

Appendix 1

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1. Description of regional points

Regional points are sites where outcrops of high interest occur, from a didactic standpoint. They clearly and explicitly represent different types of facies found in the Itararé Group, in various places in São Paulo State (Brazil) in the area of Itu/Salto, Porto Feliz and Sorocaba. For those intending to conduct scientific studies, visiting these sites is of high didactic interest, and they are important as a starting place for conducting area reconnaissance.

Site R1 – Outcrop located in Monções Park, in Porto Feliz

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude (m)	Error	Datum
23K	0241316	7431029	489	1m	Córrego Alegre

The outcrop is located in Monções Park, in Porto Feliz (Figure 1.1). It consists of a N-S wall, essentially constituted of sandstone, that can be divided into three packages with great lateral variation. At the point marked on the sketch, the outcrop wall has approximately 15m high and at least 80m long (Figure 1.1).

R.1 - Parque das Monções, Porto Feliz (SP, Brazil)

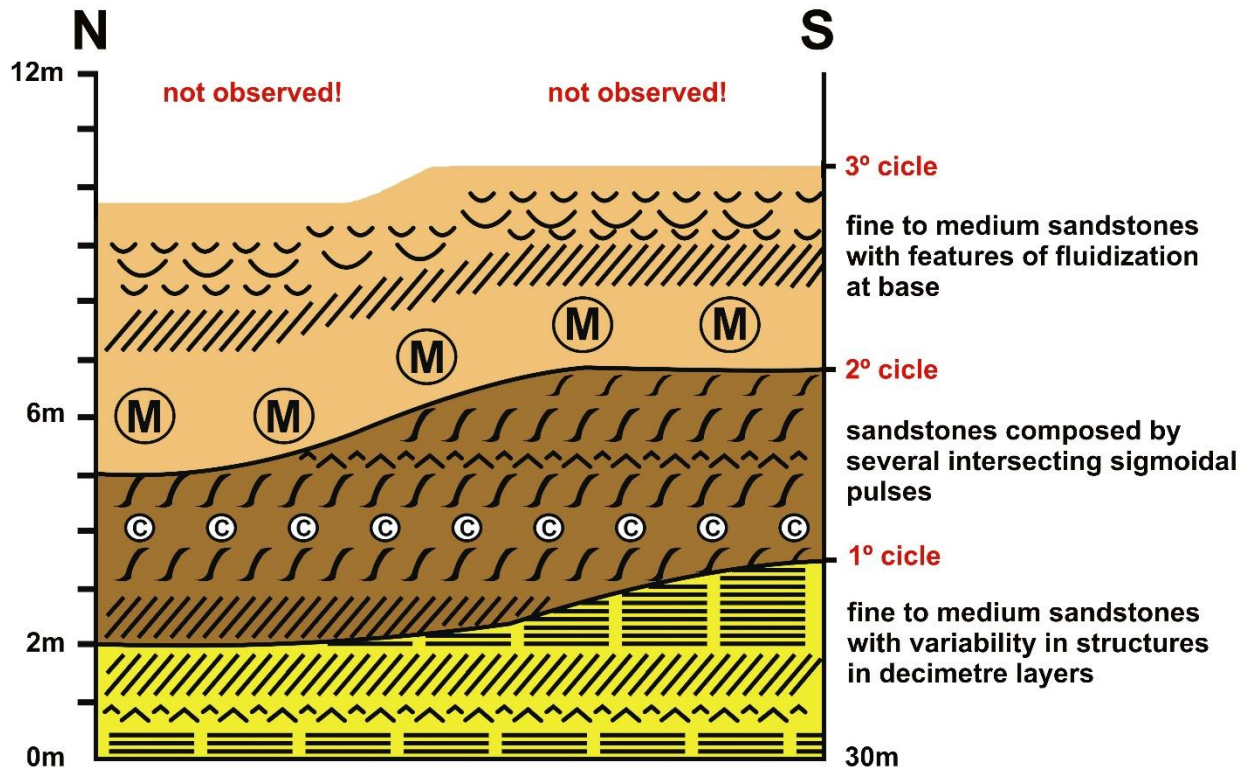


Figure 1.1 – Sketch of the outcrop at Monções Park.

The first package consists of four tabular sandstone strata, with fine to medium grain size, constituted of well sorted yellow colored particles. It exhibits various structures, from base to top: plane-parallel stratification; unidirectional flow ripples; tabular cross stratification; and another layer with plane-parallel stratification (facies Str; Table 3).

