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THE FURNAS/PONTA GROSSA CONTACT AND THE AGE OF THE LOWERMOST PONTA GROSSA FORMATION IN THE APUCARANA SUB-BASIN (PARANÁ BASIN, BRAZIL): INTEGRATED PALYNOLOGICAL AGE DETERMINATION

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ABSTRACT – The Furnas/Ponta Grossa Formation contact was until recently considered gradational or abrupt and of a Lochkovian to Pragian age in the Apucarana Sub-basin (Paraná Basin, south Brazil). Based on sedimentology and palynomorph evidence a hiatus has been revealed between the Furnas Formation and the overlying Ponta Grossa Formation. The boundary between the topmost Furnas sandstones and the lowermost Ponta Grossa fine-grained sandstones constitutes a transgressive ravinement surface generated during a latest Pragian – early Emsian transgression. The hiatus corresponds to a maximum of ca. 4 Ma. A similar gap is also present in the Alto Garças Sub-basin.

Key words: Furnas/Ponta Grossa contact, palynology, Early Devonian, Paraná Basin.

RESUMO – O contato entre as formações Furnas e Ponta Grossa na Sub-bacia de Apucarana (bacia do Paraná, sul do Brasil) foi considerado até recentemente como gradacional ou abrupto e de idade Lockoviana/Praguiana. Com base em evidências sedimentológicas e palinológicas um hiato foi revelado entre a Formação Furnas e a sobrejacente Formação Ponta Grossa. O limite entre os arenitos da porção superior da Formação Furnas e os folhelhos e arenitos finos basais da Formação Ponta Grossa constitui uma superfície de ravinamento gerada na transgressão entre o final do Praguiano e o Eo-Emsiano. O hiato observado envolve um máximo de 4 Ma. Uma lacuna similar também foi descrita na Sub-bacia de Alto Garças.

Palavras-chave: contato Furnas/Ponta Grossa, Palinologia, Eodevoniano, bacia do Paraná.

INTRODUCTION

Outcrops with a continuous sedimentary record over the Furnas/Ponta Grossa (or Ponta Grossa equivalents) contact are known from many localities in the Paraná Basin (Figures 1-2; for references see Grahn *et al*., 2000, 2010; Pereira, 2000; Mauller *et al*., 2009). Published information of lithologies is also known from several Petrobras wells (*e.g.* Lange, 1967; Bergamaschi, 1999; Grahn *et al*., 2000, 2010; Bergamaschi & Pereira, 2001; Gaugris & Grahn, 2006). Most of these localities display an arenaceous or silty facies in the lowermost part of the Ponta Grossa Formation in the Apucarana Sub-basin. Petri (1948) and Sanford & Lange (1960) considered these beds to be transitional to the Ponta Grossa Formation. Based on spores, Dino & Rodrigues (1995) dated early land plants in the upper Furnas Formation (included in the transitional beds by Petri, 1948) at PISA (Figure 2) to be of Pragian age, and the overlying Ponta Grossa Formation to be of Emsian age. Spores identified by Steemans from PISA during the 1990s was partially published by Gerrienne *et al.* (2001). The same samples, complemented by new ones, were used to review the age previously assigned, which was considered as early Lochkovian (Gerrienne *et al*., 2001). The lithostratigraphic lateral equivalent level at Jackson de Figueiredo (Figure 2), *ca.* 11 km west of the PISA locality, is probably coeval of the PISA locality. However, no spores have been found at this locality (Gerrienne *et al*., 2001). Loboziak *et al*. (1995), based on spores in the uppermost Furnas Formation (*ca.* 8 m below the Furnas/Ponta Grossa contact) from core 23 in the Petrobras 2-CN-1-SC well (Figure 2), regarded the Furnas/Ponta Grossa contact as early Pragian. Loboziak & Melo (2002, p. 141-142) pointed out that the miospores from core 23 in well 2-CN-1-SC (Figure 7) are comparable to those of the lowermost Jatapu and uppermost

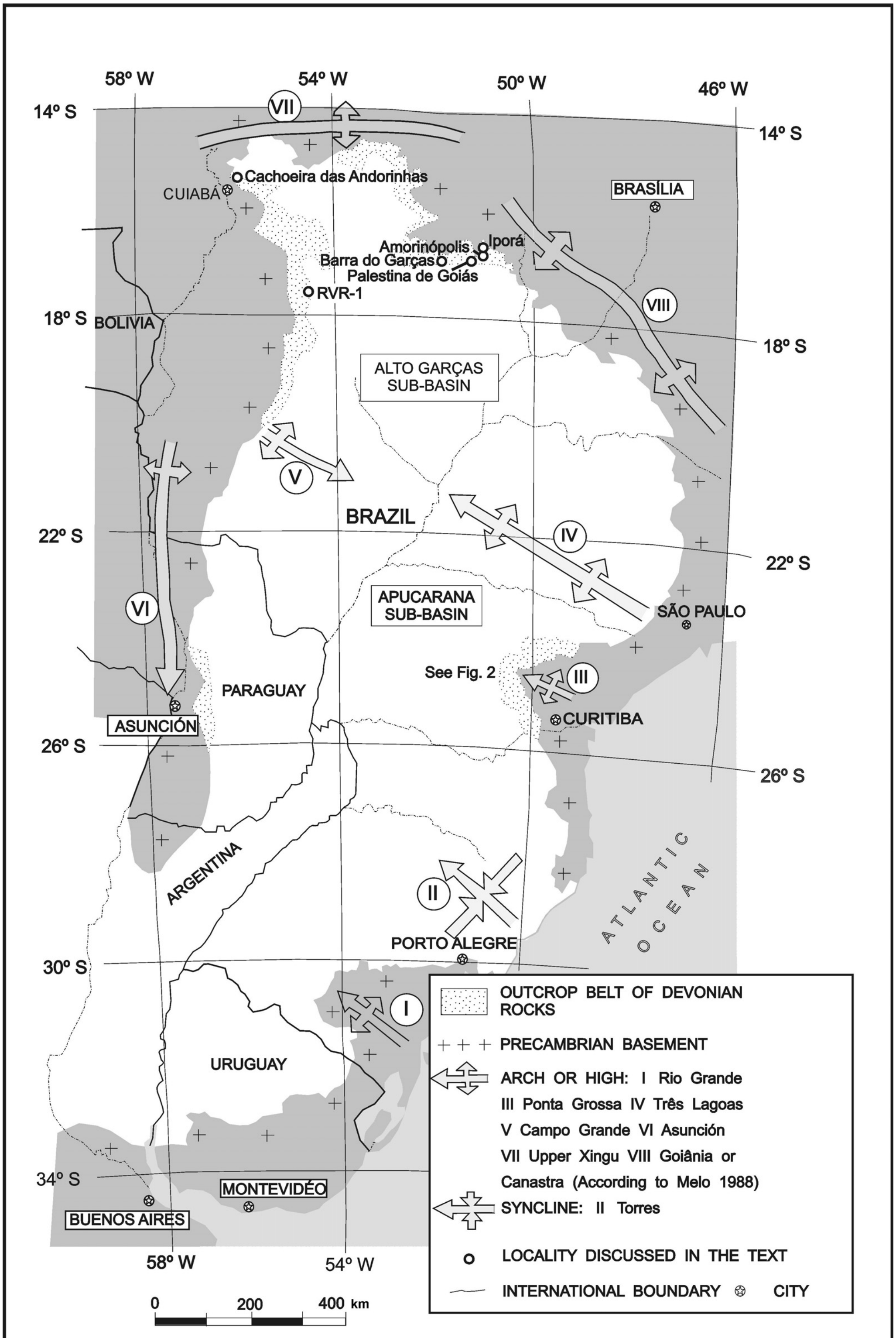

Figure 1. Location map of the localities from the Alto Garças Sub-basin discussed in this study.

