# SIMPÓSIO INTERNACIONAL SOBRE OS SISTEMAS CARBONÍFERO E PERMIANO NA AMÉRICA DO SUL

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# TREND-SURFACE ANALYSIS OF CARBONIFEROUS AND PERMIAN THICKNESS DATA FROM PARANÁ BASIN (*)

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## INTRODUCTION

The Paraná Basin with an area of approximately 1,500,000 $km^2$ is limited by parallels of 15° and 34° S and 47° and 58° W meridians. Its main geotectonic features are: the Canastra Arch in the northeast; the Ponta Grossa Arch, the Torres Syncline and the Uruguayan Shield in the east; the Martim Garcia Arch in the south; and the Puna, Asunción and Pampean Arches in the west (Fig. 1). The basin shows presently an ovoid shape.

Proliferation of facies descriptions mainly for the Paleozoic formations, although of great value for paleoenvironmental reconstruction, has caused some difficulties to the understanding of the tectonic evolution of the basin. However, if one considers only the great sedimentary cycles, which are separated by regional unconformities, its tectonic history could be much easier understood.

Stratigraphic sequences, as defined by Sloss (1963) for North America, represent a valuable tool for the interpretation of the tecto-sedimentary history of intracratonic units and its correlation with other basins. In this sense, Fúlfaro & Landim (1972) proposed the subdivision of the Paraná Basin sedimentary cover into three stratigraphic sequences: the lowermost Devonian, the middle one-Permo-Carboniferous, and the uppermost Mesozoic.

An analysis of the Paraná Basin Permo-Carboniferous sequence, which includes the glacial, interglacial and post-glacial sedimentary deposits of the Tubarão and Passa Dois groups is presented in this paper (Table 1).

Regional stratigraphic studies of, this unit on basis of outcrop analysis is complicated by facies change and intervening episodes of erosion at the margin of the basin. The scarce subsurface data (less than 50 wells in an area of 1,500,000 $km^2$) can, nowithstanding, be adequately analysed trough the trend surface technique. This technique allows us to work with sequences thicknesses, since their variations represent an effective measure for the study of evolution of structural features.

The tectonic evolution of a region can then be studied through the preparation of a series of isopach maps for successive stratigraphic intervals. Since the isopach maps tend to show considerable influence of local variations, the smoothening effect of the trend analysis is useful for depicting large scale local variations and re-

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gional thickness variations (Harbaugh & Merrian, 1968).

## GENERAL CHARACTERISTICS

### TUBARÃO GROUP

The glacial, interglacial and early post-glacial sedimentary deposits outcropping on the eastern and southern side of the Paraná Basin are included in the Tubarão Group. Sedimentary rocks correlatable to this sequence in the northern and western parts of the basin are known as the Aquidauana Formation. These rocks rest unconformably on the Paraná Group sediments (Middle to Upper Devonian) and the crystalline basement of pre-Silurian age. The upper contact with the Passa Dois Group sediments is arbitrarily established, since no break in the sedimentary process is recognized, except in the basin marginal areas (Landim, 1967, and Fúlfaro, 1970). The black shales and interbedded limestones of the Irati Formation, nowiths tanding constitute a good guide-horizon for separation of the two groups (Mendes & Fúlfaro, 1966).

Spatial relationships among formations within the groups are complex and not very well understood. The stratigraphic relationship between the Itararé and Aquidauana formations is a good example of this situation, the latter being considered, either as older (Northfleet et al., 1969) or younger than the Itararé (Fúlfaro, 1971).

Landim (1970) suggested, alternatively interfingering relationship between the two formations in the northeastern part of the State of São Paulo. Unconformable contact of the Aquidauana with the overlying Palermo Formation (Northfleet et al., 1969) and transitional contact with the Irati Formation have been described (Petri & Fúlfaro, 1967). Fúlfaro & Landim (1972) on basis of lithological difference between the Aquidauana outcropping in the western basin margin (State of Mato Grosso and Republic of Paraguay) and the same formation in the State of Goias, suggested that they may actually represent two different stratigraphic units.

Sediments of the Itararé Formation were deposited under glacial and interglacial conditions which ruled the Paraná Basin during the Upper Carboniferous and Lower Permian. Analysis of sedimentary structures and rock distribution indicate that continental type of glaciation, very similar to the one prevailing in the northern hemisphere during the Pleistocene is an adequate model for the study of the glacial deposits of the Paraná Basin. Recognition of number of glacial phases is doubtfull. Frakes and Crowell (1969) admited 10 distinct ice advances.

The glacial sediments deposited in subsiding basins (Landim, 1970) were very often subjected to reworking during retreat of the ice-wedges. Consequently, only a few sedimentary deposits may represent norainic material, the larger part being constituted by outwash sediments. Contacts of the Tubarão Group with the pre-Silurian basement in the State of São Paulo is generally marked by a well defined surface of erosion with lowermost sediments being constituted by breccias and conglomerates including clasts of local basement deposited in channel-like depressions. A high tectonic margin instability can thus be admited, which resulted in a intense process of reworking of previous sedimentary deposits at the basin margins. Petri & Fúlfaro (1967) showed that most part of Devonian sediments in southern São Paulo were removed by erosion after an uplift caused by faulting. The reworked material was deposited in channels excavated in the basement rocks.

