (Roddaz *et al.,* 2005a).

▪ **PHASE 2:** Corresponds to the interval between 300 m and 185 m. The same mature rocks of the base form it. The isotopic signatures indicate a change of source area but still of Andean origin, with predominance of type 1 sand and one type 2 at 255 m. The age of this interval given by two different palynological biozones (Lorente, 1986): Asteraceae Interval Zone (299,05 – 238,33 m) and *Psilatricolporites caribbiensis* Interval Subzone (238,33 – 32,00 m) corresponds to late Miocene / Pliocene. The palynological association II dominates this phase with one temporary environmental change at 232,18 m. The vegetation is typical of fresh water swampy environments but the XRD analysis indicates three levels of brackish water (232,18; 212,60 and 193,50m). Possibly the landscape was altered by the uplift of the forebulge that dammed the water of the drainages and created a favourable environment for the development of this type of vegetation.

▪ **PHASE 3:** Corresponds to the interval from ca.185,00 m to the surface. This last phase is marked by a greater contribution of sands in the profile indicating a change in the deposition dynamics. It is formed by immature rocks resulted of a feldspathic-micaceous source area, close to the depositional setting with a thin or absent weathering cover. The age is probably Pliocene corresponding to the upper part of the Psilatricolporites caribbiensis Interval Subzone (Lorente, 1986). The general palynological association changes constantly (I and II). For the first time at 137,00 and 55,00 m are registered palynological associations typical of lakes, probably ox bow. The intercalated sand beds possibly represent riverbanks of the fluvial system. There is a predominance of type 1 isotopic sand signature with two type 2 values at 85 and 10 m.

According to the paleoenvironmental reconstruction proposed by Roddaz *et al.* (2005b), an orogenic pulse in the Pliocene caused the burying of the forebulge and its later incision by transverse rivers issued from the Andes. This scenario fits with the immature character of the rocks, the thick sand beds, the constant variation of the palynological assemblage and the age assigned to the interval.

Observing the graphics of the paleoenvironment and εNd(0) it is possible to recognize a similar curve that maybe expresses the relation of the vegetation cover with the composition of the soil derived from different source rocks. Wesselingh and Salo (2006) suggest that some floristic patterns reflect edaphic variation related to the Andean foreland tectonics. However in this study this similarity cannot be proved and demands further studies.

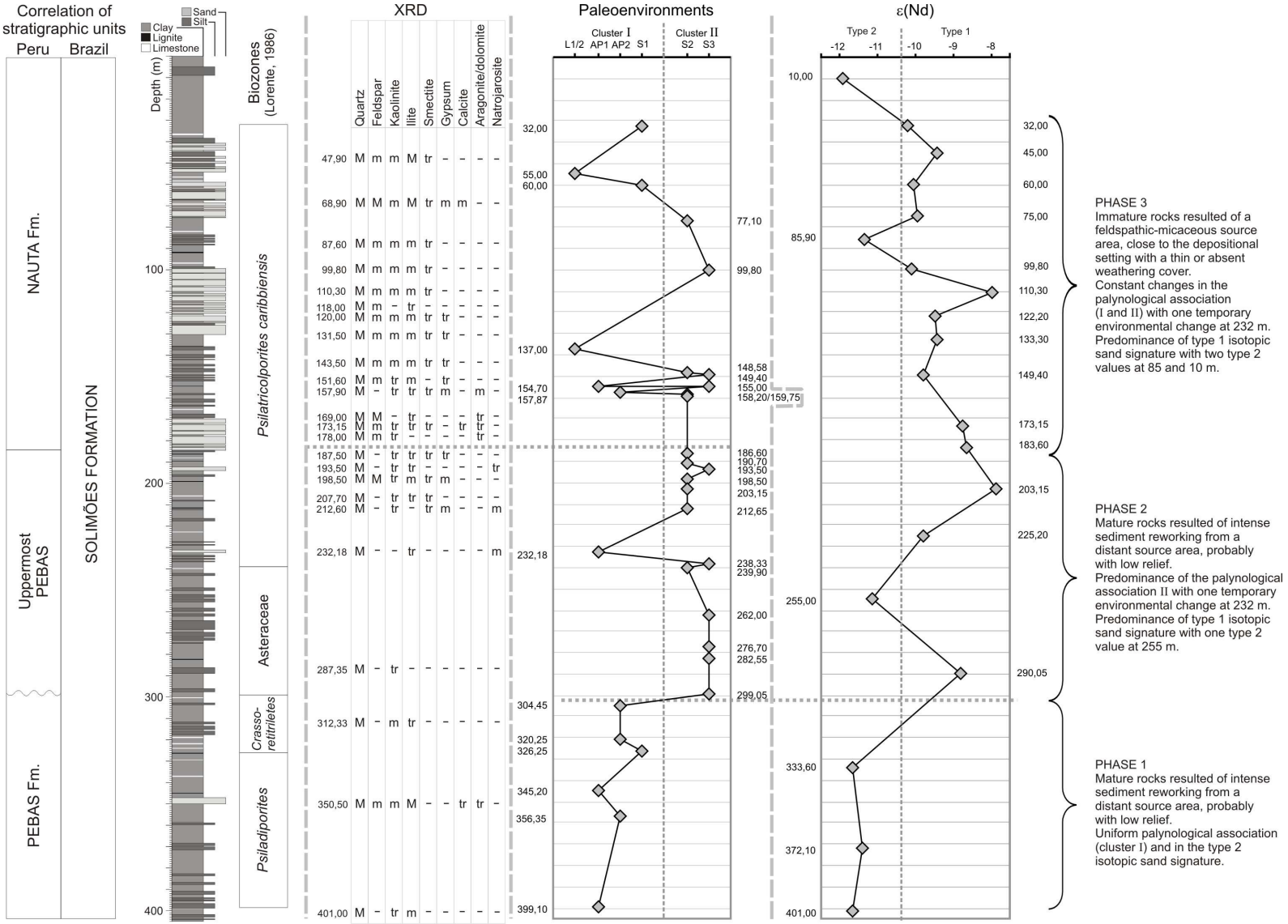
Considering the lithology, depositional environment and approximate age, it is possible to correlate the Solimões Formation in Brazil with the Pebas and Nauta Formations

near the Iquitos arch in Peru (Roddaz *et al.,* 2005ab; Rebata *et al.,* 2006ab), now with the advantage of a biostratigraphic framework that enable a direct dating for the sediments.

The interval between 401 m and 300 m (early / middle Miocene) deposited under a mainly fresh water environment with some marine influence corresponds to the Pebas Formation.

The following interval between 300 m and 185 m corresponds to the 'Uppermost Pebas' Formation. Since the Uppermost Pebas Formation may unconformably overlie the Pebas Formation in Peru (Rebata et al 2006a), it is suggested here that the top of the Pebas Formation in Brazil is younger then it is in Peruvian Amazonia, and thus diachronic. The lower part of the interval (299,05 – 238,33 m) is in the Asteraceae Interval Zone *sensu* Lorente (1986), the same zone assigned to Uppermost Pebas Formation in Peru (Rebata et al 2006a). The upper part (238,33 – 185,00) is in the *Psilatricolporites caribbiensis* Interval Subzone *sensu* Lorente (1986). It was not observed any evidence of discontinuity between both biozones.

The last interval from *ca.*185,00 m to the surface is a typical fluvial system deposit and is correlated here to the Nauta Formation. It is considered Pliocene, corresponding to the upper part of the *Psilatricolporites caribbiensis* Interval Subzone (Lorente, 1986), a younger age than the originally proposed to it (Roddaz *et al.,* 2005a; Rebata *et al.,* 2006b).



Text-Figure 10: Profile of the well 1 AS 33 AM and compound graphic of the results of the different analysis and interpretations.

CONCLUSIONS

The Iquitos arch influenced significantly the landscape since its uplift in the late Miocene and it is possible to verify the forebulge dynamics, originally observed in outcrops, in the sub-surface sediments. Considering the lithology, depositional environment and approximate age, it is possible to correlate the Solimões Formation in Brazil with the Pebas and Nauta Formations near the Iquitos arch in Peru (Roddaz *et al.,* 2005ab; Rebata *et al.,* 2006ab), now with the advantage of a biostratigraphic framework that enable a direct dating for the sediments.

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Further studies are necessary to confirm the present conclusions. The correlation of the several formations described for the restricted basins will depend on the study of more wells drilled in the region.

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Pollen diagram (most abundant)

8. CONCLUSÕES

Os resultados sistemáticos de palinologia da perfuracão 1 AS 33 AM da Formação Solimões consistem em 95 tipos identificados sempre que possível em nível específico. A maioria deles são grãos de pólen de angiospermas com 85 espécies. Apenas uma espécie de gimnosperma foi encontrada e sempre em quantidades reduzidas. De esporos, apesar muito abundantes, somente oito espécies foram identificadas. Oito novas espécies de grãos de pólen são propostas e formalmente descritas: *Fenestrites garciae, Inaperturopollenites microechinatus, Inaperturopollenites elizabetei, Inaperturopollenites solimoensis, Polyadopollenites marileae, Psilaperiporites elizabetei, Psilatricolporites hoornii, Retitricolporites toigoi*.