Manacapuru formations in the Amazonas Basin. Both intervals are late Lochkovian as dated by chitinozoans (Grahn, 2005a,b). Lithostratigraphic lateral unit in the Solimões Basin (uppermost Jutaí Fm.) was dated as late Lochkovian (Z Phylozone of the BZ Oppel Zone and *Urochitina loboi* chitinozoan Sub-zone) by acritarchs and miospores (Rubinstein *et al*., 2005, 2008) and chitinozoans (Grahn & Melo, 2003).

The early land plant bearing beds in the uppermost Furnas Formation at the PISA locality are slightly older (Si Phylozone of the MN Oppel Zone; Rubinstein *et al*., 2005) and of late but not latest Lochkovian age. Dino (1999), Mauller *et al.* (2009) and Grahn *et al.*(2010) considered the lower Ponta Grossa Formation as latest Pragian-early Emsian, but the lowermost 10 m of the Ponta Grossa shales and the Ponta Grossa sandstones below were not sampled

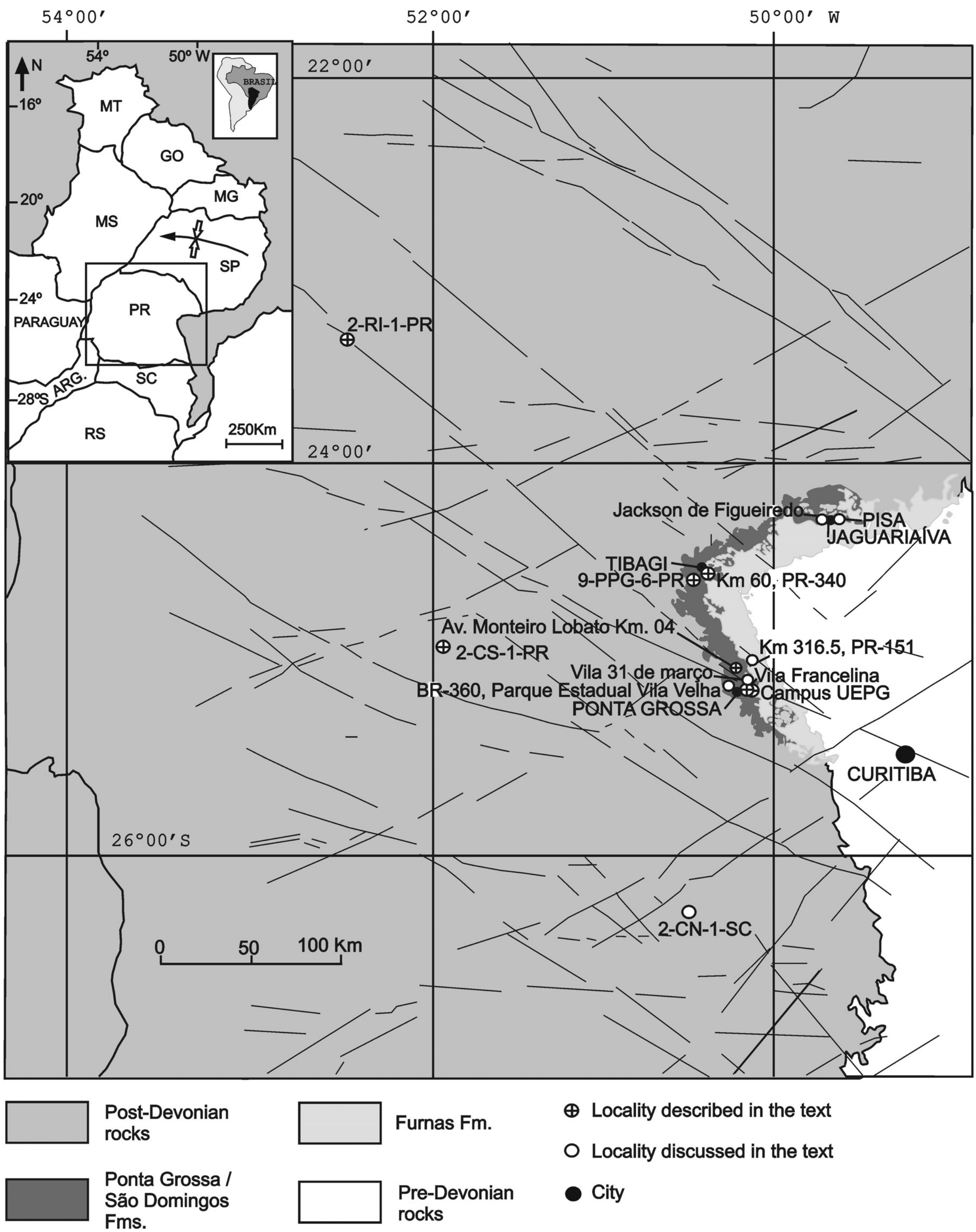

Figure 2. Location map of the localities from the Apucarana Sub-basin discussed and/or investigated in this study.

or provided no palynological results. The first body fossils from the Ponta Grossa shales in the Apucarana Sub-basin, described in the literature, are from a level 10-15 m above the contact with the arenaceous beds in the lowermost Ponta Grossa Formation. These fossils are of late Pragian-early Emsian age as evidenced by palynomorphs (Mauller *et al*., 2009). The base of the Ponta Grossa Formation remains undated. About 2.7 km north of Amorinópolis city (Figure 1) in the northeastern part of the Alto Garças Sub-basin, chitinozoans have been described from a level *ca.* 1 m above a conglomerate between the Furnas and Ponta Grossa (= Chapada Group unit 2 *sensu* Grahn *et al*., 2010) equivalents (Grahn *et al*., 2000, 2010). This is in agreement with the lowermost Chapada Group unit 2 in well RVR-1 (Figure 1; Mauller *et al*., 2009), where a sample *ca.* 4 m above the contact with the Furnas Formation (= Chapada Group unit 1 *sensu* Grahn *et al*., 2010) is latest Pragian-early Emsian (Mauller *et al*., 2009; Grahn *et al*., 2010). At Amorinópolis the plant-bearing layers occur 4-5 m below the conglomerate in a deltaic/lagoonal environment (Quadros & Melo, 1986; Pereira, 2000). The plant remains are fragmented and probably transported. Other localities with uppermost Furnas Formation in the Alto Garças Sub-basin occur between Iporá and Palestina de Goiás, close to the Caiapó River, and at Barra do Garças (Figure 1; Pereira, 2000). Plant-bearing beds are also known ca. 6-12 m below typical Ponta Grossa shales in a hummocky cross stratified fine-grained sandstone associated with *Skolithos* at Cachoeira das Andorinhas in the Parque Nacional da Chapada dos Guimarães near Chapada dos Guimarães (Figure 1). The contact with the Furnas sandstones is a ravinement surface, and between the lowermost Ponta Grossa sandstones and the Ponta Grossa shales at this locality there is an interval, *ca.* 4 m thick, with fine-grained sandstone with hummocky cross stratification (Pereira, 2000). The preservation of the plant remains suggests transport from continental or transitional beds.