At least in these areas initiation of deposition of the Itararé sediments occurred in small basins formed mainly by faulting, which could represent the initial phases of formation of the Paraná intracratonic basin. Althought striated basement rocks are know from several places developed on crystalline and Devonian rocks, glacial deposits have not been recognized in the basal Itararé.

Marine layers may occur associated with mixtites specially toward the eastern margin of this basin. The meager fossil assemblages of these beds vary in the different outcrops. Thin coal beds, probably related to interglacial or interstadial phases also occur intercalated within the sequence. An autoctonnous limnic origin is generally accepted for these beds, an interpretation not entirely consistent with the available geological evidences. Both the marine layers and coal beds are restricted to the eastern margin of the Paraná Basin.

Post-glacial conditions probably started earlier in the southern Paraná Basin, while glacial conditions were still prevailing in the north. Basin-wide tectonic changes during the depositional cycles can be detected from the glacial and post-glacial thickness analysis. The greater thickness of the glacial sequence is located at the «paulista-goiano-matogrossense» sub-basin (Fúlfaro, 1970), which shows higher rate of subsidence in relation to the southern part of Paraná Basin which behaved as a more positive tectonic area.

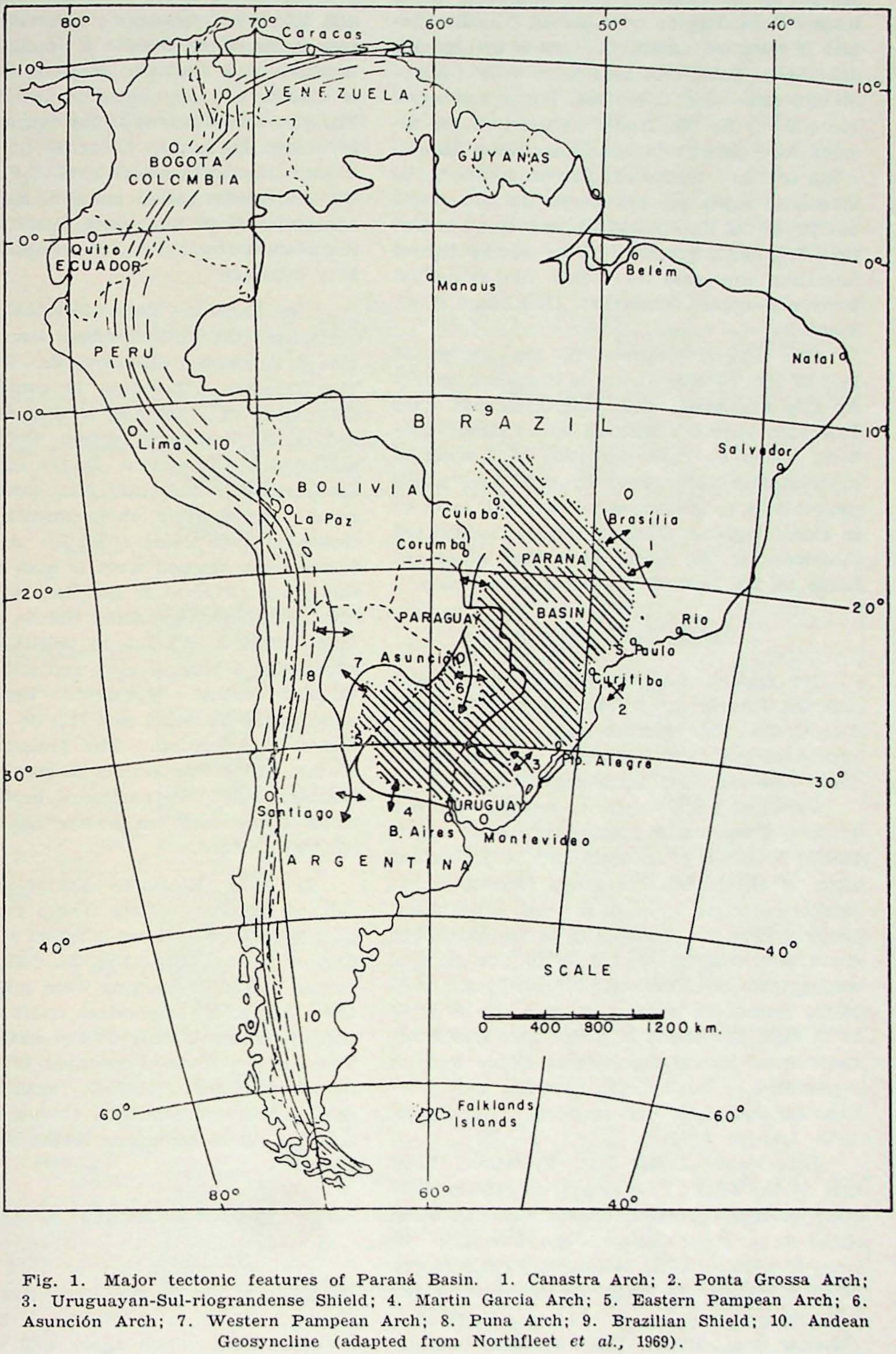


Fig. 1. Major tectonic features of Paraná Basin. 1. Canastra Arch; 2. Ponta Grossa Arch; 3. Uruguayan-Sul-riograndense Shield; 4. Martin Garcia Arch; 5. Eastern Pampean Arch; 6. Asunción Arch; 7. Western Pampean Arch; 8. Puna Arch; 9. Brazilian Shield; 10. Andean Geosyncline (adapted from Northfleet *et al.*, 1969).

