

Storm deposited pebble and cobble-sized particles in the early Emsian of the Ponta Grossa Formation, Paraná Basin (state of Paraná, Brazil)

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Abstract Quartzite pebble and cobble-sized particles from an arenaceous siltstone with fine sandstone lenses have been found at two localities in the Campos Gerais region, Apucarana Sub-Basin (Paraná Basin), south Brazil. These particles were first interpreted as glacial diamictites, but their smooth surfaces and surrounding sediments indicate another origin. Two of the pebbles are associated with a small scale hummocky cross stratification in the top layer, and with fine sandstone layers below, which is indicative of currents formed by oscillatory flow. None of the particles show any traces of encrustation, and their morphology suggests they have been formed in a fluvial environment. The surrounding siltstone is affected by bioturbation and contain brachiopods (*Australospirifer*). Palynomorphs indicate that these storm deposits were formed during an early Emsian maximum inundation on a transgressive ravinement surface.

Keywords: Storm deposited particles, palynomorphs, early Emsian.

Resumo Seixos depositados por tempestades durante o Eoemsiano na Formação Ponta Grossa, Bacia do Paraná (estado do Paraná, Brasil). Seixos de quartzito em siltito arenoso com finas lentes de areia foram encontrados em duas localidades da região dos Campos Gerais do Paraná, sub-bacia de Apucarana, Bacia do Paraná, sul do Brasil. Estes seixos foram inicialmente interpretados como diamictitos glaciais mas suas superfícies lisas e as características sedimentares circunvizinhas indicam outra origem. Dois dos seixos são associados a estruturas do tipo hummocky cross stratification de pequeno porte, o que é indicativo de correntes formadas por oscilação de ondas. Nenhum dos seixos mostram traços de encrustação. O siltito que suporta os seixos é afetado por bioturbação e contém braquiópodes (*Australospirifer*). Palinórfos indicam que estes depósitos de tempestades foram depositados durante uma inundação máxima do Eoemsiano.

Palavras-chave: seixos depositados por tempestades, palinórfos, Eoemsiano.

INTRODUCTION Only one publication has mentioned or discussed big pebbles or cobbles in the Ponta Grossa Formation. Soares & Malanski (1968) described three quartzite particles found in the Ponta Grossa Formation in a well near Franco da Rocha Hospital (= Franco da Rocha in this paper). They interpreted these as glaciogenic diamictites. Another possible explanations, not discussed by these authors, are transport with plants or unidirectional currents. Conglomerates containing gravels (≤ 1 cm) are well-known from the Furnas Formation (Lange & Petri 1967, Bigarella & Salamuni 1967), where they occur at several stratigraphic levels within the sandstones. A similar conglomerate has been mentioned from the Middle Devonian São Domingos Formation sensu Melo 1988 and Grahn 1992 (Lange & Petri 1967 p. 23). However, in these conglomerates the gravel occurs in an arenaceous matrix of fluvial or near shore origin, in contrast to the siltstone matrix in which occur the big quartzite particles here described.

LOCALITIES Two localities with big quartzite pebbles and cobble are known from the Ponta Grossa Formation, i.e. Franco da Rocha and Tibagi 2 (Figs. 1

e 2). At both localities the particles occur in sediments deposited during a maximum inundation (MFS – maximum flood surface) in sequence B sensu Bergamaschi & Pereira (2001). The lithology is an arenaceous siltstone with lenses of fine sandstone.

Franco da rocha

(25° 03' 21,43" S, 50° 08' 10,18" W)

This locality (Figs. 1 e 2) was first described by Soares & Malanski (1968). It is a 12,5 m deep well constructed for the water supply of a nearby hospital (Fig. 2). Two quartzite pebbles and a cobble occurred about 8 m from the top, and an estimated 52-53 m above the Furnas/Ponta Grossa contact (Fig. 2). No fossils were collected. The sequence probably corresponds to the top of the section at Curva 1 (25° 03' 56" S, 50° 08' 00" W), described by Bosetti (2004), situated ca. 150 m SSE of the Franco da Rocha locality (Fig. 2).