LOCALITIES AND PALYNOLOGICAL RESULTS

A more argillaceous facies, suitable for palynomorph preservation, is known from four outcrops in the Campos Gerais region (Vila Francelina, Campus UEPG, Avenida Monteiro Lobato km 04 (CEFET), and km 60 on road PR-340) in the Apucarana Sub-basin, and from some wells (*e.g.* 2-CS-1-PR, 2-RI-1-PR and 9-PPG-6-PR) in the same sub-basin. Some of the samples from these localities have yielded spores and acritarchs, and allow dating of the base of the Ponta Grossa Formation, and the initial Early Devonian transgression represented by Ponta Grossa sandstones. The localities are described below. The palynomorphs identified are listed in the Appendix 1.

Vila Francelina (25°04’55”S, 50°06’54”W)

The Furnas/Ponta Grossa contact does not crop out at this locality (Figures 2, 4), and the closest exposure with Furnas sandstone is *ca.* 120 m north-northeast of the outcropping of lowermost Ponta Grossa shales (Bosetti *et al*., 2006, 2009; Myszynski Jr. & Bosetti, 2006; Zabini *et al*., 2010). Three outcrops constitute the locality (Francelina 1-3), of which the lower part (Francelina 2) is the section investigated (Bosetti *et al*., 2009). The lithology of the Furnas Formation is fine-grained sandstones with intercalated siltstone layers (*ca.* 5 cm thick). No intervening faults are known. The palynomorphs present are not age-diagnostic (Figure 4).

Campus UEPG (25°05’33”S, 50°06’15”W)

The Furnas/Ponta Grossa contact is not exposed at this locality (Figures 2, 4), but *ca.* 450 m towards the east occur Furnas sandstones (Bosetti *et al*., 2006, 2009; Myszynski Jr. & Bosetti, 2006; Horodyski *et al*., 2006; Zabini *et al*., 2010) with the same lithologies as those near Vila Francelina. None of the palynomorphs present are age-diagnostic (Figure 4).

Av. Monteiro Lobato, km 04, CEFET (25 °03'18,67"S, 50 °08'01,52"W)

A new road-cut near the corner of rua Antônio Saad and Avenida Monteiro Lobato in Ponta Grossa (Figures 2, 4), and about 100 m from Franco da Rocha (Grahn & Bosetti, 2010), display a *ca.* 7 m thick sequence from the upper Furnas (*ca.* 3 m) and lower Ponta Grossa (*ca.* 4 m). The Furnas sandstones have the same lithology as at Vila Francelina and Campus UEPG, and the contact with the Ponta Grossa Formation is distinct. A sample collected immediately above the Furnas/Ponta Grossa contact yielded no palynomorphs.

PR-340, km 60, Tibagi (24°46’04”S, 50°09’24”W)

This is the classical locality with the Furnas/Ponta Grossa contact situated ca. 100 m from the Tibagi River (Figures 2, 4). The levels with early land plant remains are ca. 6 m below the Furnas/Ponta Grossa contact (Bigarella *et al*., 1966; Bergamaschi, 1999). Maack (1951) interpreted the siltitic layers with plant remains as representative of glacially varved layers, while Rodrigues *el al*. (1988) interpreted the outcrop as a record of the early Devonian transgression. The faciological aspect of the outcrop shows a lagoon and deltaic plain covered by barrier sandstone deposited on a foreshore. The outcrop is deeply weathered, and it has not been possible to extract any palynomorphs from the boundary beds, which are very distinct at this locality (Maack, 1951). Petri (1948) and Rodrigues *et al.*(1988) regarded the fine-grained sandstones above typical Furnas sandstones as transitional beds between the Furnas and Ponta Grossa formations.

2-CS-1-PR, Chapéu do Sol no. 1 (24°57’49.789’’S, 51°58’2.940”W)

This well was used by Milani *et al.*(1994), Bergamaschi (1999) and Bergamaschi & Pereira (2001) for correlations in the Paraná Basin. The lower Ponta Grossa shale in this well (Figure 3) is dated as late Pragian-early Emsian as indicated by chitinozoans. *Dictyotriletes* sp. cf. *D. richardsonii* (= *D. favosus* in Grahn *et al*., 2005) is known to occur in the lower Ponta Grossa (Mauller *et al*., 2009), and in the contemporary upper Jaicós Fm., Parnaíba Basin (Grahn *et al*., 2005). *Ancyrochitina pachycerata* first occurs at the Pragian-Emsian transition in the Paraná Basin (Grahn, 2005a).

2-RI-1-PR, Rio Ivai no. 1 (23°19'52.067"S, 52°27'18.436"W)

This well was used for correlations in the Paraná Basin by Assine *et al.* (1994), Milani *et al.* (1994), Bergamaschi (1999), Bergamaschi & Pereira (2001) and Zabini *et al.* (2010). The lower Ponta Grossa shales yielded *Ramochitina magnifica* which is in agreement with a late Pragian-early Emsian age.

9-PPG-6-PR, Ponta Grossa project no. 6 (24°35'12.2833"S, 50°26'10.6697"W)

Gaugris & Grahn (2006) dated the upper part of this core (20-30 m) as pre-late Emsian. Later investigations (*e.g.* Mauller *et al*., 2009; Grahn *et al*., 2010) suggest a late Emsian age for that part of the core, and where *Ancyrochitina* n. sp. C (*pars*) *sensu* Gaugris & Grahn (2006) is conspecific with *Ancyrochitina* aff. *A. pachycerata* (Mauller *et al*., 2009). The latter species ranges through Emsian strata in the Paraná Basin (Mauller *et al*., 2009; Grahn *et al*., 2010). The presence of a diverse *Ancyrochitina* assemblage including *Ancyrochitina pachycerata* s.s. characterizes the late Emsian in the Paraná Basin. This age assignment is in agreement with the present results. A low diversity miospore assemblage including *Dictyotriletes subgranifer* dominates the sequence in the lowermost Ponta Grossa Formation (Figure 5), which is developed as storm bars (Rezende & Bergamaschi, 2008). Latest Emsian chitinozoans occur at 68.80 m. Layers with