The second package, consisting of a yellowish, fine to medium sandstone with well selected grain size, exhibits a sigmoidal shape (facies Ssp, Table 3) (Figure 1.2). The presence of this sigmoid shape indicates progradation. At the base, it exhibits tabular cross stratification, which indicates that the direction of the paleocurrent was to northward (S_0 5°/23°). The top of this layer exhibits undulations, indicating that it was a dune created by a current. Above this layer, three series of sigmoidal lobes were observed. Between them, there are carbonate levels, concretions and nodules of medium sand grain size. There are also ripples originated by a unidirectional flow. The analysis of the climbing angle of the ripples revealed that they are supercritical, with the angle rapidly increasing towards the North, which is indicative of a strong deceleration of the flow.



Figure 1.2 - Photos representative of the second outcrop package. A. Panoramic. B. Showing carbonate concretions. C. Massive to tabular, with some ripples and tabular cross stratification.

The third outcrop package is massive to tabular, with some ripples and tabular cross stratification (Facies Ssp). These facies probably represent a progradational delta deposit dominated by gradational flows processes, in glaciomarine context. Similar facies have been associated to resedimentation processes in the context of retreat of glaciers along the eastern border of the basin.

Site R2.1 – Outcrop located in an abandoned rock quarry

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0261637	7426867	540m	3m	Córrego Alegre

Outcrop located in a site used for clay extraction for the ceramic industry, close Marechal Rondon highway (km 110), approximately 15m thick, divided in packages, from base to top (Figure 1.3):

- Dark gray laminated siltstone intercalated with very fine sandstone milimetric laminas (like a distal rithmite) (Facies Rh). The dark color of this facies is not linked with high organic matter content, but rather may be associated with the presence of Mn. Average thickness is 3 m.
- Red shale, due to oxidation, with internal plane parallel geometry. It exhibits slump features caused by the overlying layers, indicating that it originated from a fluidized sediment with ductile behavior. The package is approximately 3 m thick (facies Rh).
- Polymictic diamictite with grayish-brown colored, with a silty/clay matrix and oblate quartz and pebbles of Itu Granito Vermelho (red granite) from the basement (Figure 1.4). Its external geometry is sigmoidal and, sometimes, tabular, and the internal structure is massive (facies Df, Dm). The package is approximately 2 m thick.



Figure 1.3 - Photo representative of the outcrop wall of the quarry. Facies Dm.

Package approximately 7 m thick, exhibiting light, fine sandstone with tabular external geometry and massive internal geometry. The top has current ripples (critical and supercritical climbing ripples). The sandstone is interbedded with centimetric levels of dark siltstone, with plane parallel laminations (facies Str and Fl).

Package approximately 2.5 m thick, exhibiting interbedding between lightly laminated dark shale and fine to medium sandstone. Externally, exhibits slump folding. The rock exhibits low grade alteration, thus its original yellowish color is still preserved (facies Fl and Str).

Package approximately 4 m thick, with an internal arched structure at the base, onlaps at the sides of the arch, and plane parallel structure at the top. It exhibits interbedded fine and very fine sandstones, defined by their coloring. In the darker strata (very fine), current ripple structures are more evident. Each variation exhibits subtle fining upwards (facies Str).

The organization of the packages first exhibits a coarsening-upwards, then, from the fourth package onwards, a thinning-upwards.

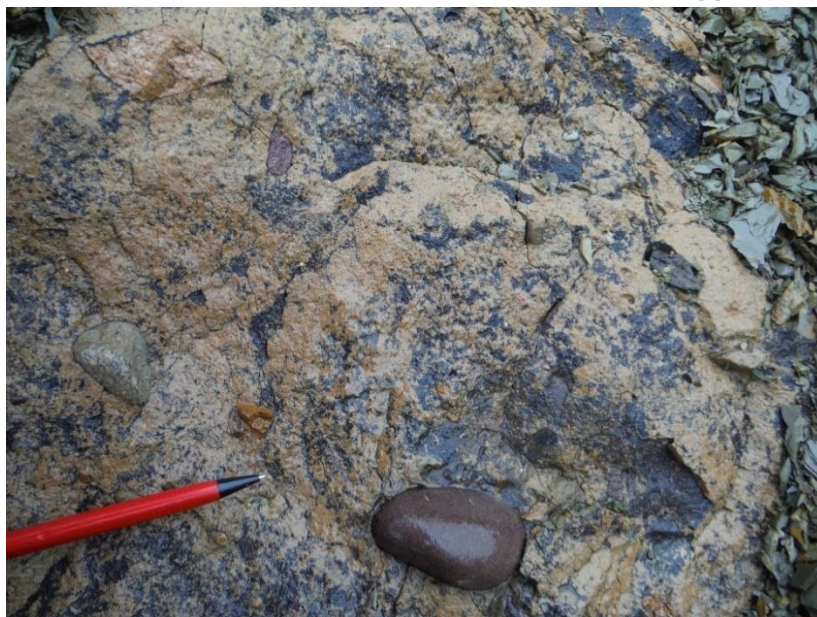


Figure 1.4 - Photo of the diamictite with dispersed faceted clasts (facies Dm).