Tibagi 2

(24° 29' 51" S, 50° 25' 00" W)

The locality (Figs. 1 e 2), no longer accessible, was described by Zabini (2007) and Zabini *et al.* (2010) in pa-

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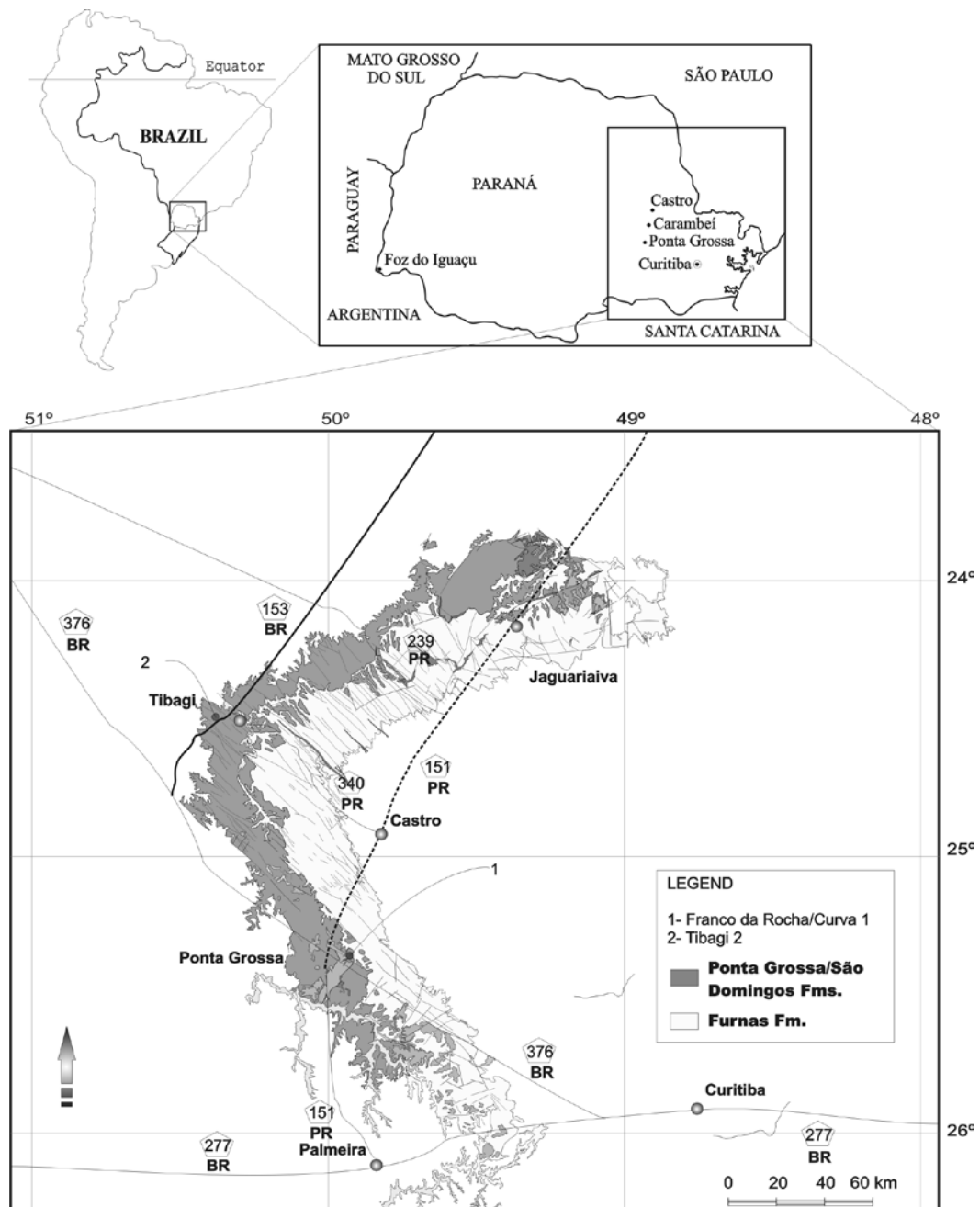


Figure 1 - Location map for the localities investigated.

pers discussing lingulid taphofacies. Two quartzite pebbles were collected from the upper part (Fig. 2), and at an estimated 55 m above the Furnas/Ponta Grossa contact (Fig. 2). A sample was taken for dating purposes from a horizon stratigraphically above the top layer of Tibagi 2 in an outcrop along the Tibagi – Alto da Amparo road (BR-153). No palynomorphs were encountered.

EVIDENCE FOR STORM DEPOSITION OF THE PEBBLES AND THE COBBLE Altogether four quartzite pebbles and one cobble with a size range between 12.5 and 95 mm (Fig. 3) are known from the Ponta Grossa Formation, attributed to a maximum inundation surface in the early Emsian (see below).