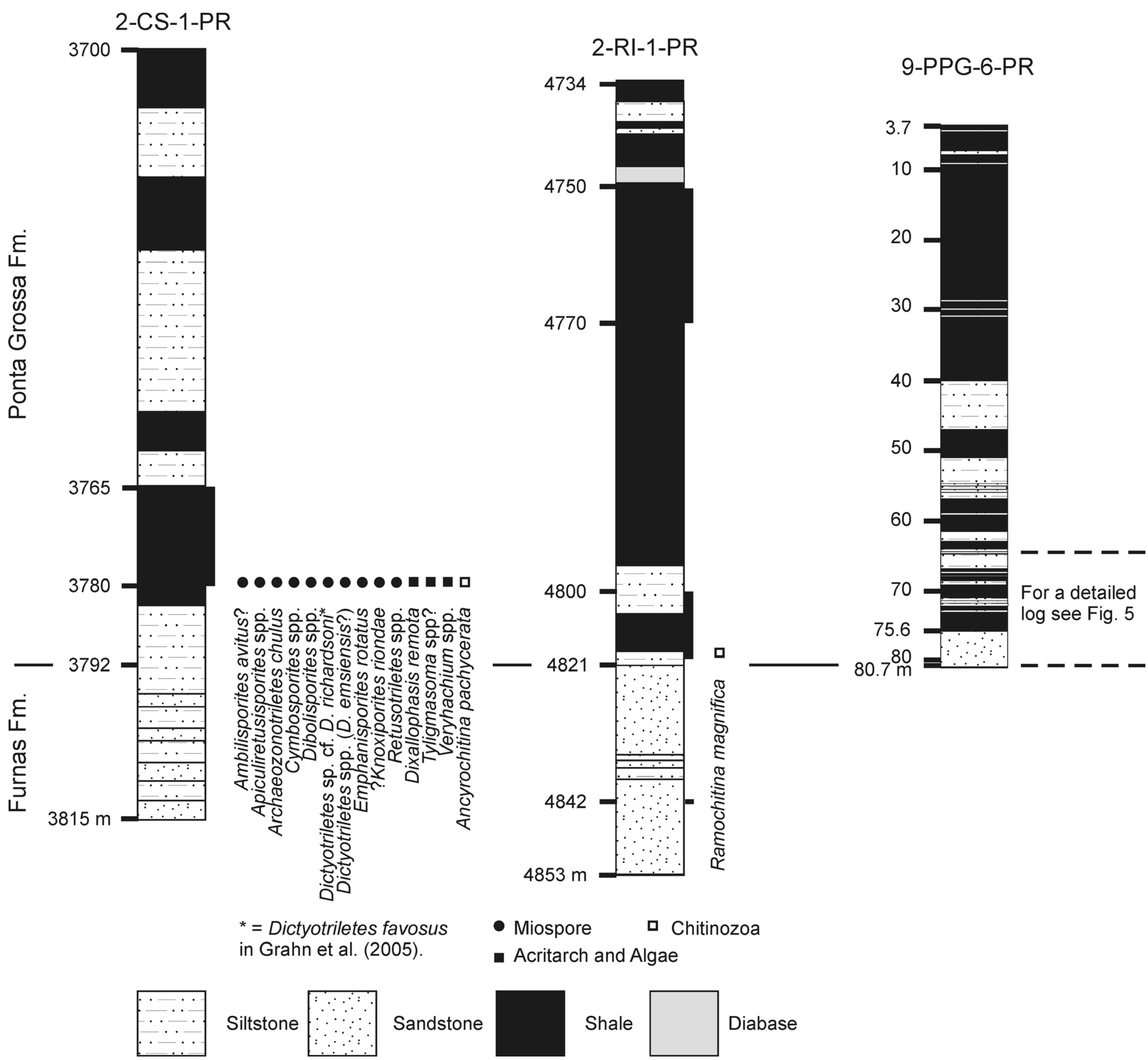

Figure 3. Lithologic column and palynomorph range chart for the wells investigated.

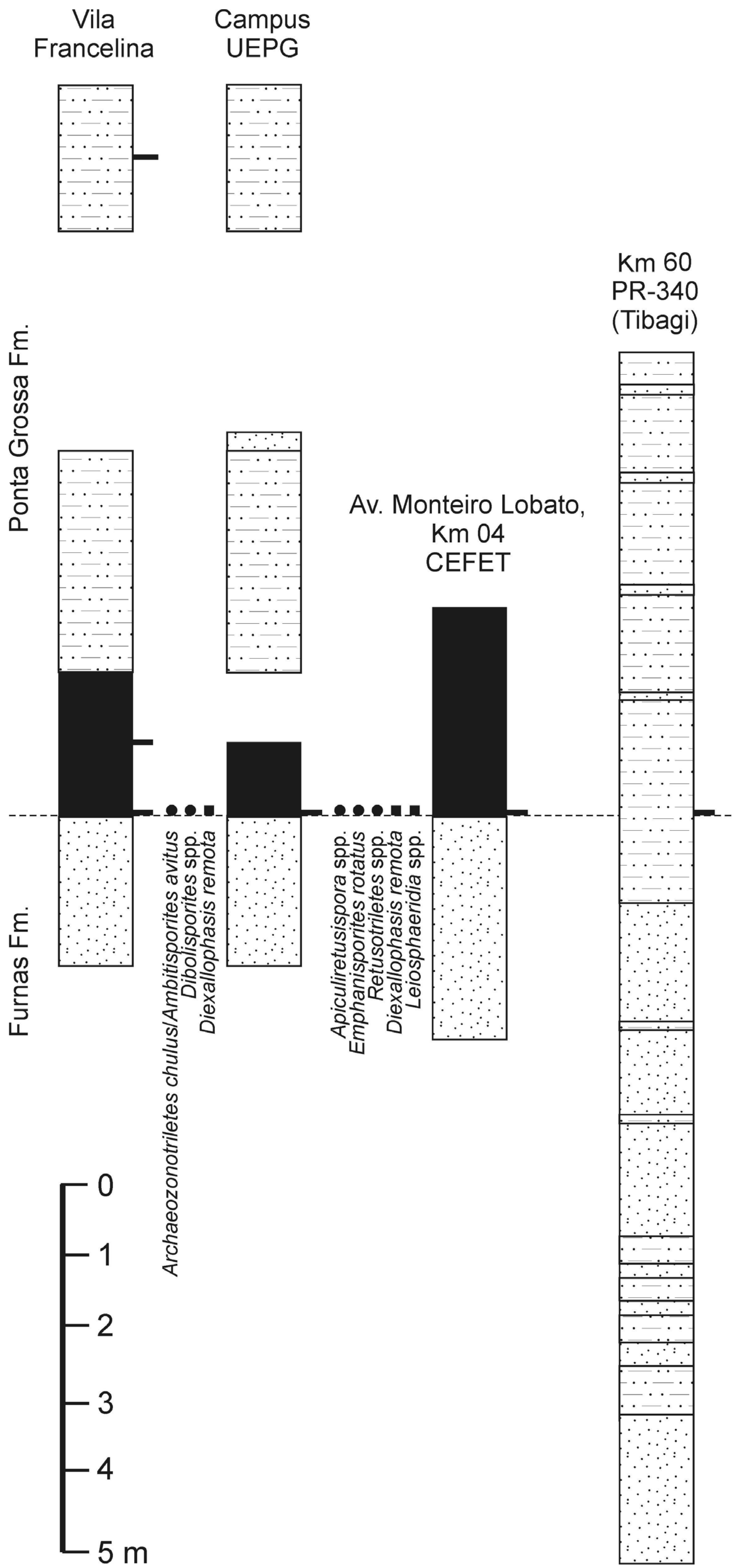

Figure 4. Lithologic column and palynomorph range chart for the outcrops investigated. For legend, see Figure 3.

reworked material occur at 72.00 and 72.30 m, and the early Emsian (PoW Su spore Zone)/late Emsian (AP spore Zone) boundary is questionable, drawn at 72.30 m (Figure 5). No positive evidence was found for the Emsian AB and FD spore zones.