Sediments of the Rio Bonito Formation are usually interpreted as representing the iniciation of deposition of the post-glacial phase. They seem though to interfinger with sediments of the Itararé Formation at some places. The Rio Bonito is composed mainly by quartz and arkosic sandstones. Some coal beds occur a little above the uppermost mixtite horizon. Lower and upper contacts of the Rio Bonito Formation are always very difficult to establish, either in outcrops or in subsurface. By convention, the lowermost sandstone bed above the uppermost mixtite of the Itararé and the uppermost sandstone bed under greenish shales at the top of formation are used to define the formation lower and upper boundaries (Northfleet et al., 1969).

The Palermo Formation, the uppermost unit of the Tubarão Group is composed mainly by silty-sandstones and sandy-silststones, often lenticular. They are followed up by clayey-siltstones which mark the initiation of a cycle of sedimentation under reducing conditions which predominate in the deeper parts of the basin or in closed lagoons. Black shales and associated limestones of this cycle (Irati Formation) are taken as the base of the Passa Dois Group.

## PASSA DOIS GROUP

No regional unconformity seems to separate the Tubarão Group from the overlying Passa Dois Group. This sequence begins with the above mentioned gray, silty sediments known as the Serra Alta and Irati formations (Table 1).

Erosional surface seem to separate the two groups. These erosional episodes followed uplifts caused by excess of sedimentation in the central parts of the basin. The group formations represent heteropic facies of a great sedimentary complex (Fig. 2). Difficulties in understanding these facies relationships has led to previous rigid stratigraphic classifications. Regionally the sediments present an increase in grain size from W to E, from the Asunción Arch where sandstones predominate toward a postulated deltaic complex represented by black shales, siltstones and limestones benches in the eastern margin (Harrington, 1950; Landim, 1971).

Limestones of the Irati Formation, basal unit of the Passa Dois Group vary from dolomitic to true dolomites, alternating with black shales in a cyclic pattern. The formation belongs to a larger siltic sedimentary cycle (Serra Alta) in which the black shales represent the sedimentary response to reducing conditions (Mendes et al., 1966). The limestones, predominantly clastic in origin (Mendes, 1967; Landim, 1970), some showing cross-stratification and other associated sedimentary structures, should represent limestones benches at the margin of lagoons and the limestone-shale alternation may indicate areas of environment oscilations. To the northern and western margins the shale facies is substituted by siltstones to fine sandstones. The greatest thickness of the Serra Alta siltstones is located in Santa Catarina State diminishing towards the northeastern part of São Paulo State. These siltstones, often massive, may bear calciferous concretions sometimes fossiliferous. Pyrobituminous horizons are not uncommon along the silty sequence.

The Estrada Nova Formation (Table 1) comprises three lithossomes: Serra Alta, Terezina e Serrinha (Mendes & Fúlfaro, 1966). The Terezina lithossome is constituted by an alternation of siltstones, shales, fine sandstones and oölitic limestone layers. Coquina beds are scattered in the section. In the northern part of the basin siltstones and fine sandstones predominate representing environments of deposition closer to flood plains (Fig. 2). A grain size increase from east to west is also present within this group (Fúlfaro & Landim, 1971). The Serrinha lithossome, comprising fine to medium sandstone benches (1-1.5 m thick) separated by alternating layers of clay and silt with horizontal stratification represents the natural link between the Terezina and Rio do Rasto environments of deposition. The greatest thicknesses of this lithossome occur in Paraná and Santa Catarina. In the northern basin area these three lithossomes are poorly characterized and not well defined.

The Rio do Rasto Formation, uppermost unit of the Passa Dois Group represents flood plain deposits which are a reflex of the final process of basin filling (Fig. 2). Equivalent deposits at the basin margins were probably removed after the basin peripherical uplift with preservation of sediments only in the basin central area. The Rio do Rasto Formation is constituted by fine to medium grained sandstone lenses in rhythmic alternation with clay and silt laminae. Some of these sadnstone lenses show cross-stratification.

## TREND SURFACE ANALYSIS

Previous application of this technique to the study of the Paraná Basin stratigraphic units (Landim, 1970b, and Fúlfaro & Landim, 1972), showed results which agree well with the areal lithologic distribution of the several units analized. Because of inadequate surface information quantitative methods are an imperative in the analysis of the depositional mechanism and tectonic evolution.

In order to depict basin changes during glacial and post-glacial cycles, each sequence was treated separately. As stated previously, the Itararé and Aquidauana formations are thought to represent the glacial and interglacial cycle and the Rio Bonito and Palermo formations plus the Passa Dois Group, comprise the post-glacial phase.