Reflexos da dinâmica de soerguimento do arco de Iquitos durante o Neomioceno, antes vistos apenas em afloramentos, podem também ser observados em sub-superfície através do estudo de palinologia, mineralogia e geoquímica de isótopos das amostras do poço 1 AS 33 AM. Pôde-se correlacionar a Formação Solimões com as formações Pebas e Nauta da região de Iquitos. Essa correlação possibilita a aplicação direta de um arcabouço palinostratigráfico a essas formações.

O intervalo 401 – 300 m (Mioceno inferior / médio), depositado em ambiente principalmente de água doce com alguma influência marinha, corresponde à Formação Pebas.

O intervalo seguinte 300 – 185 m (Mioceno superior / Plioceno) corresponde à camada superior da Formação Pebas, designada na literatura como 'Uppermost Pebas'. Na seção estudada esta camada recobre discordantemente a Formação Pebas, assim como em algumas localidades no Peru. É sugerido aqui um diacronismo para essa unidade uma vez que a idade atribuída a ela é mais jovem que a descrita na literatura. A porção inferior desse intervalo (299,05 – 238,33 m) está na zona de intervalo Asteraceae e a porção superior (238,33 – 185,00m) está na subzona de intervalo *Psilatricolporites caribbiensis*. Não foi observada nenhuma discordância entre as duas biozonas.

O último intervalo de *ca.* 185 m até a superfície é formado por depósitos típicos de sistema fluvial e é correlacionado aqui com a Formação Nauta. É considerado Plioceno por corresponder à parte superior da subzona de intervalo *Psilatricolporites caribbiensis*, idade mais jovem que a proposta anteriormente.

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ANEXO 1

Tabelas com contagens originais e valores percentuais

Tabelas com contagens originais e valores percentuais

ORIGINAL COUNTINGS

POLLEN GRAINS	32,00	55,00	60,00	77,10	99,80	137,00	148,58	149,40	154,70	155,00	157,87	158,20	159,75
Proxapertites tertiaria	2	1	1	10	2	0	1	3	2	15	3	31	3
Perisyncolporites pokornyi	8	0	2	18	65	2	3	6	11	5	26	24	17
Corsinipollenites oculusnoctis	7	3	7	3	1	0	0	1	0	5	0	4	0
Psilamonocolpites medius	7	0	0	2	3	1	0	3	0	0	2	8	2
Monoporites annulatus	15	0	3	26	2	184	2	1	4	6	23	17	1
Psilatricolporites vanus	7	0	0	2	3	1	17	3	15	3	16	14	14
Mauritiidites franciscoi	0	0	0	3	1	4	24	27	6	1	71	8	32
Retitricolporites sp.1	6	0	3	1	1	0	0	29	44	6	4	10	2
Retitricolporites medius	0	0	0	0	0	0	0	0	2	0	0	0	0
Psilastephanoporites tesseroporus	0	0	0	0	1	0	0	0	0	2	0	0	0
Margocolporites aff. M. vanwijhei	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolpites cf. R. simplex	5	0	1	1	0	0	0	3	11	1	1	5	4
Echitricolporites maristellae	11	0	0	2	0	17	1	7	0	0	0	4	1
Bombacacidites bellus	14	2	10	31	0	1	1	0	0	0	1	3	8
Crototricolpites sp.	53	0	15	12	1	0	0	4	13	0	2	10	5
Crassiectoapertites colombianus	1	0	2	1	0	0	0	0	7	1	0	3	0
Striatricolpites catatumbus	0	0	4	0	41	1	0	1	16	7	2	14	45
Psilatricolporites operculatus	0	0	0	1	0	0	0	0	3	0	8	1	0
Retitricolporites guianensis	2	0	4	3	2	5	0	1	0	0	0	4	1
Psilastephanocolporites aff. P. fissilis	0	0	0	0	0	0	0	1	0	0	0	0	3
Retitricolporites irregularis	2	0	0	0	0	0	0	0	0	0	41	0	0
Perfotricolpites digitatus	2	0	4	5	2	2	0	3	0	0	0	5	0
Inaperturopollenites spp.	0	0	0	0	0	2	2	1	0	0	11	0	3
Syncolporites incomptus	2	0	0	0	0	0	0	0	0	2	0	1	10
Retitricolporites aff. R.magnus	0	0	0	0	1	1	2	0	0	0	0	0	0
Malvacipollis cf. M. spinulosa	0	0	1	0	0	14	0	0	0	0	2	15	0
Multimarginites vanderhammeni	0	0	0	0	1	0	0	0	0	0	0	0	0
Retitricolpites amapaensis	3	0	0	0	0	0	0	0	0	0	0	1	0
Psilatricolpites minutus	1	0	0	0	0	0	0	0	0	0	1	0	0
Retimonocolpites maximus	0	0	0	1	0	0	0	1	0	0	3	0	0
Inaperturopollenites solimoensis	0	0	0	1	3	0	0	0	0	0	6	3	7
Retitricolpites conciliatus	1	0	0	0	0	0	0	0	0	3	0	1	0
Echiperiporites stelae	94	0	43	27	6	15	1	1	5	2	0	8	3
Retistephanoporites crassiannulatus	0	0	0	1	1	0	0	0	4	0	4	0	1
Retitricolporites ticuneorum	0	0	0	0	0	0	0	0	0	0	2	0	0
Bombacacidites baculatus	0	0	0	2	15	0	2	0	0	0	0	0	0
Echitriporites sp.	0	4	0	0	0	4	0	0	0	0	0	0	0
Podocarpidites sp.	0	0	0	0	0	0	0	0	0	2	1	0	0
Retitricolporites cf. R. perpusillus	3	0	0	0	0	0	0	0	0	0	0	1	0
Myrtaceidites spp.	1	0	2	0	0	0	0	4	5	0	0	0	0
Heterocolpites incomptus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retibrevitricolpites cf. R. catatumbus	0	0	0	0	0	0	5	0	0	0	10	0	0
Retitricolpites perforatus	0	0	0	0	1	1	2	0	0	0	0	0	0
Psiladiporites minimus	0	0	0	0	0	0	0	0	1	0	3	0	0
Echitricolporites spinosus	2	0	0	0	4	8	0	2	0	0	0	3	1
Psilatricolporites hoornii	0	0	0	1	3	0	0	0	0	0	1	0	1
Fenestrites garciae	0	0	0	0	0	2	0	0	0	0	0	0	0
Polyadopollenites mariae	1	0	0	0	0	2	0	0	0	0	0	0	0
Inaperturopollenites elizabetei	0	0	0	1	0	0	0	1	0	0	0	1	0
Costatricolporites reticulatus	1	0	0	3	0	0	0	0	0	0	0	2	0
Verrutricolporites sp.	2	0	0	0	0	3	0	6	2	0	0	0	0
Fenestrites spinosus	1	0	0	1	0	2	0	3	0	0	0	0	0
Margocolporites vanwijhei	1	0	0	1	0	0	0	0	0	1	0	0	0
Psilatricolporites labiatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retibrevitricolporites speciosus	1	0	0	0	4	0	2	0	0	1	1	6	6