The occurrences of these particles are scattered and found in a dark arenaceous siltstone with gravel indicating either a transport to their position in the inner shelf or as a result of reworking (Tamura & Masuda 2005) of earlier sediments (transgressive ravinement surface). The surrounding siltstone contains a benthic fauna dominated by lingulids and bivalves (Bosetti & Horodyski 2009). The particles are smooth, and there are no glacial striations, encrustation or any eroded remains of encrusting organisms. Their shape suggests they were formed in a fluvial environment. The brachiopod *Australospirifer* is associated with the pebbles (Fig. 3J), and this genus characterizes the Marine Benthic Life Zone 3 and/or 4 (Boucot, 1975, personal

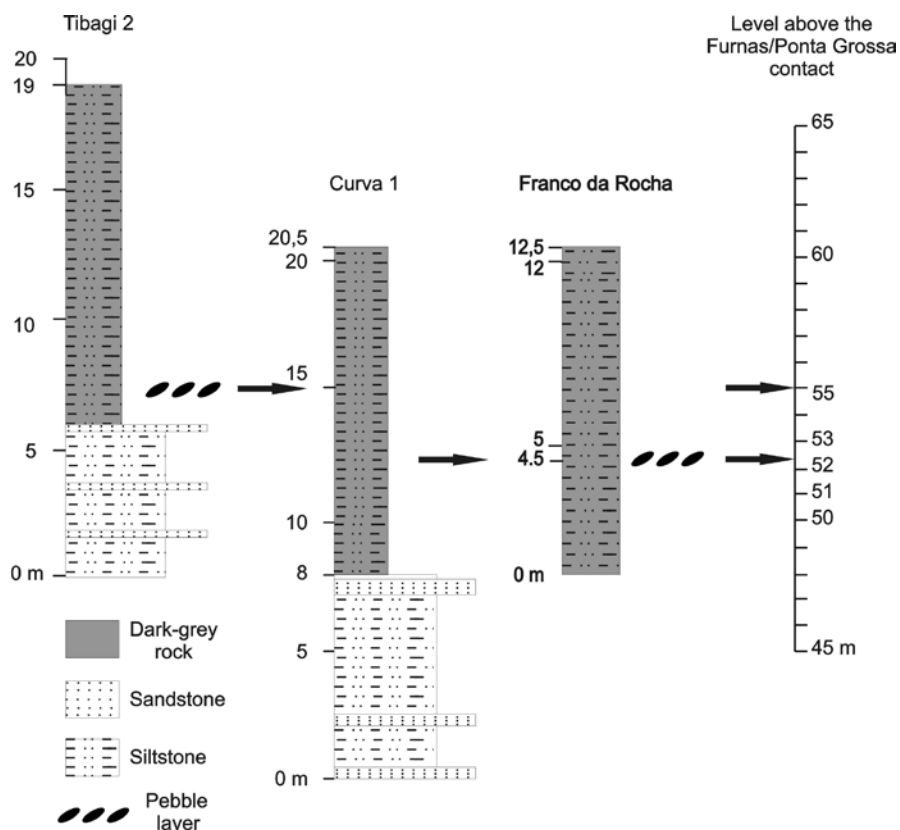


Figure 2 - Lithologic columns for the Tibagi 2, Curva 1, and Franco da Rocha localities.

communication 2009), representative of a shoreface to shallow inner shelf environment, at a depth interval between 15 and 75 to 175 m.

Land plants with roots large enough to transport big pebbles are known from the upper Emsian Fort Prével Member of the Battery Point Formation, Gaspé Bay, Québec, Canada (Elick *et al.* 1998). These plants had rhizomatous roots that penetrated the sandy soils up to a depth of ca. 1 m. If uprooted, such plants could have been transported with riverine pebbles of comparable size to the shoreface. However, the age of the sediments hosting the pebbles in the Ponta Grossa Formation are older than the Battery Point Formation plant-bearing beds. Furthermore, there are no root impressions or any other evidence that suggests this possibility.

Another possibility are currents combined with oscillatory flow. The surface layer containing the big pebbles is irregular and displays a small scale hummocky cross stratification confirming influence of oscillatory movements (Fig. 3K). Hummocky cross stratification is thought to be formed by storm wave surges on the shoreface (Harms *et al.* 1975). The structure is also considered as diagnostic of inner shelf storm deposits (Swift *et al.* 1983). Below the hummocky cross stratified layer the beds contain lenses of fine-grained sandstone (Fig. 3K). No truncation surfaces have been observed, and the beds can only be explained by the deposition of sand by a single event.