For the glacial and interglacial cycle, the goodness of fit is obtained with the third degree surface, with a strenght of 81.51% (Fig. 3).

As observed in the third degree surface map sediment thickness diminishes toward south across a main east to west oriented center of subsidence, with greater thickness to the west. Thickness diminishes to the north of the more subsiding axis. Trend surface analysis of thickness data of the Itararé Formation only shows also a progressive increase in thickness toward the northeast part of the basin indicating a great subsidence area (Fúlfaro & Landim, 1972).

The obtained trend surface map is in agreement with observed thickness and cyclic lithofacies distribution within the basin. Coarser sediments showing features which indicate rapid subsidence are found in the postulated marginal

PARANÁ BASIN STRATIGRAPHIC COLUMN

| AGE | | | GROUP | FORMATION | LITHOLOGY | MAXIMUM THICKNESS IN METERS | DESCRIPTION | ENVIRONMENT OF DEPOSITION |
|---|---|---|---|---|---|---|---|---|
| CENOZOIC | | | | SMALL ISOLATED BASINS (SÃO PAULO, CURITIBA, TAUBATÉ, etc.) | | 150 | CONGLOMERATES, POORLY SORTED SANDS AND CLAY IN LENTICULAR BEDS. CROSS-STRATIFICATION, GRADATIONAL BEDDING AND BRECCIA CONGLOMERATES | CONTINENTAL. FLOOD PLAIN AND LACUSTRINE |
| MESOZOIC | CRETACEOUS | UPPER | | BAURU | | 200 | SANDSTONES, COMMONLY WITH CALCAREOUS CEMENT, CLAYEY SILTSTONE AND LIMESTONE LENSES. CROSS-STRATIFICATION, RIPPLE-DRIFT CROSS LAMINATION AND CUT AND FILL. | CONTINENTAL. FLOOD PLAIN AND LACUSTRINE |
| MESOZOIC | CRETACEOUS | LOWER | SÃO BENTO | SERRA GERAL | | 1550 | BASALTIC LAVA FLOWS AND AEOLIAN LENSES. | VOLCANIC |
| MESOZOIC | JURASSIC / TRIASSIC | U / M / L | SÃO BENTO | BOTUCATU | | 1200 | WELL SORTED SANDS WITH SCATTERED CLAY LENSES AT THE BASE. CROSS-STRATIFICATION AND BRECCIA CONGLOMERATES AT THE BASE | CONTINENTAL. FLUVIAL AND EOLIAN |
| PALEOZOIC | PERMIAN | UPPER | PASSA DOIS | RIO DO RASTO | | 600 | MEDIUM-SIZED SANDSTONE LENSES IN HORIZONTAL, LAMINATED SILTSTONES. CROSS-STRATIFICATION IN THE SANDSTONE BODIES | CONTINENTAL. FLOOD PLAIN. |
| PALEOZOIC | PERMIAN | UPPER | PASSA DOIS | ESTRADA NOVA | | 700 | FINE-GRAINED SANDSTONES, OOLITIC LIMESTONES, SILTSTONES AND COQUINAS IN INTERFINGERING RELATION. CROSS-STRATIFICATION RIPPLE DRIFT CROSS LAMINATION, WAVY BEDDING, MUD CRACKS, FLASER, WORM BURROS, ETC | CONTINENTAL. FLUVIAL, FLOOD PLAIN AND LACUSTRINE |
| PALEOZOIC | PERMIAN | UPPER | PASSA DOIS | SERRA ALTA · IRATI | | 195 | SILTSTONES, BLACK SHALES AND LIMESTONE LENSES. HORIZONTAL STRATIFICATION. | CONTINENTAL. LACUSTRINE. TRANSITIONAL LAGOONAL. |
| PALEOZOIC | PERMIAN | UPPER | TUBARÃO | AQUI / PALERMO | | 300 | SILTSTONES AND SANDY SILTSTONES. | TRANSITIONAL |
| PALEOZOIC | PERMIAN | MIDDLE | TUBARÃO | RIO BONITO | | 400 | SANDSTONES AND SILTSTONES WITH INTERCALATED COAL BEDS. CROSS-STRATIFICATION IN THES | CONTINENTAL. FLUVIAL TRANSITIONAL |
| PALEOZOIC | PERMIAN / CARBON | MIDDLE / LOWER / UPPER | TUBARÃO | ITARARÉ | | 1300 | SANDSTONES, SILTSTONES AND VARVED CLAYS CUT BY THICK DIAMICTITE LENSES (SOME TRUE TILITES). THIN MARINE FOSSILIFEROUS LAYERS ARE COMMON AT THE TOP OF THE DIAMICTITE BODIES. CROSS-BEDDED SANDSTONE LENSES. HORIZONTAL LAMINATION, WAVY BEDDING, FLASER, CUT AND FILL STRUCTURES, ETC. GLACIAL STRUCTURES, LIKE STRIATED FLOORS AND PEBBLES, ROCHE MOUTONEE, ESKERS AND DRUMLINS ARE FOUND WITHIN THE SEQUENCE. | CONTINENTAL GLACIAL FLUVIAL LACUSTRINE TRANSITIONAL MARINE |
| PALEOZOIC | CARBON / DEVONIAN | LOWER / UPPER | | | | | | |
| PALEOZOIC | DEVONIAN | MIDDLE | PARANÁ | PONTA GROSSA | | 650 | SILTSTONES AND MARINE FOSSILIFEROUS SHALES WITH FINED-GRAINED SANDSTONE LENSES. HORIZONTAL LAMINATION WITH WAVY BEDDING. | MARINE |
| PALEOZOIC | DEVONIAN | LOWER | PARANÁ | FURNAS | | 450 | CROSS-BEDDED SANDSTONES FREQUENTLY CONGLOMERATIC AT THE BASE. CLAY LENSES AND LAYERS ARE FOUND NEAR THE BASIN MARGIN | TRANSITIONAL TO MARINE |
| PRE-SILURIAN | | | | | | | CRYSTALLINE BASEMENT. GRANITES, GNEISSES AND SCHISTS. AT THE TOP OF THE SEQUENCE, CROSS-BEDDED QUARTZITES AND CONGLOMERATIC LAYERS ARE COMMON. | |