POLLEN GRAINS	32,00	55,00	60,00	77,10	99,80	137,00	148,58	149,40	154,70	155,00	157,87	158,20	159,75
Retitricolporites hispidus	2	0	0	1	0	0	0	0	8	0	0	6	0
Psilatricolporites silvaticus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitriporites dubiosus	0	0	0	0	8	0	0	2	2	0	0	0	1
Scabratricolporites planetensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites toigoi	0	0	0	4	3	0	0	0	1	4	1	0	0
Grimsdalea magnaclavata	5	1	34	86	37	7	42	135	8	9	2	26	55
Polyadopollenites marileae	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilastephanocolporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites finitus	0	0	0	0	2	0	0	1	3	0	0	0	2
Ilexpollenites sp.	0	0	0	1	1	0	2	0	0	0	0	0	0
Monoporites annuloides	0	0	0	1	0	0	0	0	0	1	0	1	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	0	0	0	0	0	0	0	0	0
Proteacidites triangulatus	0	0	0	1	0	0	0	0	0	0	0	0	1
Foveotricolporites caldensis	0	0	0	0	0	0	2	0	0	4	1	0	0
Rugotricolporite arcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites sp.2	0	0	1	1	1	0	0	0	2	0	3	0	2
Echitricolporites sp.	0	0	0	0	0	0	0	5	0	0	2	0	1
Retitricolporites squarrosus	0	0	0	0	1	0	0	0	9	0	0	0	0
Inaperturopollenites microechinatus	2	0	0	2	0	0	1	6	0	8	0	6	2
Jandufouria seamrogiformis	0	0	0	0	0	0	0	0	0	0	0	0	0
Multiareolites formosus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilaperiporites sp.	1	0	3	9	24	1	0	3	0	0	0	1	5
Foveotricolporites florschutzi	3	0	1	0	3	4	0	18	41	4	0	0	6
Retitricolporites sp.3	0	0	0	1	12	0	0	0	26	4	0	1	8
Striatricolpites tenuissimus	1	0	0	5	1	0	0	2	19	0	3	0	0
Retitricolpites florentinus	0	0	0	0	3	0	0	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	0	0	1	0	0	0	0	1	0	1	0	0
Striatricolporites digitatus	3	0	0	0	0	0	1	0	4	1	0	9	2
Psilatricolporites sp.	0	0	0	0	4	0	0	0	0	0	2	7	0
Indeterminate angiosperm	36	6	11	32	39	18	8	45	27	8	41	38	48
POLLEN SUM	**309**	**17**	**152**	**305**	**303**	**302**	**121**	**329**	**302**	**106**	**301**	**302**	**303**
SPORES													
Deltoidospora adriennis	34	9	37	4	52	3	4	30	0	7	3	6	15
Magnastriatites grandiosus	74	86	28	32	24	4	2	89	1	0	33	10	14
Laevigatosporites spp.	4	2	13	126	626	16	32	2025	22	380	77	115	70
Verrucatosporites spp.	1	2	13	39	54	13	21	567	9	37	32	48	36
Echitriletes muellerii	0	0	1	0	0	0	0	0	0	0	0	2	0
Perinomonoletes sp.	4	0	1	0	3	3	2	0	0	0	10	1	0
Polypodiaceoisporites potoniei	0	1	0	7	2	0	0	0	0	1	0	0	1
Crassoretitriletes vanraadshoovenii	2	0	3	4	2	0	4	0	0	1	15	1	1
SPORE SUM	**119**	**100**	**96**	**212**	**763**	**39**	**65**	**2711**	**32**	**426**	**170**	**183**	**137**
OTHERS													
Dinoflagelate	0	0	0	0	0	0	0	0	1	0	0	0	0
Steevipollenites sp.	0	1	0	0	0	0	0	0	0	0	0	0	0
Pediastum sp.	0	284	0	0	0	0	0	0	0	0	0	0	0
TOTAL SUM	**428**	**401**	**248**	**517**	**1066**	**341**	**186**	**3040**	**334**	**532**	**471**	**485**	**440**
SPORE %	**27,8**	**24,9**	**38,7**	**41**	**71,6**	**11,4**	**34,9**	**89,2**	**9,58**	**80,1**	**36,1**	**37,7**	**31,1**
POLLEN %	**72,2**	**4,24**	**61,3**	**59**	**28,4**	**88,6**	**65,1**	**10,8**	**90,4**	**19,9**	**63,9**	**62,3**	**68,9**
EXOTIC POLLEN	**111**	**300**	**300**	**217**	**72**	**295**	**130**	**49**	**78**	**195**	**77**	**671**	**37**

ORIGINAL COUNTINGS (continued)

POLLEN GRAINS	186,60	190,70	193,50	198,50	203,15	212,65	232,18	238,33	239,90	262,00	276,70	282,55	299,05
Proxapertites tertiaria	6	24	8	3	23	7	1	1	8	1	18	7	21
Perisyncolporites pokornyi	9	38	3	22	0	4	7	14	30	0	21	10	11
Corsinipollenites oculusnoctis	2	3	3	1	4	2	0	1	2	1	16	4	5
Psilamonocolpites medius	42	4	8	4	26	25	13	3	0	0	0	4	1
Monoporites annulatus	9	0	5	2	5	4	4	1	3	4	0	3	0
Psilatricolporites vanus	5	6	13	21	3	25	61	18	2	0	5	27	0
Mauritiidites franciscoi	2	0	5	8	17	18	3	42	23	46	2	37	119
Retitricolporites sp.1	0	0	3	3	3	6	9	5	0	0	1	7	0
Retitricolporites medius	4	0	0	6	0	0	1	2	0	0	2	0	0
Psilastephanoporites tesseroporus	0	0	0	0	0	0	0	0	0	0	0	0	0
Margocolporites aff. M. vanwijhei	0	1	0	0	0	0	7	0	0	0	0	1	4
Retitricolpites cf. R. simplex	1	4	10	4	1	7	22	13	3	1	13	9	3
Echitricolporites maristellae	1	4	0	0	0	1	0	0	0	2	26	0	2
Bombacacidites bellus	14	40	18	8	10	45	6	7	6	0	12	88	1
Crototricolpites sp.	1	1	7	2	1	0	4	5	1	17	9	24	88
Crassiectoapertites colombianus	1	2	0	1	0	0	2	1	0	1	3	0	6
Striatricolpites catatumbus	17	3	24	13	0	2	3	13	5	2	2	0	0
Psilatricolporites operculatus	2	0	0	11	0	0	2	6	0	0	0	0	4
Retitricolporites guianensis	1	0	0	1	1	3	2	1	0	0	1	0	0
Psilastephanocolporites aff. P. fissilis	1	1	0	1	0	1	0	0	1	0	1	0	0
Retitricolporites irregularis	1	0	1	0	0	11	2	2	1	200	1	0	0
Perfotricolpites digitatus	1	4	5	0	7	0	2	8	0	0	4	0	1
Inaperturopollenites spp.	5	6	11	5	11	2	0	3	1	0	5	0	5
Syncolporites incomptus	1	0	1	4	1	0	0	0	0	0	2	1	0
Retitricolporites aff. R.magnus	0	0	0	0	0	0	0	0	1	0	1	0	0
Malvacipollis cf. M. spinulosa	1	0	1	1	1	2	3	3	0	2	0	0	0
Multimarginites vanderhammeni	0	0	1	0	0	0	4	0	0	0	0	0	0
Retitricolpites amapaensis	0	0	1	0	0	0	1	0	0	0	0	0	0
Psilatricolpites minutus	1	1	11	1	0	0	1	1	1	0	17	22	0
Retimonocolpites maximus	7	0	0	0	0	0	1	2	4	1	1	6	0
Inaperturopollenites solimoensis	0	7	26	8	1	2	1	14	1	0	8	10	0
Retitricolpites conciliatus	2	0	5	0	14	0	3	0	0	0	0	0	0
Echiperiporites stelae	2	2	3	0	9	4	10	3	0	1	25	3	3
Retistephanoporites crassiannulatus	0	2	7	1	1	0	0	4	7	1	0	4	1
Retitricolporites ticuneorum	2	0	0	2	0	0	0	1	0	0	0	0	0
Bombacacidites baculatus	1	0	0	2	0	0	0	4	50	0	0	0	0
Echitriporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Podocarpidites sp.	0	0	1	0	0	0	0	0	0	0	1	0	0
Retitricolporites cf. R. perpusillus	6	0	0	4	0	0	0	0	0	0	1	0	0
Myrtaceidites spp.	0	0	0	1	0	0	1	1	0	0	0	2	1
Heterocolpites incomptus	0	0	0	1	0	0	1	2	0	0	4	0	0
Retibrevitricolpites cf. R. catatumbus	0	0	0	5	0	0	0	5	0	2	0	0	0
Retitricolpites perforatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psiladiporites minimus	0	0	0	0	0	0	0	0	0	0	0	0	0
Echitricolporites spinosus	1	6	4	0	1	0	1	6	0	32	13	0	6
Psilatricolporites hoornii	0	3	1	0	3	0	0	1	0	0	1	0	6
Fenestrites garciae	1	0	0	0	0	0	0	1	0	0	1	0	1
Polyadopollenites mariae	0	1	0	0	0	0	5	0	0	0	0	0	1
Inaperturopollenites elizabetei	0	0	2	0	0	2	2	0	2	2	8	6	0
Costatricolporites reticulatus	1	0	2	5	0	1	1	3	0	0	1	2	0
Verrutricolporites sp.	0	0	0	0	0	0	0	0	0	0	0	2	0
Fenestrites spinosus	0	0	0	0	0	0	0	1	0	2	1	0	0
Margocolporites vanwijhei	0	0	0	0	0	0	0	0	1	0	1	0	0
Psilatricolporites labiatus	5	0	0	5	0	0	0	1	1	0	2	0	0
Retibrevitricolporites speciosus	1	0	5	4	0	0	1	1	0	0	20	0	0

ORIGINAL COUNTINGS (continued)