A strong and highly concentrated unidirectional flow is required to transport the amount of sediments needed (Myrow & Southard 1991). Beds like those from Tibagi 2 (Figs. 3 I, K) can be produced by flows on slopes with an angle less than 1° (Carter 1975).

A possibility is that storms eroded the beach sediments and transported the sands to the inner shelf by grain flow, strongly influenced by oscillatory waves (Duke *et al.* 1991). The gravel, pebbles and the cobble settled on the top of the grain flow through pore pressure when the beds were deposited through frictional freezing (Carter 1975). Modified grain flows with a high concentration and cohesive matrix support and a lift provided with flow turbulence (Enos 1977), or traction carpets, would concentrate larger particles on the top of laminar flows through dispersive pressure (Lowe 1979).

However, we favour an explanation that the pebbles and the cobble in the lower Ponta Grossa Formation were a part of a transgressive ravinement surface and deposited in a shoreface environment, where storm processes completely reworked previous deposits, and redistributed the scattered larger particles on these surfaces. In this case, coarse clasts must form surfaces, even though as scattered pebbles (Souza Cruz personal communication 2009). However, hummocky cross-stratified beds generally are too thick (> 20 cm) to be accounted for by in situ suspension (Swift *et al.*

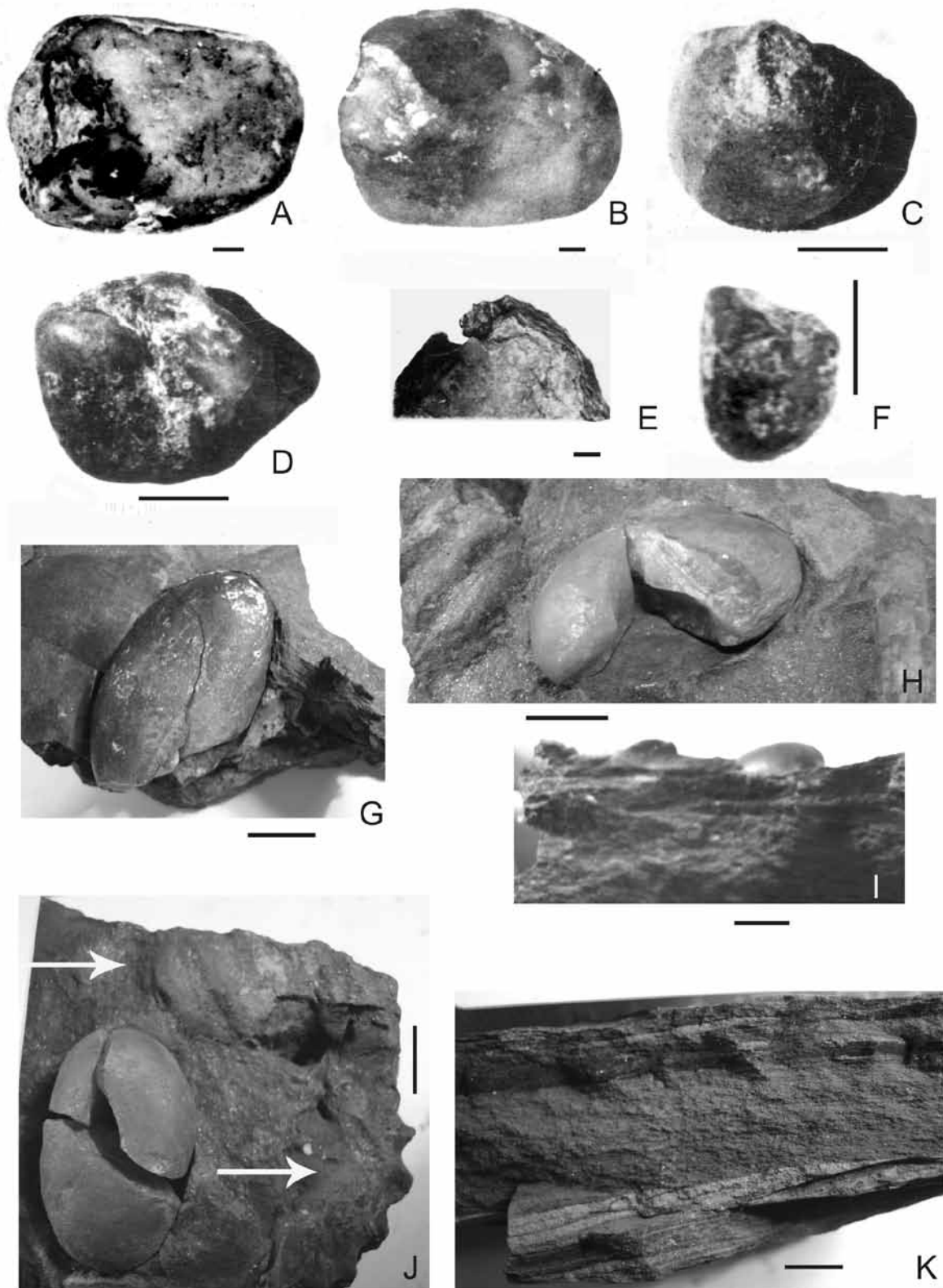


Figure 3 - Quartzite pebbles and associated sedimentary structures from the Ponta Grossa Formation. Figures A-F from Soares & Malanski (1968). MPI = Museu de Paleontologia – Invertebrados. Ponta Grossa. The scale bar represent 10 mm. A-B) Pebble no.1 by Soares & Malanski (1968). Franco da Rocha. C-D) Pebble no.2 by Soares & Malanski (1968). Franco da Rocha. E) Detail of pebble no.1. F) Pebble no.3 by Soares & Malanski (1968). Franco da Rocha. G) Pebble MPI 1500 from Tibagi 2. H) Pebble MPI 1501 from Tibagi 2. Note the gravel on the surface of the siltstone. I) Side-view of pebble MPI 1500. J) Complete pebble MPI 1501. The arrows points at specimens of *Australospirifer*. K) Detail of the storm deposit with pebble MPI 1500. Note the 2 cm thick hummocky cross stratification followed by laminated sedimentation with fine sandstone lenses.

1983), but in this case they are only 2 cm thick (< 1 cm wide). If this is a correct interpretation the reworking took place at a depth of 15 m, or slightly below, according to the incorporated fauna. The closed valves of the *Australospirifer* specimens suggests they either were in situ or transported a short distance.

