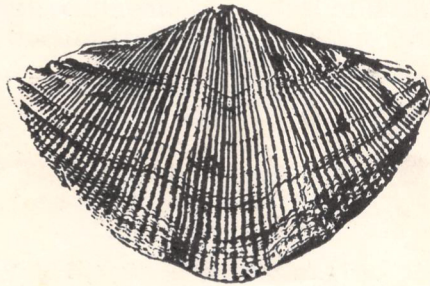


INTERNATIONAL SYMPOSIUM ON THE CARBONIFEROUS AND PERMIAN SYSTEMS IN SOUTH AMERICA



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SÃO PAULO
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POST-SYMPOSIUM EXCURSION

25-30 November, 1972

Late Paleozoic Geology of Northern Paraná Basin

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INTRODUCTION

This excursion has been designed to provide opportunities for the participants to see aspects of the eastern outcrop belt of Late Paleozoic (Lower Gondwana) sediments of central and southern São Paulo State and south and northeastern Paraná State, Brazil (Fig. 1).

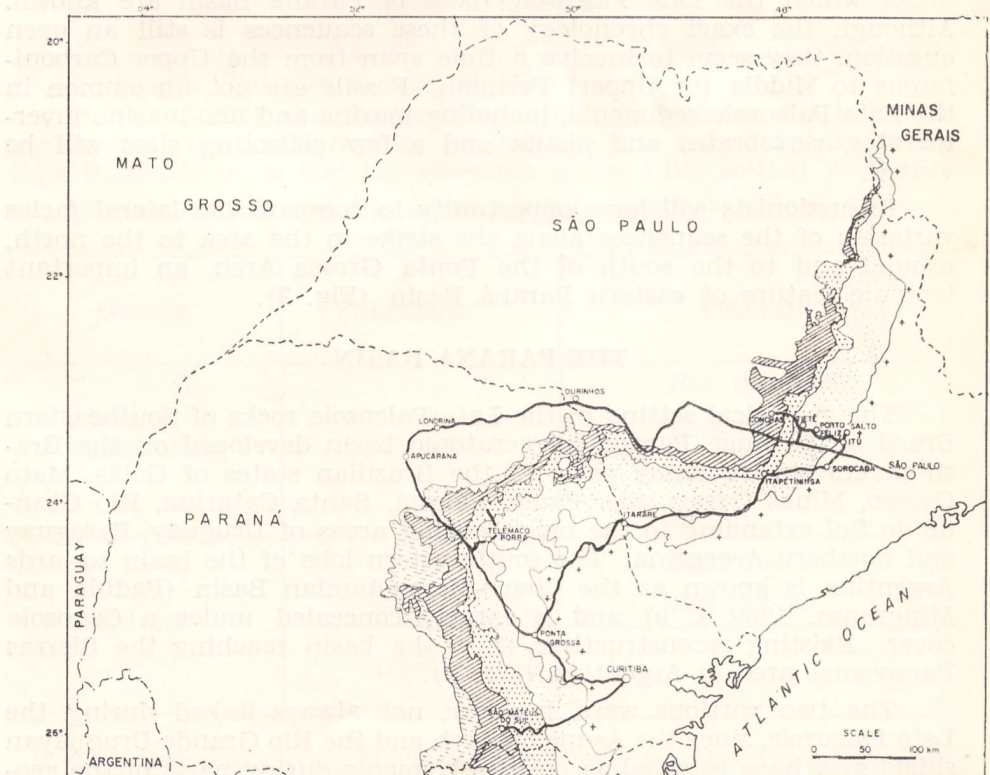


Fig. 1 — Itinerary of excursion. Explanation: crosses: basement; blank: Devonian; dotted: Itararé Subgroup; coarse dotted: Guatá Subgroup; hatched: Irati and Estrada Nova formations (Passa Dois Group); interrupted lines: Rio do Rasto Formation (Passa Dois Group); western blank area = Cretaceous.

Because of the general low topography and practically horizontal behaviour of the Late Paleozoic sequences, with regional dips of the order of 1° - 2.5° , associated with deep weathering of the soft sediments, the quality of outcrops in the Paraná Basin is, with few exceptions, poor. In the selection of the excursion itinerary, the Organizing Committee found considerable difficulty in trying to combine the technical aspects of the excursion with a reasonable traversing distance and adequate logistical support.