POLLEN GRAINS	186,60	190,70	193,50	198,50	203,15	212,65	232,18	238,33	239,90	262,00	276,70	282,55	299,05
Retitricolporites hispidus	0	0	2	8	0	0	0	1	0	0	1	0	0
Psilatricolporites silvaticus	4	0	0	4	0	0	0	8	0	0	7	0	0
Retitriporites dubiosus	1	1	8	0	1	0	0	1	0	0	1	0	0
Scabratricolporites planetensis	0	0	1	0	0	0	0	1	0	0	10	0	0
Retitricolporites toigoi	0	0	0	0	0	0	0	0	0	0	1	0	0
Grimsdalea magnaclavata	77	82	19	46	44	55	4	26	120	0	0	0	0
Polyadopollenites marileae	0	0	0	0	0	0	9	1	2	0	0	0	0
Psilastephanocolporites sp.	0	0	0	2	0	0	1	0	5	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0	3	1	0	0	0	0	0
Retitricolporites finitus	0	0	2	0	0	0	3	8	0	0	0	0	0
Ilexpollenites sp.	0	0	0	0	0	1	0	1	0	0	0	0	0
Monoporites annuloides	1	3	2	0	60	0	0	1	0	0	0	0	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	4	1	0	3	0	0	0	0	0
Proteacidites triangulatus	0	0	2	2	0	2	0	2	0	0	0	0	0
Foveotricolporites caldensis	0	0	0	0	0	25	1	0	0	0	0	0	0
Rugotricolporite arcus	0	5	0	0	0	3	3	0	0	0	0	0	0
Retitricolporites sp.2	0	2	0	0	0	0	19	0	0	0	0	0	0
Echitricolporites sp.	1	0	0	0	0	0	4	0	0	0	0	0	0
Retitricolporites squarrosus	0	0	0	0	0	0	3	0	0	0	0	0	0
Inaperturopollenites microechinatus	1	5	1	2	16	4	0	0	0	0	0	0	0
Jandufouria seamrogiformis	3	0	0	1	0	1	0	0	0	0	0	0	0
Multiareolites formosus	0	1	0	0	1	0	0	0	0	0	0	0	0
Psilaperiporites sp.	0	0	0	4	0	0	0	0	0	0	0	0	0
Foveotricolporites florschutzi	0	1	6	0	0	0	0	0	0	0	0	0	0
Retitricolporites sp.3	0	3	14	0	0	0	0	0	0	0	0	0	0
Striatricolpites tenuissimus	0	0	2	0	0	0	0	0	0	0	0	0	0
Retitricolpites florentinus	0	0	7	0	0	0	0	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	1	0	0	0	0	0	0	0	0	0	0	0
Striatricolporites digitatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilatricolporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate angiosperm	63	33	40	79	32	36	63	62	42	31	44	45	27
POLLEN SUM	**308**	**300**	**301**	**308**	**301**	**302**	**300**	**316**	**323**	**349**	**314**	**324**	**317**
SPORES													
Deltoidospora adriennis	85	66	30	11	0	7	4	17	13	3	22	56	11
Magnastriatites grandiosus	7	74	24	3	2	3	1	3	6	15	18	19	29
Laevigatosporites spp.	277	97	432	89	59	138	41	583	195	588	1638	1441	1700
Verrucatosporites spp.	141	8	47	42	1	11	11	100	34	153	59	300	460
Echitriletes muellerii	0	0	1	0	0	0	20	0	2	0	0	0	8
Perinomonoletes sp.	0	1	0	0	0	4	81	4	0	0	0	0	0
Polypodiaceoisporites potoniei	0	1	2	1	0	5	0	3	1	4	0	0	13
Crassoretitriletes vanraadshoovenii	7	4	1	0	2	14	2	10	0	23	52	188	94
SPORE SUM	**517**	**251**	**537**	**146**	**64**	**182**	**160**	**720**	**251**	**786**	**1789**	**2004**	**2315**
OTHERS													
Dinoflagelate	0	0	0	0	0	0	0	0	0	0	0	0	0
Steevipollenites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL SUM	**825**	**551**	**838**	**454**	**365**	**484**	**460**	**1036**	**574**	**1135**	**2103**	**2328**	**2632**
SPORE %	**62,7**	**45,6**	**64,1**	**32,2**	**17,5**	**37,6**	**34,8**	**69,5**	**43,7**	**69,3**	**85,1**	**86,1**	**88**
POLLEN %	**37,3**	**54,4**	**35,9**	**67,8**	**82,5**	**62,4**	**65,2**	**30,5**	**56,3**	**30,7**	**14,9**	**13,9**	**12**
EXOTIC POLLEN	**9**	**122**	**0**	**11**	**71**	**0**	**197**	**28**	**364**	**34**	**3**	**6**	**26**

ORIGINAL COUNTINGS (continued)

POLLEN GRAINS	304,45	320,25	326,25	345,20	356,35	399,10
Proxapertites tertiaria	1	3	12	1	4	2
Perisyncolporites pokornyi	45	39	14	1	7	1
Corsinipollenites oculusnoctis	1	0	3	1	2	1
Psilamonocolpites medius	3	3	2	7	14	7
Monoporites annulatus	3	1	0	6	4	4
Psilatricolporites vanus	12	5	0	3	1	10
Mauritiidites franciscoi	84	146	13	0	267	8
Retitricolporites sp.1	0	0	0	0	3	1
Retitricolporites medius	0	0	0	0	1	1
Psilastephanoporites tesseroporus	0	0	0	0	2	2
Margocolporites aff. M. vanwijhei	0	1	0	1	0	4
Retitricolpites cf. R. simplex	1	0	0	47	0	121
Echitricolporites maristellae	0	0	0	1	0	21
Bombacacidites bellus	0	3	5	0	0	2
Crototricolpites sp.	0	17	22	0	0	4
Crassiectoapertites colombianus	0	1	0	0	0	2
Striatricolpites catatumbus	1	2	0	0	0	1
Psilatricolporites operculatus	0	2	0	0	0	7
Retitricolporites guianensis	0	4	0	0	0	5
Psilastephanocolporites aff. P. fissilis	2	0	0	0	0	3
Retitricolporites irregularis	1	0	0	0	0	3
Perfotricolpites digitatus	0	0	0	0	0	2
Inaperturopollenites spp.	0	0	0	0	0	9
Syncolporites incomptus	0	0	0	0	0	1
Retitricolporites aff. R.magnus	0	0	0	0	0	9
Malvacipollis cf. M. spinulosa	0	0	0	0	0	21
Multimarginites vanderhammeni	0	0	0	0	0	1
Retitricolpites amapaensis	0	0	0	0	0	3
Psilatricolpites minutus	20	2	14	4	1	0
Retimonocolpites maximus	7	3	2	7	8	0
Inaperturopollenites solimoensis	15	0	0	0	4	0
Retitricolpites conciliatus	0	0	0	1	0	0
Echiperiporites stelae	0	2	1	0	0	0
Retistephanoporites crassiannulatus	2	0	2	0	0	0
Retitricolporites ticuneorum	1	1	0	0	0	0
Bombacacidites baculatus	0	6	0	0	0	0
Echitriporites sp.	0	1	0	0	0	0
Podocarpidites sp.	0	1	0	0	0	0
Retitricolporites cf. R. perpusillus	0	1	0	0	0	0
Myrtaceidites spp.	2	0	0	0	0	0
Heterocolpites incomptus	1	0	0	0	0	0
Retibrevitricolpites cf. R. catatumbus	3	0	0	0	0	0
Retitricolpites perforatus	2	0	0	0	0	0
Psiladiporites minimus	53	0	0	0	0	0
Echitricolporites spinosus	0	0	0	0	0	0
Psilatricolporites hoornii	0	0	0	0	0	0
Fenestrites garciae	0	0	0	0	0	0
Polyadopollenites mariae	0	0	0	0	0	0
Inaperturopollenites elizabetei	0	0	0	0	0	0
Costatricolporites reticulatus	0	0	0	0	0	0
Verrutricolporites sp.	0	0	0	0	0	0
Fenestrites spinosus	0	0	0	0	0	0
Margocolporites vanwijhei	0	0	0	0	0	0
Psilatricolporites labiatus	0	0	0	0	0	0
Retibrevitricolporites speciosus	0	0	0	0	0	0

ORIGINAL COUNTINGS (continued)

POLLEN GRAINS	304,45	320,25	326,25	345,20	356,35	399,10
Retitricolporites hispidus	0	0	0	0	0	0
Psilatricolporites silvaticus	0	0	0	0	0	0
Retitriporites dubiosus	0	0	0	0	0	0
Scabratricolporites planetensis	0	0	0	0	0	0
Retitricolporites toigoi	0	0	0	0	0	0
Grimsdalea magnaclavata	0	0	0	0	0	0
Polyadopollenites marileae	0	0	0	0	0	0
Psilastephanocolporites sp.	0	0	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0
Retitricolporites finitus	0	0	0	0	0	0
Ilexpollenites sp.	0	0	0	0	0	0
Monoporites annuloides	0	0	0	0	0	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	0	0
Proteacidites triangulatus	0	0	0	0	0	0
Foveotricolporites caldensis	0	0	0	0	0	0
Rugotricolporite arcus	0	0	0	0	0	0
Retitricolporites sp.2	0	0	0	0	0	0
Echitricolporites sp.	0	0	0	0	0	0
Retitricolporites squarrosus	0	0	0	0	0	0
Inaperturopollenites microechinatus	0	0	0	0	0	0
Jandufouria seamrogiformis	0	0	0	0	0	0
Multiareolites formosus	0	0	0	0	0	0
Psilaperiporites sp.	0	0	0	0	0	0
Foveotricolporites florschutzi	0	0	0	0	0	0
Retitricolporites sp.3	0	0	0	0	0	0
Striatricolpites tenuissimus	0	0	0	0	0	0
Retitricolpites florentinus	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	0	0	0	0	0
Striatricolporites digitatus	0	0	0	0	0	0
Psilatricolporites sp.	0	0	0	0	0	0
Indeterminate angiosperm	43	56	15	20	14	61
POLLEN SUM	**303**	**300**	**105**	**100**	**332**	**317**
SPORES						
Deltoidospora adriennis	66	5	138	0	5	2
Magnastriatites grandiosus	2	18	49	2	10	87
Laevigatosporites spp.	55	47	36	55	290	32
Verrucatosporites spp.	25	352	12	0	58	7
Echitriletes muellerii	0	0	0	0	0	3
Perinomonoletes sp.	0	0	0	0	0	1
Polypodiaceoisporites potoniei	0	2	0	15	0	0
Crassoretitriletes vanraadshoovenii	17	26	211	0	0	0
SPORE SUM	**165**	**450**	**446**	**72**	**363**	**132**
OTHERS						
Dinoflagelate	0	0	0	0	0	0
Steevipollenites sp.	0	0	0	0	0	0
Pediastum sp.	0	0	0	0	0	0
TOTAL SUM	**468**	**750**	**551**	**172**	**695**	**449**
SPORE %	**35,3**	**60**	**80,9**	**41,9**	**52,2**	**29,4**
POLLEN %	**64,7**	**40**	**19,1**	**58,1**	**47,8**	**70,6**
EXOTIC POLLEN	**30**	**214**	**22**	**121**	**114**	**192**