THE NATURE OF THE FURNAS/PONTA GROSSA CONTACT

The upper part of the Furnas Formation is characterized by fluvial and coastal coarse sandstones with silty layers intercalated with coarse sandstones. These silty layers may contain plant remains. The base of the Ponta Grossa Formation represents the main transgressive surface into a 2nd order cycle, and a 3rd order boundary (Bergamaschi, 1999). The lithology consists of fine-grained littoral-sublittoral sandstones with *Skolithos* (Borghi, 1993), sometimes reworked by storms (hummocky cross stratification, storm bars) or by intertidal erosion in more protected parts of the basin (cyclic tidal bars). A cycle is initiated with a hardground and ends with muddy layers. Bioturbation is common and increases upwards in the tidal bar. Up to a maximum 20 m of lowermost Ponta Grossa displays hummocky cross stratified beds, deposited by oscillatory currents during storms that reworked the sediments on the ravinement surface (Tamura & Masuda, 2005; Grahn & Bosetti, 2010). Where hummocky cross stratification, storm bars or intertidal cyclic bars are missing there are low-angle tabular sandstones indicating foreshore deposition.

Petri (1948) and Sanford & Lange (1960) considered these beds as the upper part of the transitional beds to the overlying more shaly Ponta Grossa Formation. Caster (1952) found evidence for both abrupt and what he considered a gradational contact. Diniz (1985) on the other hand regarded these beds as part of the Ponta Grossa Formation. Bigarella *et al.* (1966) remarked that the uppermost part of the Furnas Formation has several layers with siltstones, argillaceous and arenaceous siltstones, and argillaceous shaly beds although not similar to those in the Ponta Grossa Formation. These shaly layers always overlay an erosional surface and truncated cross-stratified arenites characteristic of the Furnas Formation. Bergamaschi (1999) and Bergamaschi & Pereira (2001) interpreted the plant-bearing beds as deltaic-lagoonal with the plants *in situ* and the arenites as deposited by crevasse-splay flux in a lagoonal area recovered by tabular sandstones associated with foreshore deposits (Rodrigues *et al.*, 1988; Bergamaschi & Pereira, 2001). Assine (1996) found hummocky cross-stratified arenites associated with lags of aligned disk-shaped pebbles with no excavation structures below. He interpreted these beds as trangressive ravinement surfaces reworked by storm action in a rapid transgression from northeast. Similar beds are known from the lower Emsian in the Paraná Basin (Grahn & Bosetti, 2010). Assine (1996) and Bergamaschi (1999) recognized a hiatus between the Furnas and Ponta Grossa formations, and placed the upper low angle sandstones below Ponta Grossa shales (transitional beds by Petri, 1948) in the lowermost Ponta Grossa Formation. The uppermost Furnas Formation is characterized by (i) silt layers containing plant remains and rare palynomorphs (Milagres *et al.*, 2007), dated as late, but not latest Lochkovian (Loboziak & Melo, 2002; Rubinstein *et al.*, 2005); and (ii) rare laterally extensive conglomeratic layers with gravel and pebbles. The Furnas Formation shows a general regressive tendency upwards. The early land plant beds are here considered as a late Lochkovian datum plane (Si Phylozone in the MN Oppel Zone; Gerrienne *et al.*, 2001; Rubinstein *et al.*, 2005, 2008). A dense sampling of core 9-PPG-6-PR from the base of the "transitional beds" (76.5 to 80.7 m) below typical Ponta Grossa Formation (from 76.5 m upwards; Figures 3, 5) revealed that these beds are probably late Pragian-early Emsian. Thus, the "transitional beds" are of the same age as the lower part of the typical Ponta Grossa shales. Attempts were made to date samples from lowermost Ponta Grossa Formation with the Rb-Sr-method, but these failed because of the unsuitable lithologies of the samples (Ana Maria Misuzaki, pers. comm., 2009). The lowermost Ponta Grossa sandstones were deposited as a result of an extensive reworking of a ravinement surface that delimits the Furnas Formation. The age of the ravinement surface is not older than latest Lochkovian, and not younger than latest Pragian, when the transgressive Ponta Grossa sandstones were deposited. Early land plant layers have been found at varying depths below the Furnas/Ponta Grossa contact at outcrop localities in the Apucarana Sub-basin (Figure 2): (i) PISA *ca.* 2 km east of Jaguariaiva city at approximately 20 m below the top of the Furnas Formation, which is here truncated by the Carboniferous Itararé Group (Dino & Rodrigues, 1995; Dino *et al.*, 1995; Mussa *et al.*,1996; Bergamaschi, 1999; Gerrienne *et al.*, 2001; Rubinstein *et al.*, 2005); (ii) Jackson de Figueiredo *ca.* 11 km west of the PISA locality. Plant remains occur *ca.* 5 m below the top of the Furnas Formation (Mussa *et al.*, 1996; Bergamaschi, 1999; Gerrienne *et al.*, 2001); (iii) Carambéi, km 316.5, PR-151 at *ca.* 20 m below the top of the Furnas Formation (Assine, 1996; Milagres *et al.*, 2007). The contact with Ponta Grossa Formation has not been observed; (iv) km 60, PR-340 (Figure 4) close to Tibagi River (Tibagi city) at *ca.* 6 m below the top of the Furnas Formation (Bigarella *et al.*, 1966; Bergamaschi, 1999); (v) BR-360, 1 km west of the entrance to Parque Estadual Vila Velha at 8-10 m below the top of the Furnas Formation (Bigarella *et al.*, 1966). The contact with Ponta Grossa Formation has not been observed; (vi) Vila 31 de março, Ponta Grossa, at 2.5 m below the top of the Furnas Formation (Rodrigues *et al.*, 1989). The contact with Ponta Grossa Formation has not been observed.

The variable thickness of the basal Ponta Grossa sandstones suggests a surface with a slightly undulating relief when the late Pragian-early Emsian transgression reached the area. The maximum gap between the youngest dated Furnas Formation and the base of the Ponta Grossa