Table 1.

parts of the basin coinciding with most subsiding areas interpreted from the map (Landim, 1970 b). This east-west structural axis, already indicated for the Tubarão Group may be related with a structural trend which influenced the deposition of the Paraná Group, as shown in the cubic trend surface map of the Furnas Formation (Fúlfaro & Landim, 1972). This partially supports the hypothesis that the beginning of the glacial cycle followed the reactivation of ancient structural lines of the basin with the formation of several isolated areas of deposition.

The trend surface residuals map (Fig. 4) shows more positive areas to the north, northeast, southeast and southwest. In the residual areas of less subsidence, reworked sediments indicate periodic tectonic oscilations and in the residuals areas of greater subsidence, a great sediment thickness showing sometimes features indicative of rapid subsidence is present. Coarser clastics occurring in between those two areas of different tectonic behaviour indicate the presence of regional highs. To the southeastern and southwestern margins, the Uruguayan Shield and the Martim Garcia Arch are suggested. Towards the east the most positive structural feature had its center in the Apucarana region (PR) roughly coinciding with the present structural trend of the Ponta Grossa Arch. To the northeast presence of the Canastra Arch is suggested. Between these two structural directions, a tectonically more negative area with a SE-NW axis coincides in its disposition with a region where greatest thicknesses of sediments are preserved. The large tectonic positive areas are thought to indicate a multiplicity of local tectonic highs which could be depicted if a larger amount of data was available.

For the post-glacial cycle comprising sediments of the Rio Bonito and Palermo formations and the Passa Dois Group, the goodness of fit was obtained by the fourth degree surface (Fig. 5), with a strenght of 85.40%. The lines show a basin with a tendency to a linear shape with thickness of the strata increasing towards the more tectonic positive margin. Results obtained by Fúlfaro & Landim (1972) for the several stratigraphic units treated separately show that the map in the Fig. 5 represents the sum of the individual features. Formations with greatest thicknesses are responsible for the general trend.

The basin shape represented in Fig. 5 is in agreement with the sediment distribution during the post-glacial cycle of deposition, mainly for the uppermost formations, with coarser sediments to the west and finer to the east. The tectonic high observed at the northeast corner of the map may explain the facies difference between the north and south areas of the Paraná Basin for this stratigraphic interval. This