PERCENTAGE RELATED TO THE TOTAL SUM

POLLEN GRAINS	32,00	55,00	60,00	77,10	99,80	137,00	148,58	149,40	154,70	155,00	157,87	158,20	159,75
Proxapertites tertiaria	0,47	0,25	0,4	1,93	0,19	0	0,54	0,1	0,6	2,82	0,64	6,39	0,68
Perisyncolporites pokornyi	1,87	0	0,81	3,48	6,1	0,59	1,61	0,2	3,29	0,94	5,52	4,95	3,86
Corsinipollenites oculusnoctis	1,64	0,75	2,82	0,58	0,09	0	0	0,03	0	0,94	0	0,82	0
Psilamonocolpites medius	1,64	0	0	0,39	0,28	0,29	0	0,1	0	0	0,42	1,65	0,45
Monoporites annulatus	3,5	0	1,21	5,03	0,19	54	1,08	0,03	1,2	1,13	4,88	3,51	0,23
Psilatricolporites vanus	1,64	0	0	0,39	0,28	0,29	9,14	0,1	4,49	0,56	3,4	2,89	3,18
Mauritiidites franciscoi	0	0	0	0,58	0,09	1,17	12,9	0,89	1,8	0,19	15,1	1,65	7,27
Retitricolporites sp.1	1,4	0	1,21	0,19	0,09	0	0	0,95	13,2	1,13	0,85	2,06	0,45
Retitricolporites medius	0	0	0	0	0	0	0	0	0,6	0	0	0	0
Psilastephanoporites tesseroporus	0	0	0	0	0,09	0	0	0	0	0,38	0	0	0
Margocolporites aff. M. vanwijhei	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolpites cf. R. simplex	1,17	0	0,4	0,19	0	0	0	0,1	3,29	0,19	0,21	1,03	0,91
Echitricolporites maristellae	2,57	0	0	0,39	0	4,99	0,54	0,23	0	0	0	0,82	0,23
Bombacacidites bellus	3,27	0,5	4,03	6	0	0,29	0,54	0	0	0	0,21	0,62	1,82
Crototricolpites sp.	12,4	0	6,05	2,32	0,09	0	0	0,13	3,89	0	0,42	2,06	1,14
Crassiectoapertites colombianus	0,23	0	0,81	0,19	0	0	0	0	2,1	0,19	0	0,62	0
Striatricolpites catatumbus	0	0	1,61	0	3,85	0,29	0	0,03	4,79	1,32	0,42	2,89	10,2
Psilatricolporites operculatus	0	0	0	0,19	0	0	0	0	0,9	0	1,7	0,21	0
Retitricolporites guianensis	0,47	0	1,61	0,58	0,19	1,47	0	0,03	0	0	0	0,82	0,23
Psilastephanocolporites aff. P. fissilis	0	0	0	0	0	0	0	0,03	0	0	0	0	0,68
Retitricolporites irregularis	0,47	0	0	0	0	0	0	0	0	0	8,7	0	0
Perfotricolpites digitatus	0,47	0	1,61	0,97	0,19	0,59	0	0,1	0	0	0	1,03	0
Inaperturopollenites spp.	0	0	0	0	0	0,59	1,08	0,03	0	0	2,34	0	0,68
Syncolporites incomptus	0,47	0	0	0	0	0	0	0	0	0,38	0	0,21	2,27
Retitricolporites aff. R.magnus	0	0	0	0	0,09	0,29	1,08	0	0	0	0	0	0
Malvacipollis cf. M. spinulosa	0	0	0,4	0	0	4,11	0	0	0	0	0,42	3,09	0
Multimarginites vanderhammeni	0	0	0	0	0,09	0	0	0	0	0	0	0	0
Retitricolpites amapaensis	0,7	0	0	0	0	0	0	0	0	0	0	0,21	0
Psilatricolpites minutus	0,23	0	0	0	0	0	0	0	0	0	0,21	0	0
Retimonocolpites maximus	0	0	0	0,19	0	0	0	0,03	0	0	0,64	0	0
Inaperturopollenites solimoensis	0	0	0	0,19	0,28	0	0	0	0	0	1,27	0,62	1,59
Retitricolpites conciliatus	0,23	0	0	0	0	0	0	0	0	0,56	0	0,21	0
Echiperiporites stelae	22	0	17,3	5,22	0,56	4,4	0,54	0,03	1,5	0,38	0	1,65	0,68
Retistephanoporites crassiannulatus	0	0	0	0,19	0,09	0	0	0	1,2	0	0,85	0	0,23
Retitricolporites ticuneorum	0	0	0	0	0	0	0	0	0	0	0,42	0	0
Bombacacidites baculatus	0	0	0	0,39	1,41	0	1,08	0	0	0	0	0	0
Echitriporites sp.	0	1	0	0	0	1,17	0	0	0	0	0	0	0
Podocarpidites sp.	0	0	0	0	0	0	0	0	0	0,38	0,21	0	0
Retitricolporites cf. R. perpusillus	0,7	0	0	0	0	0	0	0	0	0	0	0,21	0
Myrtaceidites spp.	0,23	0	0,81	0	0	0	0	0,13	1,5	0	0	0	0
Heterocolpites incomptus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retibrevitricolpites cf. R. catatumbus	0	0	0	0	0	0	2,69	0	0	0	2,12	0	0
Retitricolpites perforatus	0	0	0	0	0,09	0,29	1,08	0	0	0	0	0	0
Psiladiporites minimus	0	0	0	0	0	0	0	0	0,3	0	0,64	0	0
Echitricolporites spinosus	0,47	0	0	0	0,38	2,35	0	0,07	0	0	0	0,62	0,23
Psilatricolporites hoornii	0	0	0	0,19	0,28	0	0	0	0	0	0,21	0	0,23
Fenestrites garciae	0	0	0	0	0	0,59	0	0	0	0	0	0	0
Polyadopollenites mariae	0,23	0	0	0	0	0,59	0	0	0	0	0	0	0
Inaperturopollenites elizabetei	0	0	0	0,19	0	0	0	0,03	0	0	0	0,21	0
Costatricolporites reticulatus	0,23	0	0	0,58	0	0	0	0	0	0	0	0,41	0
Verrutricolporites sp.	0,47	0	0	0	0	0,88	0	0,2	0,6	0	0	0	0
Fenestrites spinosus	0,23	0	0	0,19	0	0,59	0	0,1	0	0	0	0	0
Margocolporites vanwijhei	0,23	0	0	0,19	0	0	0	0	0	0,19	0	0	0
Psilatricolporites labiatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retibrevitricolporites speciosus	0,23	0	0	0	0,38	0	1,08	0	0	0,19	0,21	1,24	1,36

PERCENTAGE RELATED TO THE TOTAL SUM (continued)