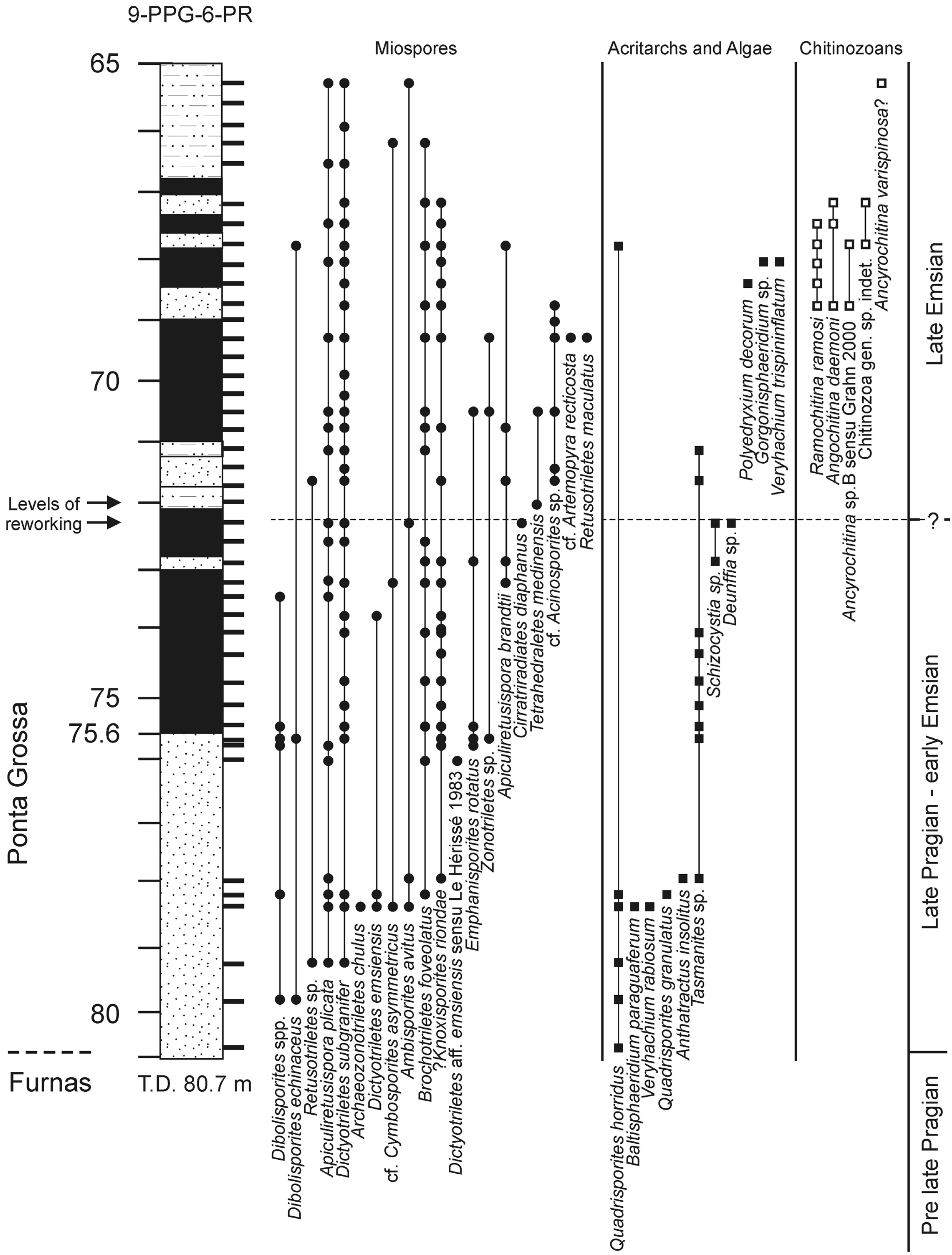

Figure 5. Lithologic column and palynomorph range chart for well 9-PPG-6-PR. For legend, see Figure 3.

Formation corresponds to the E Phylozone of the BZ Oppel Zone-pre PoW Su spore Zone (latest Lochkovian and most of the Pragian), a time interval representing *ca.* 4 Ma (Figure 6).

REMARKS ON THE MIOSPORE AND CHITINOZOAN ASSEMBLAGES

In the Paraná Basin, late Lochkovian spores have been described from the uppermost Furnas Formation. Dino and Rodrigues (1995) and Dino *et al.*(1995) found *Dictyotriletes emsiensis* and *Dictyotriletes subgranifer* at the PISA locality and dated these beds as Pragian. Loboziak *et al.*(1995) described a miospore assemblage from the uppermost Furnas in well 2-CN-1-SC, and based on the occurrence of *Dictyotriletes emsiensis* and *Dibolisporites* cf. *eifeliensis*, these beds were considered early Pragian. The samples from PISA were re-investigated by Gerrienne *et al.*(2001), and the specimens of *Dictyotriletes emsiensis* are now interpreted as intermediate forms between *D. emsiensis* and *D. granulatus*. These forms are known from the late Lochkovian MN Oppel Zone and younger strata in western Gondwana (*D. emsiensis* Morphon Assemblage Zone by Rubinstein *et al*., 2005). The presence of *Aneurospora geikiei* and *Synorisporites verrucatus* further strengthen a Lochkovian age for the uppermost Furnas Formation. According to Rubinstein *et al.*(2005), the absence of characteristic species such as *Dibolisporites eifeliensis* and *Dibolisporites echinaceus* at PISA suggests a late, but not latest Lockovian age (Si Phylozone of the MN Oppel Zone). The presence of *Dibolisporites* cf. *eifeliensis* in core 23 in well 2-CN-1-SC suggests a slightly younger age, but not older than the Z Phylozone of the BZ Oppel Zone. Core 23 probably has a coeval stratigraphic position with the latest Lochkovian assemblages from the Solimões Basin (Rubinstein *et al*., 2005). No chitinozoans are known from the Furnas Formation.