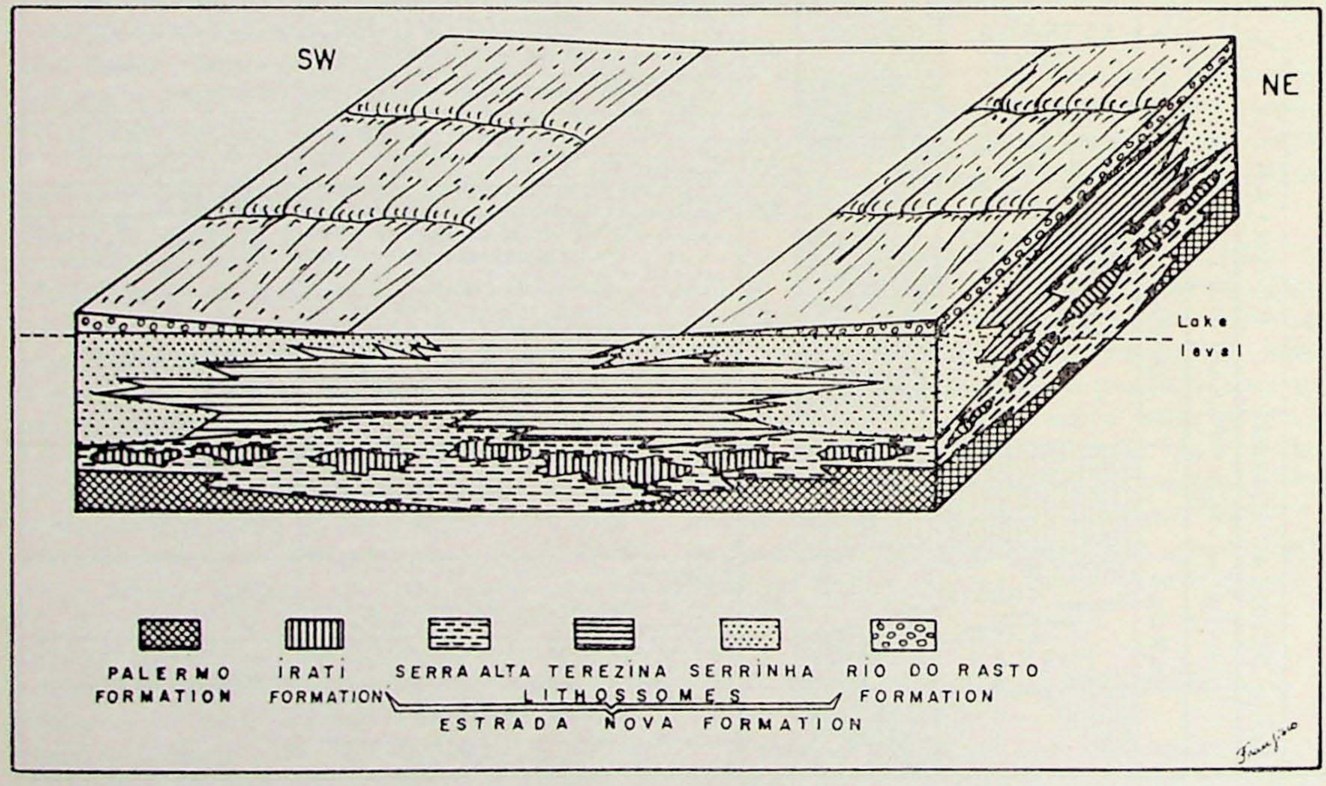


Fig. 2. Hypothetical sketch of a section in the Paraná Basin showing the Upper Paleozoic facies relationship at the final filling of the Basin.

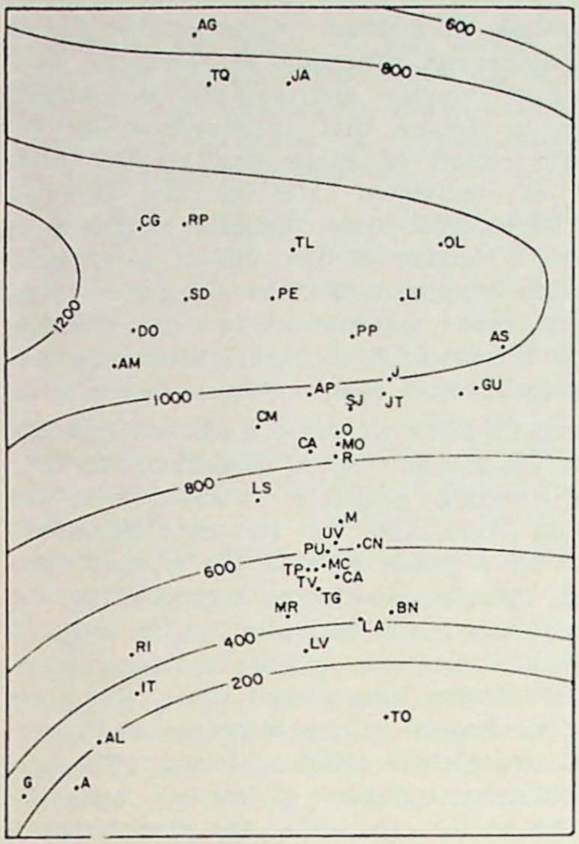


Fig. 3. Third degree trend surface map of the glacial cycle.

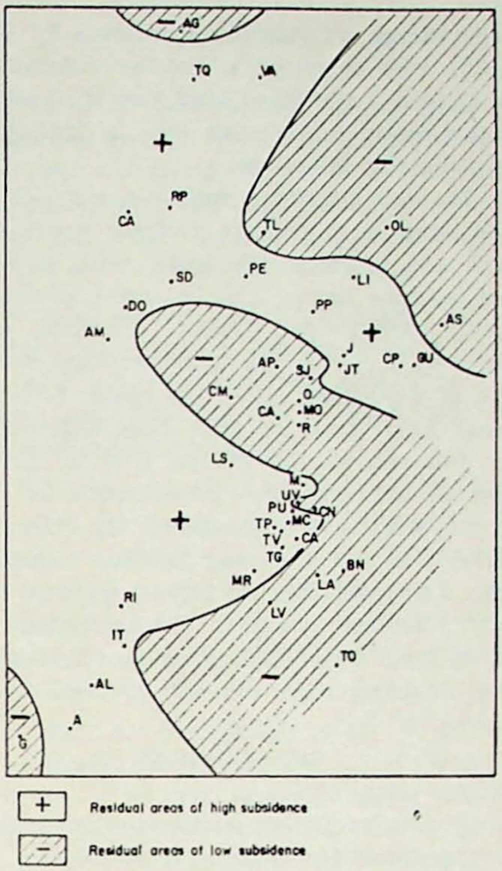


Fig. 4. Cubic degree trend surface residuals of the glacial and interglacial cycle.