POLLEN GRAINS	32,00	55,00	60,00	77,10	99,80	137,00	148,58	149,40	154,70	155,00	157,87	158,20	159,75
Retitricolporites hispidus	0,47	0	0	0,19	0	0	0	0	2,4	0	0	1,24	0
Psilatricolporites silvaticus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitriporites dubiosus	0	0	0	0	0,75	0	0	0,07	0,6	0	0	0	0,23
Scabratricolporites planetensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites toigoi	0	0	0	0,77	0,28	0	0	0	0,3	0,75	0,21	0	0
Grimsdalea magnaclavata	1,17	0,25	13,7	16,6	3,47	2,05	22,6	4,44	2,4	1,69	0,42	5,36	12,5
Polyadopollenites marileae	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilastephanocolporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites finitus	0	0	0	0	0,19	0	0	0,03	0,9	0	0	0	0,45
Ilexpollenites sp.	0	0	0	0,19	0,09	0	1,08	0	0	0	0	0	0
Monoporites annuloides	0	0	0	0,19	0	0	0	0	0	0,19	0	0,21	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	0	0	0	0	0	0	0	0	0
Proteacidites triangulatus	0	0	0	0,19	0	0	0	0	0	0	0	0	0,23
Foveotricolporites caldensis	0	0	0	0	0	0	1,08	0	0	0,75	0,21	0	0
Rugotricolporite arcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitricolporites sp.2	0	0	0,4	0,19	0,09	0	0	0	0,6	0	0,64	0	0,45
Echitricolporites sp.	0	0	0	0	0	0	0	0,16	0	0	0,42	0	0,23
Retitricolporites squarrosus	0	0	0	0	0,09	0	0	0	2,69	0	0	0	0
Inaperturopollenites microechinatus	0,47	0	0	0,39	0	0	0,54	0,2	0	1,5	0	1,24	0,45
Jandufouria seamrogiformis	0	0	0	0	0	0	0	0	0	0	0	0	0
Multiareolites formosus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilaperiporites sp.	0,23	0	1,21	1,74	2,25	0,29	0	0,1	0	0	0	0,21	1,14
Foveotricolporites florschutzi	0,7	0	0,4	0	0,28	1,17	0	0,59	12,3	0,75	0	0	1,36
Retitricolporites sp.3	0	0	0	0,19	1,13	0	0	0	7,78	0,75	0	0,21	1,82
Striatricolpites tenuissimus	0,23	0	0	0,97	0,09	0	0	0,07	5,69	0	0,64	0	0
Retitricolpites florentinus	0	0	0	0	0,28	0	0	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	0	0	0,19	0	0	0	0	0,3	0	0,21	0	0
Striatricolporites digitatus	0,7	0	0	0	0	0	0,54	0	1,2	0,19	0	1,86	0,45
Psilatricolporites sp.	0	0	0	0	0,38	0	0	0	0	0	0,42	1,44	0
Indeterminate angiosperm	8,41	1,5	4,44	6,19	3,66	5,28	4,3	1,48	8,08	1,5	8,7	7,84	10,9
POLLEN SUM	**309**	**17**	**152**	**305**	**303**	**302**	**121**	**329**	**302**	**106**	**301**	**302**	**303**
SPORES													
Deltoidospora adriennis	7,94	2,24	14,9	0,77	4,88	0,88	2,15	0,99	0	1,32	0,64	1,24	3,41
Magnastriatites grandiosus	17,3	21,4	11,3	6,19	2,25	1,17	1,08	2,93	0,3	0	7,01	2,06	3,18
Laevigatosporites spp.	0,93	0,5	5,24	24,4	58,7	4,69	17,2	66,6	6,59	71,4	16,3	23,7	15,9
Verrucatosporites spp.	0,23	0,5	5,24	7,54	5,07	3,81	11,3	18,7	2,69	6,95	6,79	9,9	8,18
Echitriletes muellerii	0	0	0,4	0	0	0	0	0	0	0	0	0,41	0
Perinomonoletes sp.	0,93	0	0,4	0	0,28	0,88	1,08	0	0	0	2,12	0,21	0
Polypodiaceoisporites potoniei	0	0,25	0	1,35	0,19	0	0	0	0	0,19	0	0	0,23
Crassoretitriletes vanraadshoovenii	0,47	0	1,21	0,77	0,19	0	2,15	0	0	0,19	3,18	0,21	0,23
SPORE SUM	**119**	**100**	**96**	**212**	**763**	**39**	**65**	**2711**	**32**	**426**	**170**	**183**	**137**
OTHERS													
Dinoflagelate	0	0	0	0	0	0	0	0	0,3	0	0	0	0
Steevipollenites sp.	0	0,25	0	0	0	0	0	0	0	0	0	0	0
Pediastum sp.	0	70,8	0	0	0	0	0	0	0	0	0	0	0
TOTAL SUM	**428**	**401**	**248**	**517**	**1066**	**341**	**186**	**3040**	**334**	**532**	**471**	**485**	**440**
SPORE %	**27,8**	**24,9**	**38,7**	**41**	**71,6**	**11,4**	**34,9**	**89,2**	**9,58**	**80,1**	**36,1**	**37,7**	**31,1**
POLLEN %	**72,2**	**4,24**	**61,3**	**59**	**28,4**	**88,6**	**65,1**	**10,8**	**90,4**	**19,9**	**63,9**	**62,3**	**68,9**
EXOTIC POLLEN	**111**	**300**	**300**	**217**	**72**	**295**	**130**	**49**	**78**	**195**	**77**	**671**	**37**

PERCENTAGE RELATED TO THE TOTAL SUM (continued)

POLLEN GRAINS	186,60	190,70	193,50	198,50	203,15	212,65	232,18	238,33	239,90	262,00	276,70	282,55	299,05
Proxapertites tertiaria	0,73	4,36	0,95	0,66	6,3	1,45	0,22	0,1	1,39	0,09	0,86	0,3	0,8
Perisyncolporites pokornyi	1,09	6,9	0,36	4,85	0	0,83	1,52	1,35	5,23	0	1	0,43	0,42
Corsinipollenites oculusnoctis	0,24	0,54	0,36	0,22	1,1	0,41	0	0,1	0,35	0,09	0,76	0,17	0,19
Psilamonocolpites medius	5,09	0,73	0,95	0,88	7,12	5,17	2,83	0,29	0	0	0	0,17	0,04
Monoporites annulatus	1,09	0	0,6	0,44	1,37	0,83	0,87	0,1	0,52	0,35	0	0,13	0
Psilatricolporites vanus	0,61	1,09	1,55	4,63	0,82	5,17	13,3	1,74	0,35	0	0,24	1,16	0
Mauritiidites franciscoi	0,24	0	0,6	1,76	4,66	3,72	0,65	4,05	4,01	4,05	0,1	1,59	4,52
Retitricolporites sp.1	0	0	0,36	0,66	0,82	1,24	1,96	0,48	0	0	0,05	0,3	0
Retitricolporites medius	0,48	0	0	1,32	0	0	0,22	0,19	0	0	0,1	0	0
Psilastephanoporites tesseroporus	0	0	0	0	0	0	0	0	0	0	0	0	0
Margocolporites aff. M. vanwijhei	0	0,18	0	0	0	0	1,52	0	0	0	0	0,04	0,15
Retitricolpites cf. R. simplex	0,12	0,73	1,19	0,88	0,27	1,45	4,78	1,25	0,52	0,09	0,62	0,39	0,11
Echitricolporites maristellae	0,12	0,73	0	0	0	0,21	0	0	0	0,18	1,24	0	0,08
Bombacacidites bellus	1,7	7,26	2,15	1,76	2,74	9,3	1,3	0,68	1,05	0	0,57	3,78	0,04
Crototricolpites sp.	0,12	0,18	0,84	0,44	0,27	0	0,87	0,48	0,17	1,5	0,43	1,03	3,34
Crassiectoapertites colombianus	0,12	0,36	0	0,22	0	0	0,43	0,1	0	0,09	0,14	0	0,23
Striatricolpites catatumbus	2,06	0,54	2,86	2,86	0	0,41	0,65	1,25	0,87	0,18	0,1	0	0
Psilatricolporites operculatus	0,24	0	0	2,42	0	0	0,43	0,58	0	0	0	0	0,15
Retitricolporites guianensis	0,12	0	0	0,22	0,27	0,62	0,43	0,1	0	0	0,05	0	0
Psilastephanocolporites aff. P. fissilis	0,12	0,18	0	0,22	0	0,21	0	0	0,17	0	0,05	0	0
Retitricolporites irregularis	0,12	0	0,12	0	0	2,27	0,43	0,19	0,17	17,6	0,05	0	0
Perfotricolpites digitatus	0,12	0,73	0,6	0	1,92	0	0,43	0,77	0	0	0,19	0	0,04
Inaperturopollenites spp.	0,61	1,09	1,31	1,1	3,01	0,41	0	0,29	0,17	0	0,24	0	0,19
Syncolporites incomptus	0,12	0	0,12	0,88	0,27	0	0	0	0	0	0,1	0,04	0
Retitricolporites aff. R.magnus	0	0	0	0	0	0	0	0	0,17	0	0,05	0	0
Malvacipollis cf. M. spinulosa	0,12	0	0,12	0,22	0,27	0,41	0,65	0,29	0	0,18	0	0	0
Multimarginites vanderhammeni	0	0	0,12	0	0	0	0,87	0	0	0	0	0	0
Retitricolpites amapaensis	0	0	0,12	0	0	0	0,22	0	0	0	0	0	0
Psilatricolpites minutus	0,12	0,18	1,31	0,22	0	0	0,22	0,1	0,17	0	0,81	0,95	0
Retimonocolpites maximus	0,85	0	0	0	0	0	0,22	0,19	0,7	0,09	0,05	0,26	0
Inaperturopollenites solimoensis	0	1,27	3,1	1,76	0,27	0,41	0,22	1,35	0,17	0	0,38	0,43	0
Retitricolpites conciliatus	0,24	0	0,6	0	3,84	0	0,65	0	0	0	0	0	0
Echiperiporites stelae	0,24	0,36	0,36	0	2,47	0,83	2,17	0,29	0	0,09	1,19	0,13	0,11
Retistephanoporites crassiannulatus	0	0,36	0,84	0,22	0,27	0	0	0,39	1,22	0,09	0	0,17	0,04
Retitricolporites ticuneorum	0,24	0	0	0,44	0	0	0	0,1	0	0	0	0	0
Bombacacidites baculatus	0,12	0	0	0,44	0	0	0	0,39	8,71	0	0	0	0
Echitriporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Podocarpidites sp.	0	0	0,12	0	0	0	0	0	0	0	0,05	0	0
Retitricolporites cf. R. perpusillus	0,73	0	0	0,88	0	0	0	0	0	0	0,05	0	0
Myrtaceidites spp.	0	0	0	0,22	0	0	0,22	0,1	0	0	0	0,09	0,04
Heterocolpites incomptus	0	0	0	0,22	0	0	0,22	0,19	0	0	0,19	0	0
Retibrevitricolpites cf. R. catatumbus	0	0	0	1,1	0	0	0	0,48	0	0,18	0	0	0
Retitricolpites perforatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psiladiporites minimus	0	0	0	0	0	0	0	0	0	0	0	0	0
Echitricolporites spinosus	0,12	1,09	0,48	0	0,27	0	0,22	0,58	0	2,82	0,62	0	0,23
Psilatricolporites hoornii	0	0,54	0,12	0	0,82	0	0	0,1	0	0	0,05	0	0,23
Fenestrites garciae	0,12	0	0	0	0	0	0	0,1	0	0	0,05	0	0,04
Polyadopollenites mariae	0	0,18	0	0	0	0	1,09	0	0	0	0	0	0,04
Inaperturopollenites elizabetei	0	0	0,24	0	0	0,41	0,43	0	0,35	0,18	0,38	0,26	0
Costatricolporites reticulatus	0,12	0	0,24	1,1	0	0,21	0,22	0,29	0	0	0,05	0,09	0
Verrutricolporites sp.	0	0	0	0	0	0	0	0	0	0	0	0,09	0
Fenestrites spinosus	0	0	0	0	0	0	0	0,1	0	0,18	0,05	0	0
Margocolporites vanwijhei	0	0	0	0	0	0	0	0	0,17	0	0,05	0	0
Psilatricolporites labiatus	0,61	0	0	1,1	0	0	0	0,1	0,17	0	0,1	0	0
Retibrevitricolporites speciosus	0,12	0	0,6	0,88	0	0	0,22	0,1	0	0	0,95	0	0