The analysis of the stacking suggests that the sediments probably were deposited in a glacio-lacustrine environment, contemplating both facies of more distal portions and relatively more proximal facies of this system (facies Dm, Df, Ssp, Str). The presence of diamictite facies with sigmoidal geometry (Dm and Df facies) and tabular and sigmoidal bodies of sandstone with climbing ripples suggest the action of gravity flows (debris and mudflows, facies Dm and Df, and turbidity currents, Str) in this subaqueous system. Such gravity flows are associated with advances and retreats of glacier, which induce the release of a significant amount of sediment and water, as well such as triggering of resedimentation processes in this depositional system. The slumps observed in the second shale package may be due to the sliding of the overlying diamictite and sandstone packages, as well as the own weight of the moving glacier.

Site R2.2 – Outcrop located along a railroad right-of-way

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0261653	7426852	546m	3m	Córrego Alegre

Outcrop located along a railroad right-of-way, oriented S-N, near the prior quarry outcrop (just above the top of the outcrop of the site R2.1). It is composed of decametric packages of fine sandstone interbedded with centimetric levels of shale (Fl). The sandstone packages are, in general, yellowish, with fine to medium sand size, tabular geometry, and massive or with unidirectional flow ripples (climbing ripples) (facies Str). At a certain point in the outcrop, there is a deformation (Figure 1.5). On the North flank of the deformation, the interbedded layers are thicker.



Figure 1.5 - Outcrop located along a railroad right-of-way, showing deformed layers.

Further south, still along the railroad right-of-way, there is a cut in which a yellowish sandstone package can be observed. It is tabular and display current ripples. The package is characterized by plastic deformations in a specific interval (Figure 1.6), that is, folds, which were caused by plastic deformation the deposition of truncated and overlain layers, possibly originated by plastic deformations by sliding of strata on a slope in depositional lobe.



Figure 1.6 - Plastic deformation of layers.

This facies association (Str and Fl) records the action of turbidity currents in the context of unconfined gravity flows, which may represent the distal portions of the depositional lobes or interlobes domains.

Local R3 – Outcrop along a road right-of-way (located on Rodovia do Açúcar)

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0262176	7432814	520 m	2m	Córrego Alegre

Outcrop, of the type “cut along a road right-of-way”, located on Açúcar highway. Its total thickness is approximately 12 m, divided in two packages, from base to top:

Polymictic diamictite, 4 m thick, intermediate grade alteration, and brownish red color (Figure 1.7). Formed by a melting flow, it has a sandy matrix, fine to medium grain size, rounded clasts varying from pebbles to boulders, of various origins, and even lithic, highly angular fragments concentrated along the base of the package (facies Dm).



Figure1.7 - Photo representative of the diamictite (Dm).

Overlying the diamictite basal level is a at least 6 m thick interval composed by metric yellowish sandstone bodies intercalated with thin siltstone intervals (Figure 1.8) (facies Fm). The sandstone bodies have a grain size ranging from fine to medium and sigmoidal geometries (facies Ssp). The sigmoidal lobes present massive or small scale cross bedding and climbing ripple internal structures, as well as fluid escape features. The siltstone levels, gray and decametric in thick, has good lamination. Above, various cycles of normal gradation were observed, composed of massive, tabular, fine sandstone packages (Str facies), with siltstone lenses that become thinner towards the top of the outcrop.



Figure 1.8 - Photo of the outcrop, showing interbedding of sandstone with siltstone (Str / Fl facies).

This composition represents a facies proximal to the glacier at the time, indicating a rise in the water column in the region of the basin, or a retreat due to more intense melting of the glacier (Figure 1.9). The observed external geometry of the packages demonstrates that the depositional space was a ramp in a shallow water body, possibly a lagoon or a lake. No erosive features were observed among the layers.