Outcrops to be examined are generally represented by road cuts and the travel will be almost entirely on paved roads. The total distance to be covered is around 2,400 km (1,500 miles).

In the selection of traverses and outcrops the organizing party took advantage of recent excursion guide-books prepared for the 1st Gondwana Symposium (Bigarella et al., 1967) and XXV Congress of the Sociedade Brasileira de Geologia (Medeiros, 1971; Fúlfaro et al., 1971).

Features to be examined include lithologies, facies aspects and boundary problems of the Tubarão and Passa Dois Groups, names under which the Late Paleozoic rocks of Paraná Basin are known. Although the exact chronology of these sequences is still an open question, they seem to involve a time span from the Upper Carboniferous to Middle (or Upper) Permian. Fossils are not uncommon in the Late Paleozoic sediments, including marine and non-marine invertebrates, vertebrates and plants and a few collecting sites will be visited.

Excursionists will have opportunity to compare the lateral facies variation of the sequences along the strike in the area to the north, around and to the south of the Ponta Grossa Arch, an important tectonic feature of eastern Paraná Basin (Fig. 2).

THE PARANÁ BASIN

The geological setting of the Late Paleozoic rocks of Southeastern Brazil is the huge Paraná intracratonic basin developed on the Brazilian craton. It covers parts of the Brazilian states of Goiás, Mato Grosso, Minas Gerais, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul extending to the neighbouring areas of Uruguay, Paraguay and northern Argentina. The southwestern lobe of the basin towards Argentina is known as the Chaco-Mesopotamian Basin (Padula and Mingramm, 1969 a, b) and is largely concealed under a Cenozoic cover. Existing reconstructions show the basin reaching the Sierras Pampeanas area in Argentina (Fig. 2).

The two portions were, however, not always linked during the Late Paleozoic, since the Asunción Arch and the Rio Grande-Uruguayan shield may have behaved as positive elements during parts of the geological history of the basin.

The total area presently covered by the basin is approximately 1,600,000 km² and it contains a thickness of up to 5,000 meters of

sediments ranging in age from Late Paleozoic to Mesozoic, including more than 1,000 meters of basaltic lava (Lower Cretaceous) distributed mainly in the present center of the basin.

The Paleozoic sediments thicken towards the present axis of the basin, which is roughly located along the Paraná River course.

The Paraná Basin may be identified as a sedimentary unit as early as in the Lower Devonian, with sedimentation proceeding until the Upper Cretaceous.

The intracratonic nature of the basin resulted in a general lack of strong tectonic effects on the sediments, which show only regional dips and local diastrophism due to faulting and igneous intrusions.

In Fig. 2, the tectonic elements of Paraná Basin are shown (Northfleet et al., 1969; Padula and Mingramm, 1969 a, e b). Of special interest for the area to be examined is the Ponta Grossa Arch which started to behave as a positive element as early as the Middle Paleozoic. Upwarping was stronger during the Lower Cretaceous with fracturing and emplacement of dykes and sills and also the extrusion of an enormous volume of basic lava.

STRATIGRAPHY

The Late Paleozoic sediments of Paraná Basin are designated as two groups, Tubarão and Passa Dois.

Mendes (1967) and Rocha-Campos (1967) reviewed the historical evolution of the stratigraphic classification and nomenclature of the Late Paleozoic units and the situation is not fully settled yet.

In the present text the following classification will be used:

Groups	Subgroups	Formations
Passa Dois		Rio do Rasto
		Estrada Nova
		Serra Alta
		Irati
Tubarão	Guatá	Palermo Rio Bonito
	Itararé-	

The Tubarão Group unconformably overlies the Devonian sediments of the Paraná Group (Furnas and Ponta Grossa formations) and Precambrian basement rocks and is conformably covered by the Passa Dois Group.