PERCENTAGE RELATED TO THE TOTAL SUM (continued)

POLLEN GRAINS	186,60	190,70	193,50	198,50	203,15	212,65	232,18	238,33	239,90	262,00	276,70	282,55	299,05
Retitricolporites hispidus	0	0	0,24	1,76	0	0	0	0,1	0	0	0,05	0	0
Psilatricolporites silvaticus	0,48	0	0	0,88	0	0	0	0,77	0	0	0,33	0	0
Retitriporites dubiosus	0,12	0,18	0,95	0	0,27	0	0	0,1	0	0	0,05	0	0
Scabratricolporites planetensis	0	0	0,12	0	0	0	0	0,1	0	0	0,48	0	0
Retitricolporites toigoi	0	0	0	0	0	0	0	0	0	0	0,05	0	0
Grimsdalea magnaclavata	9,33	14,9	2,27	10,1	12,1	11,4	0,87	2,51	20,9	0	0	0	0
Polyadopollenites marileae	0	0	0	0	0	0	1,96	0,1	0,35	0	0	0	0
Psilastephanocolporites sp.	0	0	0	0,44	0	0	0,22	0	0,87	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0	0,65	0,1	0	0	0	0	0
Retitricolporites finitus	0	0	0,24	0	0	0	0,65	0,77	0	0	0	0	0
Ilexpollenites sp.	0	0	0	0	0	0,21	0	0,1	0	0	0	0	0
Monoporites annuloides	0,12	0,54	0,24	0	16,4	0	0	0,1	0	0	0	0	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	1,1	0,21	0	0,29	0	0	0	0	0
Proteacidites triangulatus	0	0	0,24	0,44	0	0,41	0	0,19	0	0	0	0	0
Foveotricolporites caldensis	0	0	0	0	0	5,17	0,22	0	0	0	0	0	0
Rugotricolporite arcus	0	0,91	0	0	0	0,62	0,65	0	0	0	0	0	0
Retitricolporites sp.2	0	0,36	0	0	0	0	4,13	0	0	0	0	0	0
Echitricolporites sp.	0,12	0	0	0	0	0	0,87	0	0	0	0	0	0
Retitricolporites squarrosus	0	0	0	0	0	0	0,65	0	0	0	0	0	0
Inaperturopollenites microechinatus	0,12	0,91	0,12	0,44	4,38	0,83	0	0	0	0	0	0	0
Jandufouria seamrogiformis	0,36	0	0	0,22	0	0,21	0	0	0	0	0	0	0
Multiareolites formosus	0	0,18	0	0	0,27	0	0	0	0	0	0	0	0
Psilaperiporites sp.	0	0	0	0,88	0	0	0	0	0	0	0	0	0
Foveotricolporites florschutzi	0	0,18	0,72	0	0	0	0	0	0	0	0	0	0
Retitricolporites sp.3	0	0,54	1,67	0	0	0	0	0	0	0	0	0	0
Striatricolpites tenuissimus	0	0	0,24	0	0	0	0	0	0	0	0	0	0
Retitricolpites florentinus	0	0	0,84	0	0	0	0	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	0,18	0	0	0	0	0	0	0	0	0	0	0
Striatricolporites digitatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Psilatricolporites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminate angiosperm	7,64	5,99	4,77	17,4	8,77	7,44	13,7	5,98	7,32	2,73	2,09	1,93	1,03
POLLEN SUM	**308**	**300**	**301**	**308**	**301**	**302**	**300**	**316**	**323**	**349**	**314**	**324**	**317**
SPORES													
Deltoidospora adriennis	10,3	12	3,58	2,42	0	1,45	0,87	1,64	2,26	0,26	1,05	2,41	0,42
Magnastriatites grandiosus	0,85	13,4	2,86	0,66	0,55	0,62	0,22	0,29	1,05	1,32	0,86	0,82	1,1
Laevigatosporites spp.	33,6	17,6	51,6	19,6	16,2	28,5	8,91	56,3	34	51,8	77,9	61,9	64,6
Verrucatosporites spp.	17,1	1,45	5,61	9,25	0,27	2,27	2,39	9,65	5,92	13,5	2,81	12,9	17,5
Echitriletes muellerii	0	0	0,12	0	0	0	4,35	0	0,35	0	0	0	0,3
Perinomonoletes sp.	0	0,18	0	0	0	0,83	17,6	0,39	0	0	0	0	0
Polypodiaceoisporites potoniei	0	0,18	0,24	0,22	0	1,03	0	0,29	0,17	0,35	0	0	0,49
Crassoretitriletes vanraadshoovenii	0,85	0,73	0,12	0	0,55	2,89	0,43	0,97	0	2,03	2,47	8,08	3,57
SPORE SUM	**517**	**251**	**537**	**146**	**64**	**182**	**160**	**720**	**251**	**786**	**1789**	**2004**	**2315**
OTHERS													
Dinoflagelate	0	0	0	0	0	0	0	0	0	0	0	0	0
Steevipollenites sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL SUM	**825**	**551**	**838**	**454**	**365**	**484**	**460**	**1036**	**574**	**1135**	**2103**	**2328**	**2632**
SPORE %	**62,7**	**45,6**	**64,1**	**32,2**	**17,5**	**37,6**	**34,8**	**69,5**	**43,7**	**69,3**	**85,1**	**86,1**	**88**
POLLEN %	**37,3**	**54,4**	**35,9**	**67,8**	**82,5**	**62,4**	**65,2**	**30,5**	**56,3**	**30,7**	**14,9**	**13,9**	**12**
EXOTIC POLLEN	**9**	**122**	**0**	**11**	**71**	**0**	**197**	**28**	**364**	**34**	**3**	**6**	**26**

PERCENTAGE RELATED TO THE TOTAL SUM (continued)