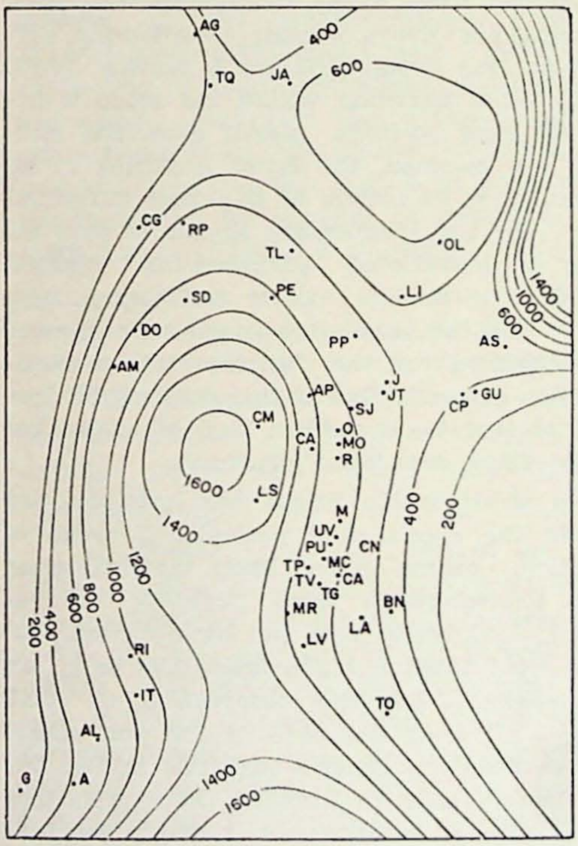


Fig. 5. Quartic degree trend surface map of the post-glacial cycle.

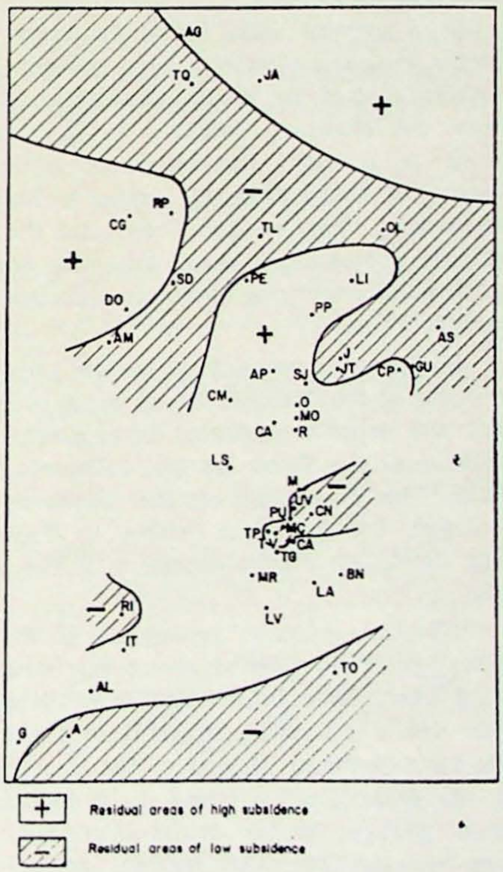


Fig. 6. Quartic degree trend surface residuals of the post-glacial cycle.

facies change was already mentioned by Fúlfaro (1970) who suggested a possible subdivision of the Paraná Basin in at least two sub-basins. A predominantly north-south axis is indicated for the basin for this stage.

The trend surface residuals map (Fig. 6) shows two main positive tectonic areas to the north and south of the basin, with two small ones between them. Residual areas of less subsidence explain the facies difference already mentioned between the northern and southern area of deposition within the cycle. Several regional highs seem to have been active during this interval, as the Campo Grande, Três Lagoas arches and the north flank of Ponta Grossa Arch. To the south, the Uruguayan Shield was still the most positive tectonic feature. Two small tectonic highs suggested in Fig. 6 need further study of the associated lithofacies, for a better understanding. E to W trending subsiding zones are still present.

## CONCLUSIONS

From the facies distribution analysis and the interpretation of the trend surface maps some conclusions about the development of the Permo-Carboniferous glacial and post-glacial cycles can de drawn.

In a general way, initial tendency for a greater subsidence were always present in the southern part of the basin. Great hiatus to the north and erosional vacuities to the south is shown in a basin time-lenght diagram. The Uruguayan Shield (Fig. 1) seems to have been permanently under erosion Even after the initial southern subsidence it seems that this area was uplifted and reworking of the previous sediments was the rule.

Facies and geometry of certain deposits at the base of the Tubarão Group seem to indicate that the deposition started in small basins of tectonic origin filled up by sediment derived mainly by reworking of the Devonian rocks. Sediment transportation seems to have been very short. No glacial deposit is known at this level.

This time coincided probably with the initial formation of the Paraná structural basin. Presently, very little information is available about other faulting periods during Itararé and Aquidauana deposition. However, the great number of intraformational breccias, local diastems and great changes in the environments of deposition indicate that other faulting periods occurred and unconformities must be expected.