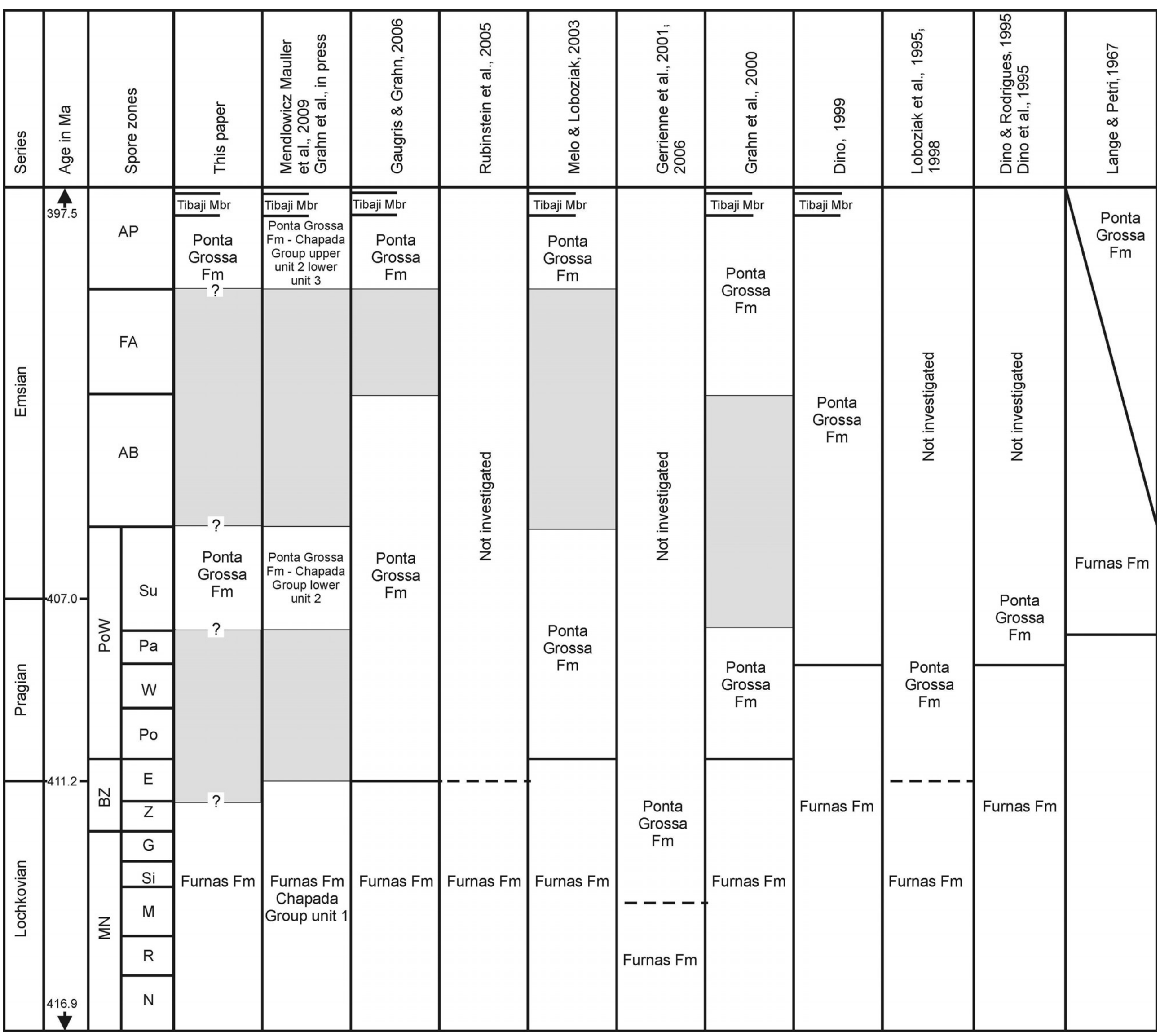

Figure 6. Correlation scheme for the Furnas/Ponta Grossa contact.

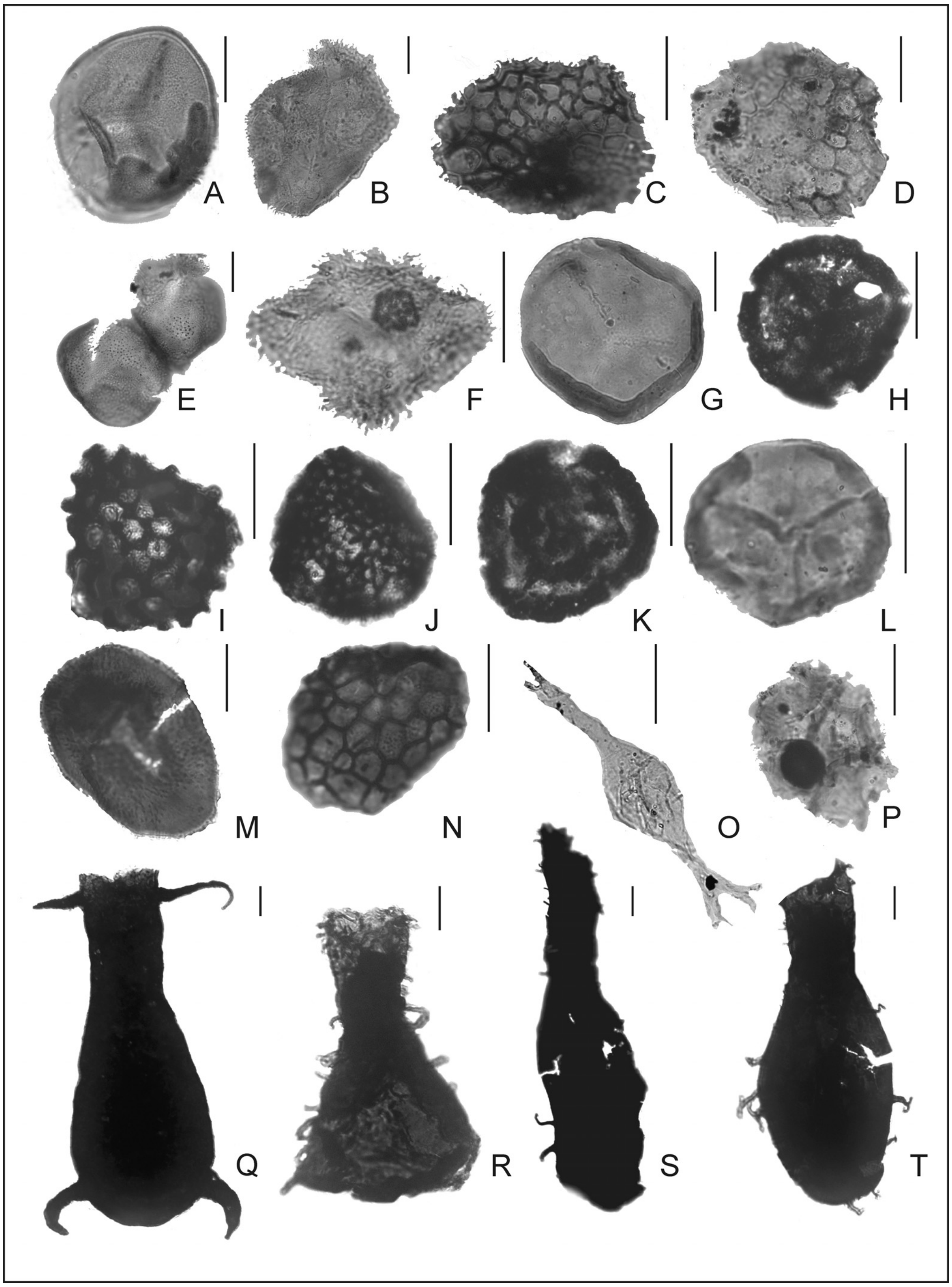

Figure 7. Selected spores (**A**-**G**, **G**-**N**), algae (**F**), acritarchs (**O**-**P**), and chitinozoans (**Q**-**T**) from the Furnas and Ponta Grossa formations in the Apucarana Sub-basin. **A**, *Apiculiretusispora plicata*. Well 9-PPG-6-PR, 79.28 m. Ponta Grossa Fm. BPA 200908831, T68/1; **B**, cf. *Cymbosporites asymmetricus*. Well 9-PPG-6-PR, 78.42 m. Ponta Grossa Fm. BPA 200908830, F58/4; **C**,*Dictyotriletes* aff. *emsiensis* sensu Le Hérisse 1983. Well 9-PPG-6-PR, 76.00 m. Ponta Grossa Fm. BPA 200908403, P57/4; **D**, *Dictyotriletes subgranifer*. Well 9-PPG-6-PR, 68.10 m. Ponta Grossa Fm. BPA 200908377, T68/2-4; **E**, *Dibolisporites* spp. Well 9-PPG-6-PR, 79.80 m. Ponta Grossa Fm. BPA 200908832, W64/2; **F**, *Quadrisporites horridus*. Well 9-PPG-6-PR, 78.42 m. Ponta Grossa Fm. BPA 200908830, U69/1; **G**, *Ambitisporites avitus*. Well 9-PPG-6-PR, 78.42 m. Ponta Grossa Fm. BPA 200908830, X45/3; **H**, *Ambitisporites avitus*? Well 2-CS-1-PR, 3765-3780 m, Ponta Grossa Fm. BPA 9407124, E17c; **I**, cf. *Brochotriletes foveolatus* Well 2-CS-1-PR, 3765-3780 m. Ponta Grossa Fm. BPA 9407124, P14; **J**, *Dictyotriletes* sp. cf. *D. richardsonii*. Well 2-CS-1-PR, 3765-3780 m. Ponta Grossa Fm. BPA 9407124, U17/3; **K**, ?*Knoxisporites riondae*. Well 2-CS-1-PR, 3765-3780 m. Ponta Grossa Fm. BPA 9407124, R34/4; **L**, *Synorisporites papillensis*. Well 2-CN-1-SC, core 23 (1455-1457 m). Furnas Fm. BPA 2917, O59/3-4; **M**, *Dibolisporites echinaceus*. Well 2-CN-1-SC, core 23 (1455-1457 m). Furnas Fm. BPA 12847, K45/2; **N**, *Dictyotriletes emsiensis* Well 2-CN-1-SC, core 23 (1455-1457 m). Furnas Fm. BPA 12848, N47/4; **O**. *Anthatractus insolithus*. Well 9-PPG-6-PR, 78.00 m. Ponta Grossa Fm. BPA 200908828, V68/3; **P**, *Polyedrixium decorum*. Well 9-PPG-6-PR, 68.40m. Ponta Grossa Fm. BPA 200908378, W70; **Q**, *Ancyrochitina pachycerata*. Well 2-CS-1-PR, 3765-3780 m. Ponta Grossa Fm. BPA 9407124, D49c; **R**, *Ancyrochitina* sp. B sensu Grahn 2000. Well 9-PPG-6-PR, BPA 200908376, 67.80 m. Ponta Grossa Fm. 200908376, O60/3; **S**, *Ramochitina magnifica*. Well 2-RI-1-PR, 4800-4820 m. Ponta Grossa Fm. BPA 9407145, T36c; **T**, *Ramochitina ramosi*. Well 9-PPG-6-PR, 68.70m. Ponta Grossa Fm. BPA 200908379, J46c. Scale bars = 20 μm.