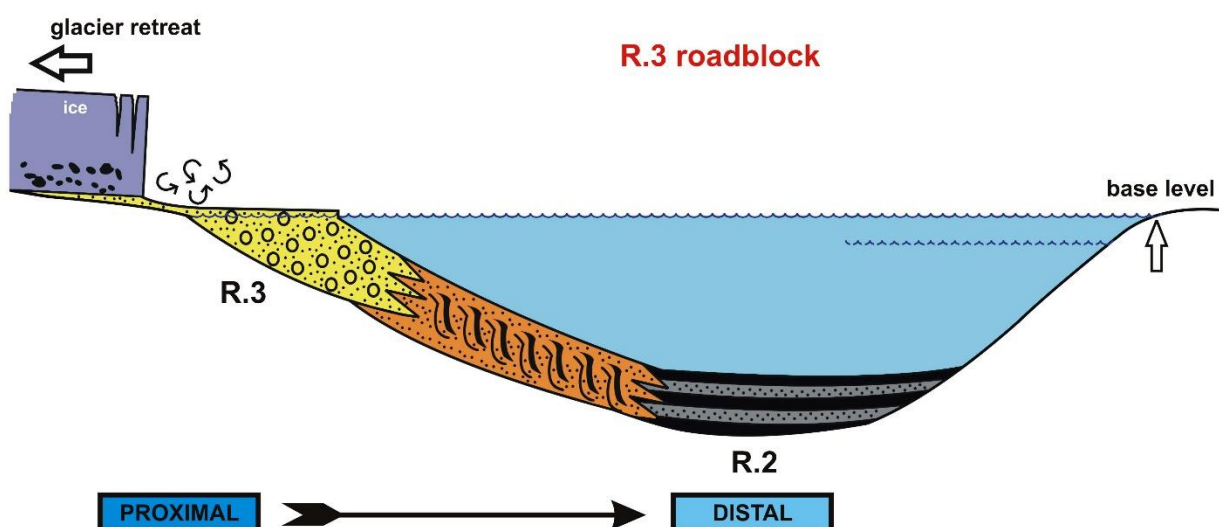


Figure 1.9 - Schematic drawing representing the environmental characteristics of the depositional space of the sedimentary packages described in the prior sites.

Site R4 – Outcrop along a cut in the road right-of-way, in Marechal Rondon Highway

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0254408	7428427	551m	X	Córrego Alegre

Outcrop along a cut in the road right-of-way, in Marechal Rondon Highway, composed of diamictite at the base, with a siltstone layer above. The grayish polymictic diamictite (Figure 1.10), 1 m thick, contains pebbles and subangular to subrounded granules of different compositions, faceted and granules, well distributed and abundant (facies Dm). This package contains a heterogeneous matrix composed of silt and very fine, immature sand. The top is composed of laminated, reddish gray siltstone, with high grade alteration. It is at least 0.5 m thick, tabular, very well laminated, and has good lateral continuity (facies Fl). This siltstone exhibits pebbles.



Figure 10 - Photo representative of the diamictite of the outcrop along a cut in the road right-of-way, in Marechal Rondon Highway (facies Dm).

Considering the prior site, the lithological characteristics of this outcrop indicates that it represents a more distal portion of the glacier (Figure 1.9), since the pebbles and granules that comprise the diamictite are smaller and less abundant.

Site R5 – Outcrop along a cut in the road right-of-way, in Porto Feliz-Boituva Road

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0254408	7428427	550m	X	Córrego Alegre

Outcrop along a cut in the road right-of-way, in Porto Feliz-Boituva Road (Figure 1.11). The total thickness of the package is at least 15 m, composed of the interbedding of shale and fine sandstone, with a tabular geometry displaying a great lateral continuity.

There can thus be observed various aggradation cycles, composed of decimeter, fine yellowish sandstone packages, tabular and massive or laminated (Str facies), interbedded with centimetric layers of grey, laminated shale (facies Fl). Along this interbedding are manganese oxide precipitations (Figure 1.12).



Figure 1.11 - Photo of the cut along the road right-of-way, in Porto Feliz-Boituva Road.

Further up along the topography, in the NNE direction, following the outcrop laterally and in top direction, the sandstone layers become progressively thinner and the shale interbedding becomes greater, as indicated by the increase in the shale thickness.

The interval as a whole represents deposits of turbidity current in more distal context of the lobe deposits. These layers suffered intense deformation caused by slumps (Figure 1.13).

Such predominantly fine facies represent the frontal part of the slump. Due to the rheological behavior of the clays, tight folds can be seen, as well as micro faults and domino faults (Figure 1.14).



Figure 1.12 - Photo of a hand sample of fine sandstone, tabular and massive, with interbedding of manganese oxide



Figure 1.13 - Photo of the slump-induced fold features (Facies Str / Fl).



Figure 1.14 - Photo of a hand sample, showing micro faults and domino faults.

Site – R6 – Outcrop in Moutonnée Rock Park

Coordinates					
UTM Zone	X Axis	Y Axis	Altitude	Error	Datum
23K	0264313	7431369	514m	X	Córrego Alegre

Outcrop of a *moutonnée* rock in Moutonnée Rock Park (Figure 1.15). It consists of a structural high of the basement, exposing the movement of the glacier over the Itu Granito Vermelho (red granite), which is the local basement rock. Structures that evidence the orientation of the glacier movement can be seen, such as striations and crescent fractures (Figure 1.16). The direction the movement was obtained from the striations, indicating that the glacier moved NE (S_0 300° and 330°).

Adjacent to the granite, a lodgment tillite (Df) can also be observed, with faceted and polyimictic pebbles of various sizes, and over them, a layer of highly altered shale (Fl).



Figure 1.15 - Moutonnée striated rock in Moutonnée Rock Park.



Figure 1.16 - Photo of a crescent-shaped fracture.