POLLEN GRAINS	304,45	320,25	326,25	345,20	356,35	399,10
Proxapertites tertiaria	0,21	0,4	2,18	0,58	0,58	0,45
Perisyncolporites pokornyi	9,62	5,2	2,54	0,58	1,01	0,22
Corsinipollenites oculusnoctis	0,21	0	0,54	0,58	0,29	0,22
Psilamonocolpites medius	0,64	0,4	0,36	4,07	2,01	1,56
Monoporites annulatus	0,64	0,13	0	3,49	0,58	0,89
Psilatricolporites vanus	2,56	0,67	0	1,74	0,14	2,23
Mauritiidites franciscoi	17,9	19,5	2,36	0	38,4	1,78
Retitricolporites sp.1	0	0	0	0	0,43	0,22
Retitricolporites medius	0	0	0	0	0,14	0,22
Psilastephanoporites tesseroporus	0	0	0	0	0,29	0,45
Margocolporites aff. M. vanwijhei	0	0,13	0	0,58	0	0,89
Retitricolpites cf. R. simplex	0,21	0	0	27,3	0	26,9
Echitricolporites maristellae	0	0	0	0,58	0	4,68
Bombacacidites bellus	0	0,4	0,91	0	0	0,45
Crototricolpites sp.	0	2,27	3,99	0	0	0,89
Crassiectoapertites colombianus	0	0,13	0	0	0	0,45
Striatricolpites catatumbus	0,21	0,27	0	0	0	0,22
Psilatricolporites operculatus	0	0,27	0	0	0	1,56
Retitricolporites guianensis	0	0,53	0	0	0	1,11
Psilastephanocolporites aff. P. fissilis	0,43	0	0	0	0	0,67
Retitricolporites irregularis	0,21	0	0	0	0	0,67
Perfotricolpites digitatus	0	0	0	0	0	0,45
Inaperturopollenites spp.	0	0	0	0	0	2
Syncolporites incomptus	0	0	0	0	0	0,22
Retitricolporites aff. R.magnus	0	0	0	0	0	2
Malvacipollis cf. M. spinulosa	0	0	0	0	0	4,68
Multimarginites vanderhammeni	0	0	0	0	0	0,22
Retitricolpites amapaensis	0	0	0	0	0	0,67
Psilatricolpites minutus	4,27	0,27	2,54	2,33	0,14	0
Retimonocolpites maximus	1,5	0,4	0,36	4,07	1,15	0
Inaperturopollenites solimoensis	3,21	0	0	0	0,58	0
Retitricolpites conciliatus	0	0	0	0,58	0	0
Echiperiporites stelae	0	0,27	0,18	0	0	0
Retistephanoporites crassiannulatus	0,43	0	0,36	0	0	0
Retitricolporites ticuneorum	0,21	0,13	0	0	0	0
Bombacacidites baculatus	0	0,8	0	0	0	0
Echitriporites sp.	0	0,13	0	0	0	0
Podocarpidites sp.	0	0,13	0	0	0	0
Retitricolporites cf. R. perpusillus	0	0,13	0	0	0	0
Myrtaceidites spp.	0,43	0	0	0	0	0
Heterocolpites incomptus	0,21	0	0	0	0	0
Retibrevitricolpites cf. R. catatumbus	0,64	0	0	0	0	0
Retitricolpites perforatus	0,43	0	0	0	0	0
Psiladiporites minimus	11,3	0	0	0	0	0
Echitricolporites spinosus	0	0	0	0	0	0
Psilatricolporites hoornii	0	0	0	0	0	0
Fenestrites garciae	0	0	0	0	0	0
Polyadopollenites mariae	0	0	0	0	0	0
Inaperturopollenites elizabetei	0	0	0	0	0	0
Costatricolporites reticulatus	0	0	0	0	0	0
Verrutricolporites sp.	0	0	0	0	0	0
Fenestrites spinosus	0	0	0	0	0	0
Margocolporites vanwijhei	0	0	0	0	0	0
Psilatricolporites labiatus	0	0	0	0	0	0
Retibrevitricolporites speciosus	0	0	0	0	0	0

PERCENTAGE RELATED TO THE TOTAL SUM (continued)

POLLEN GRAINS	304,45	320,25	326,25	345,20	356,35	399,10
Retitricolporites hispidus	0	0	0	0	0	0
Psilatricolporites silvaticus	0	0	0	0	0	0
Retitriporites dubiosus	0	0	0	0	0	0
Scabratricolporites planetensis	0	0	0	0	0	0
Retitricolporites toigoi	0	0	0	0	0	0
Grimsdalea magnaclavata	0	0	0	0	0	0
Polyadopollenites marileae	0	0	0	0	0	0
Psilastephanocolporites sp.	0	0	0	0	0	0
Psilatricolporites caribbiensis	0	0	0	0	0	0
Retitricolporites finitus	0	0	0	0	0	0
Ilexpollenites sp.	0	0	0	0	0	0
Monoporites annuloides	0	0	0	0	0	0
Retibrevitricolporites cf. R. grandis	0	0	0	0	0	0
Proteacidites triangulatus	0	0	0	0	0	0
Foveotricolporites caldensis	0	0	0	0	0	0
Rugotricolporite arcus	0	0	0	0	0	0
Retitricolporites sp.2	0	0	0	0	0	0
Echitricolporites sp.	0	0	0	0	0	0
Retitricolporites squarrosus	0	0	0	0	0	0
Inaperturopollenites microechinatus	0	0	0	0	0	0
Jandufouria seamrogiformis	0	0	0	0	0	0
Multiareolites formosus	0	0	0	0	0	0
Psilaperiporites sp.	0	0	0	0	0	0
Foveotricolporites florschutzi	0	0	0	0	0	0
Retitricolporites sp.3	0	0	0	0	0	0
Striatricolpites tenuissimus	0	0	0	0	0	0
Retitricolpites florentinus	0	0	0	0	0	0
Zonocostites cf. Z.ramonae	0	0	0	0	0	0
Striatricolporites digitatus	0	0	0	0	0	0
Psilatricolporites sp.	0	0	0	0	0	0
Indeterminate angiosperm	9,19	7,47	2,72	11,6	2,01	13,6
POLLEN SUM	**303**	**300**	**105**	**100**	**332**	**317**
SPORES						
Deltoidospora adriennis	14,1	0,67	25	0	0,72	0,45
Magnastriatites grandiosus	0,43	2,4	8,89	1,16	1,44	19,4
Laevigatosporites spp.	11,8	6,27	6,53	32	41,7	7,13
Verrucatosporites spp.	5,34	46,9	2,18	0	8,35	1,56
Echitriletes muellerii	0	0	0	0	0	0,67
Perinomonoletes sp.	0	0	0	0	0	0,22
Polypodiaceoisporites potoniei	0	0,27	0	8,72	0	0
Crassoretitriletes vanraadshoovenii	3,63	3,47	38,3	0	0	0
SPORE SUM	**165**	**450**	**446**	**72**	**363**	**132**
OTHERS						
Dinoflagelate	0	0	0	0	0	0
Steevipollenites sp.	0	0	0	0	0	0
Pediastum sp.	0	0	0	0	0	0
TOTAL SUM	**468**	**750**	**551**	**172**	**695**	**449**
SPORE %	**35,3**	**60**	**80,9**	**41,9**	**52,2**	**29,4**
POLLEN %	**64,7**	**40**	**19,1**	**58,1**	**47,8**	**70,6**
EXOTIC POLLEN	**30**	**214**	**22**	**121**	**114**	**192**

ANEXO 2

Relação dos palinomorfos do poço 1AS 33 AM no banco de dados Paleo da CPRM

Relação dos palinomorfos do poço 1AS 33 AM no banco de dados Paleo da CPRM

Prof. (m)	**Conteúdo**	**Filiação**
15,00	Raros indícios palinológicos	
60,00	*Cyatheacidites annulatus* *Fenestrites spinosus* *Clavatricolpites daemoni* *Psilaperiporites minimus* *Multicellaesporites* sp. *Dicellaesporites* sp.	Angiospermae - Dicotyledonae: Asteraceae, Aquifoliaceae, Chenopodiaceae. Pterophyta: Cyatheaceae Eumycota - Fungi
92,70	*Magnastriatites howardi* *Cyatheacidites annulatus* *Psilaperiporites minimus* *Fenestrites spinosus* *Dicellaesporites* sp. *Inapertisporites* sp.	Angiospermae - Dicotyledonae: Asteraceae, Chenopodiaceae. Pterophyta: Parkeriaceae, Cyatheaceae Eumycota - Fungi
138,45	Raros indícios palinológicos	
165,00	Raros indícios palinológicos	
210,00	Raros indícios palinológicos	
214,28	*Multiareolites formosus* *Crassoretitriletes vanraadshooveni* *Zonocostites ramonae* *Dicellaesporites* sp *Inapertisporites* sp.	Angiospermae: Acanthaceae, Pterophyta: Schizaceae Rhizophoraceae. Eumycota - Fungi
240,00	Raros indícios palinológicos	
304,65	Raros indícios palinológicos	
327,05	*Magnastriatites howardi* *Crassoretitriletes vanraadshooveni* *Cyatheacidites annulatus* *Pachydermites diederixi* *Clavatricolpites daemoni* *Pluricellaesporites* sp. *Staphlosporonites* sp.	Angiospermae: Guttiferae, Aquifoliaceae. Pterophyta: Parkeriaceae. Schizaeceae, Cyatheaceae Eumycota - Fungi
342,58	*Verrucatosporites usmensis* *Pachydermites diederixi* *Magnastriatites howardi* *Clavatricolpites daemoni* *Zonocostites ramonae* *Multicellaesporites* sp. *Dicellaesporites* sp. *Inapertisporites* sp.	Angiospermae – Dicotyledonae: Guttiferae, Aquifoliaceae, Rhizophoraceae. Pterophyta – Polypodiaceae, Parkeriaceae. Eumycota - Fungi
358,42	*Verrucatosporites usmensis* *Psilaperiporites minimus* *Echitricolporites spinosus* *Zonocostites ramonae* *Inapertisporites* sp.	Angiospermae – Dicotyledonae: Chenopodiaceae, Asteraceae, Rhizophoraceae Pterophyta: Polypodiaceae Eumycota - Fungi
374,20	*Multicellaesporites* sp. *Inapertisporites* sp. *Dicellaesporites* sp	Eumycota - Fungi
399,10	Raros indícios palinológicos	