A poorly diagnostic miospore assemblage occurs from the base of the Ponta Grossa sandstones into the more shaly parts of the formation, suggesting the PoW Su spore Zone. The index species *Dictyotriletes subgranifer* is common and occurs together with other characteristic species such as *Dictyotriletes emsiensis* morphon and *Dictyotriletes* sp. cf. *D. richardsonii*. Chitinozoans are rare but *Ramochitina magnifica* and *Ancyrochitina pachycerata* are present. The late Emsian is pooly characterized by miospores in this study. The chitinozoans constitute a characteristic latest Emsian assemblage with species such as *Ancyrochitina* sp. B *sensu* Grahn, 2000, *Angochitina daemoni*, and *Ramochitina ramosi*. These species also occur in the Tibagi Member of the Ponta Grossa Formation, as defined in the Tibagi-Telemâco Borba section (Bergamaschi, 1999; Grahn *et al*., 2000).

CONCLUDING REMARKS

For the first time the lowermost Ponta Grossa Formation has been dated. An integrated (spore, acritarch and chitinozoan) palynomorph study of the upper Furnas and lower Ponta Grossa formations reveals a hiatus between the ravinement surface that delimits the Furnas and the initial lower Devonian transgression represented by the basal Ponta Grossa sandstones (Figure 6). This gap corresponds to a maximum of *ca.* 4 Ma (E Phylozone of the MN Oppel Zone and pre-PoW Su spore Zone). The Ponta Grossa basal sandstones (transitional beds *sensu* Petri, 1948) were deposited through an extensive erosion and reworking of the ravinement surface (hummocky cross stratification, storm bars and intertidal cyclic bars), and are dated as late Pragian-early Emsian (PoW Su spore Zone). The same age is found in the lower Ponta Grossa shales. The finds of early land plants in the uppermost Furnas Formation have been previously dated as late, but not latest Lochkovian (Si Phylozone of the MN Oppel Zone) by Rubinstein *et al.* (2005, 2008). On the eastern border of the Paraná Basin a ravinement surface can be associated with a 3rd order sequence boundary. Zalan *et al.* (1987) interpreted the contact between the Ponta Grossa sandstones and shales as a gap corresponding to a maximum of *ca.* 10 Ma. A possible gap within the Ponta Grossa Formation corresponding to the Emsian AB-FD Oppel Zones, and possibly a latest Emsian age for the Tibagi Member *s.s.*, is also suggested by the present study.

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Appendix 1. List of taxa mentioned or discussed in text and/or figures.

Spores

cf. *Acinosporites* sp.
Ambitisporites avitus Hoffmeister, 1959
Aneurospora geikiei Wellman & Richardson, 1996
Apiculiretusispora brandtii Streel, 1964
Apiculiretusispora plicata (Allen) Streel, 1967
Apiculiretusispora spp.
Archaeozonotriletes chulus (Cramer) Richardson & Lister, 1969
Artemopyra recticosta Breuer *et al*., 2007
Artemopyra cf. *recticosta* Breuer *et al*., 2007
Brochotriletes foveolatus (Naumova) McGregor, 1973
cf. *Brochotriletes foveolatus* (Naumova) McGregor, 1973
Chelinospora retorrida Turnau, 1986
Cirratriradiates diaphanus Steemans, 1989
Cymbosporites asymmetricus Breuer *et al*., 2007
cf. *Cymbosporites asymmetricus* Breuer *et al*., 2007
Cymbosporites spp.
Dibolisporites echinaceus (Eisenack) Richardson, 1965
Dibolisporites eifeliensis (Lanninger) McGregor, 1973
Dibolisporites cf. *eifeliensis* (Lanninger) McGregor, 1973
Dibolisporites spp.
Dictyotriletes emsiensis (Allen) McGregor, 1973
Dictyotriletes aff. *emsiensis* sensu Le Hérisse, 1983
Dictyotriletes emsiensis morphon sensu Rubinstein *et al*., 2005.
Dictyotriletes granulatus Steemans, 1989
Dictyotriletes subgranifer McGregor, 1973
Dictyotriletes sp. cf. *D. richardsonii* Steemans, 1989
Dictyotriletes spp. (*D. emsiensis* ?)
Emphanisporites rotatus McGregor, 1973
?*Knoxisporites riondae* Cramer & Díez, 1975
Retusotriletes maculatus McGregor & Camfield, 1976
Retusotriletes sp.
Synorisporites papillensis McGregor, 1973
Synorisporites verrucatus Richardson & Lister, 1969
Tetrahedraletes medinensis Strother & Traverse emend. Wellman & Richardson, 1993
Zonotriletes sp.

Acritarchs and algae

Anthatractus insolitus Deunff, 1954
Baltisphaeridium paraguaferum Cramer, 1964
Deunffia sp.
Diexallophasis remota (Deunff) Playford, 1977
Gorgonisphaeridium sp.
Leiosphaerida spp.
Polyedryxium decorum Deunff, 1955
Quadrisporites granulatus Cramer & Cramer, 1972
Quadrisporites horridus (Hennelly) Potonié & Lele, 1961
Schizocystia sp.
Tasmanites sp.
Tyligmasoma spp.
Veryhachium rabiosum Cramer, 1964
Veryhachium trispiniflatum Cramer, 1964
Veryhachium spp.

Chitinozoans

Ancyrochitina pachycerata Gaugris & Grahn, 2006
Ancyrochitina n.sp. C sensu Gaugris & Grahn, 2006 = *Ancyrochitina* aff. *A. pachycerata*
Ancyrochitina sp. B sensu Grahn, 2000
Ancyrochitina varispinosa? (Lange, 1967)
Ancyrochitina spp.
Angochitina daemoni Grahn, 2000
Ramochitina magnífica Lange, 1967
Ramochitina ramosi Sommer & Boekel, 1964