Analysis of residual values of the Itararé and Aquidauana Formations thickness data indicate a complex and variable depositional surface, a picture that is supported by the lithologic record of these stratigraphic units. Study of individual stratigraphic intervals within the glacial cycle indicate begginning of basin axis shifting at the end of the Itararé Formation deposition (Fúlfaro & Landim, 1972). The post-glacial sequence shows a more positive tectonic character which should be expected following the passage from one cycle to another.

A multiplicity of source areas can be admited for the glacial cycle of deposition. The basin western margin probably coincided with the Asunción Arch and the eastern margins, was formed by a gentle arch of the crystalline basement. This depressed area formed during the glacial phases would facilitate the ingression of the sea in the eastern and southeastern part of the basin during inter-glacial times. The number of the marine layers increase steadly southward towards the Falkland Island. The existance of a great number of isolated basins covered by an ice cap during the glacial epochs, with their own depositional mechanisms during the fluvial and lacustrine phases of the interglacials is suggested by the residual values map.

Sedimentation of the Rio Bonito and Palermo formations shows a close relationship with the Passa Dois Group (Fúlfaro & Landim, 1972). Lateral facies variation within the group is evident; at some horizons clastic dikes and mudcracks are common, the latter occurring in sequences up to 90 meters of thickness (Salamuni, 1963). The two sedimentary structures show the variety of depositional environments, constant subsidence in shallow water and strong slopes along which the sandstones lenses were squeezed and introduced in the rhythmic layers. Sedimentation generally fine at this stratigraphic level does not leed to any other kind of explanation for the above mentioned structures.

No stratigraphic break has been detected between the glacial and post-glacial cycles of deposition, except in the basin marginal areas. These unconformites were probably simultaneous to load increase in the basin center. However, local tectonic highs inside the basin can be supposed from the observation of small clastic wedges at the base of the post-glacial beds, as near the Ometto sugarmill in the road from Iracemápolis to Limeira (SP). This type of depositional environment strongly suggests an unstable tectonic bottom for the basin, associated to oscilation mechanism which caused up and down - movements of fault blocks, not uncommon in intracratonic basin. Such mechanism could also explain the absence of regional unconformities between the cycles, in spite of the great number of diastems.

The Serra Alta facies was the sedimentary response to reducing conditions which probably vigorated in the most deep parts of the basin. However, not all the Serra Alta sediments were deposited in such kind of environment. In the eastern margin of the basin the siltstones resembles more lagoonal type of deposits, where reducing conditions were also present. In these areas the siltstone, limestone and black shale sequence has a thickness of 25 meters, opposed to 100 meters in the most central area.

The Terezina facies representing the sedimentary record of ancient lakes and associated flood plains, is a shallow water sedimentary deposit showing a variety of sedimentary structures. At some places, as in Taguaí and Porangaba (southern São Paulo State) the calcarenites of this facies, with cross-stratification, suggest beach deposits.

For the post-glacial interval, the trend surface map seems to indicate that a classical structural shape seems to have commanded deposition in the Paraná Basin, with a progressive basin confinement until its final filling by the Rio do Rasto sediments. Analysis of the post-glacial lithofacies distribution suggests an assymetrical basin with coarser sediments to the west and finer to the east, a pattern which is also supported by analysis of individual stratigraphic units (Fúlfaro & Landim, 1972).

In synthesis, analysis of the two sedimentary cycles indicates a more complex structural pattern of the basin with great subsidence in the north during the glacial and interglacial phases, passing gradually to a more classical, slightly assymetrical basin model during the post-glacial times.

As pointed out by Fúlfaro & Landim, (1972), marine counterparts of the Paraná Basin intracratonic sediments could have existed to the east and southeast of the present eastern margin, thus explaining the distribution of the Late Paleozoic marine facies. The marine sedimentary record was subsequently destroyed by erosion associated to uplifts or basin marginal faulting. Preserved Late Paleozoic strata below younger cover could possibly occur on the Brazilian continental shelf as indicated by Baccar (1970) and Miranda (1970).


## ABSTRACT

Sedimentary rocks of the Paraná Basin can be subdivided into three sequences, as defined by Sloss (1963) in North America of which, the glacial, interglacial and post-glacial rocks of the Tubarão and Passa Dois groups, of Permo-Carboniferous age represent the middle one.

Trend-surface analysis of: 1) glacial and interglacial strata (Itararé and Aquidauana formations), and 2) post-glacial beds (Rio Bonito and Palermo formations and Passa Dois Group) thickness data evidenced that:

a) for the glacial and interglacial cycle the goodness of fit is obtained with the «cubic» surface, with a «strength» of 81.51%. Thickness decrease from N to S. The residual map shows four tectonic positive areas and a multiplicity of source areas can be admited during deposition of the sediments;

b) for the post-glacial cycle the goodness of fit is obtained with the «quartic» surface, with a «strenght» of 85.40%. Thickness shows a circular pattern of distribution in the most subsiding part and the residual map shows positive areas in northern, central and southern parts of the basin

Comparison of the results indicates two distinct structural patterns during evolution of the basin, starting with a very complex one which characterized the glacial cycle, progressing towards a more simple structural model during post-glacial sedimentation.


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