AGE OF THE STORM DEPOSITS The base of the maximum inundation (MFS) in sequence B sensu Bergamaschi & Pereira (2001) has been dated as early Emsian based on spores, acritarchs, and chitinozoans from several localities in the Paraná Basin, e.g. the Jaciara (Mendlowicz Mauller *et al.* 2007, 2009), Jaguariaiva (Grahn *et al.* 2000, Mendlowicz Mauller *et al.* 2009) and Tibagi – Telemaco Borba (Grahn *et al.* 2000) sections, and the 2-AG-1-MT (Grahn *et al.* 2000, Mendlowicz Mauller *et al.* 2009), Paleosul-02-RV-MS (Mendlowicz Mauller *et al.* 2009), RVR-1 (Gaugris & Grahn 2006, Mendlowicz Mauller *et al.* 2009) and 9-PPG-7-PR (Gaugris & Grahn 2006, Mendlowicz Mauller *et al.* 2009) wells. A sample collected from a road cut (Fig. 1B) of the Tibagi – Alto de Amparo road (BR 153), just above the pebbles at Tibagi 2, did not contain any palynomorphs. Since middle Emsian (AB – FD spore zones) are missing, or very condensed, in the Paraná Basin (Melo & Loboziak 2003, Grahn 2005) the lower MFS level in sequence B probably corresponds to the uppermost PoW spore Zone.

CONCLUDING REMARKS Particles with a length over 10 mm are rare in the Ponta Grossa Formation sensu Grahn 1992. Four quartzite pebbles and a cobble with a size range from 12.5 to 95 mm have been found in two localities at levels corresponding to a maximum inundation (MFS) in sequence B by Bergamaschi & Pereira (2001). These levels have been dated as early Emsian (uppermost PoW spore Zone). The quartzite pebbles and the cobble occur parallel

to the bedding planes in an arenaceous siltstone, and they are perfectly smooth. The deposits are either unidirectional flows, where the top layer displays a small scale hummocky cross lamination, and the layers below fine sandstone lenses. This is characteristic features for a deposition of a current induced and influenced by oscillatory flow action. The pebbles are associated with brachiopods (*Australospirifer*) from a shoreface to shallow inner shelf environment. If a result of a grain flow the gravel and the pebbles settled on the top of the flow through pore pressure when the beds were deposited through freezing, or through high concentration and cohesive matrix support and a lift provided with flow turbulence and a dispersive pressure. We favour another more likely possibility that the pebbles and the cobble were a part of a transgressive ravinement surface and after the sediments were reworked by storm actions settled on top of the new surface.

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