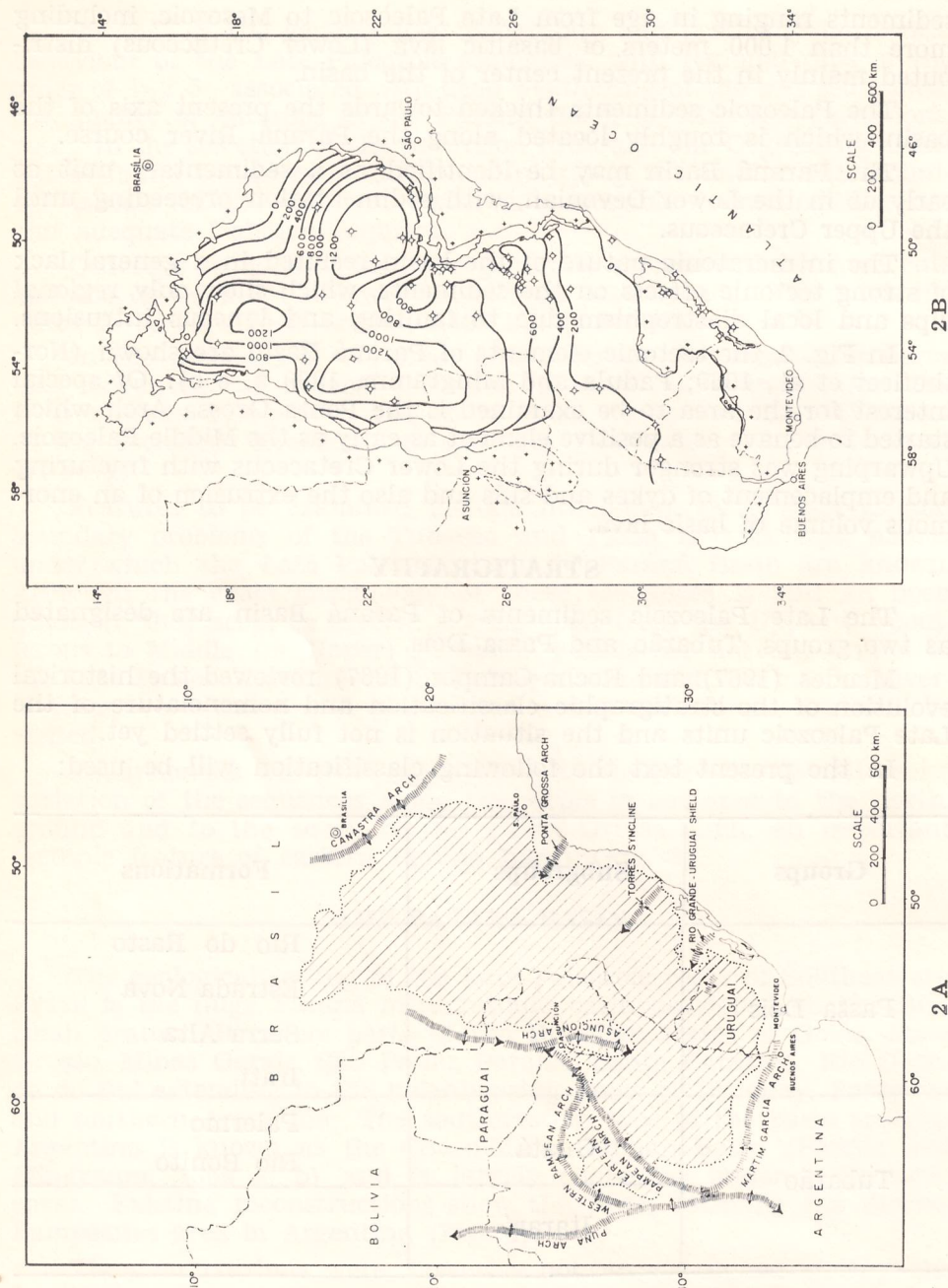
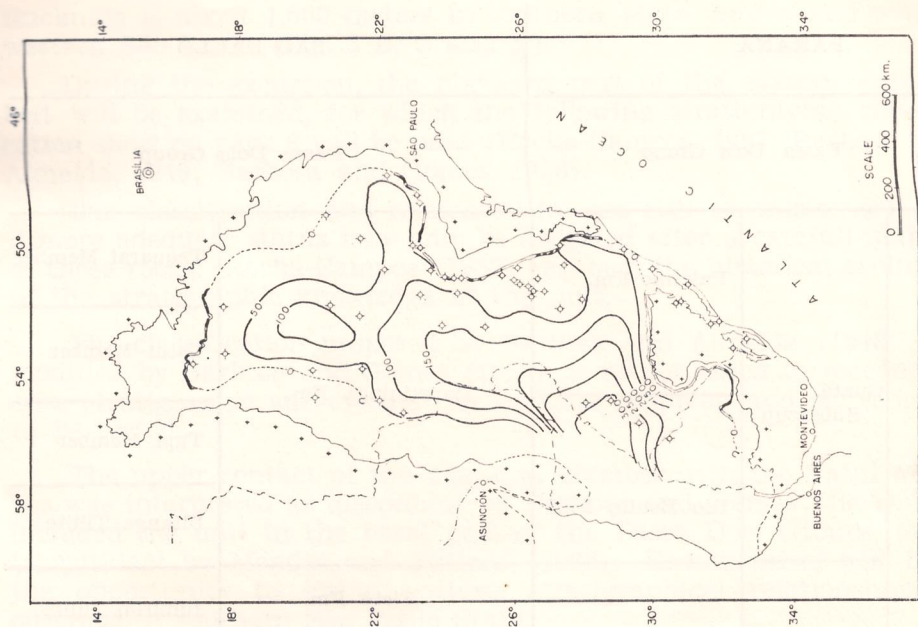
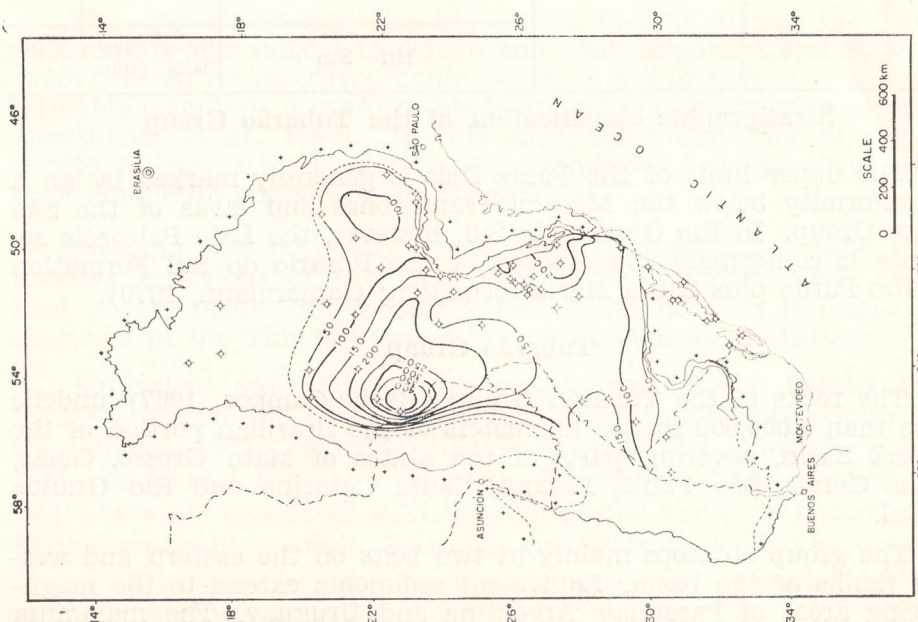


Fig. 2 — A: main tectonic features of Paraná Basin (hatched) (from Northfleet et al., 1969 and Padula and Mingramm, 1969). B: isopach map of the Itararé and Aquidauana Subgroups. Next page: C: isopach map of the Rio Bonito Formation (Guatá Subgroup); D: isopach map of the Palermo Formation (Guatá Subgroup). Interval in meters (Simplified from Northfleet et al., 1969).



2D



2C

PARANÁ			SÃO PAULO	
Passa Dois Group			Passa Dois Group	
Tubarão Group	Guatá Subgroup	Palermo Fm.	Itapetininga Fm.	Taquaral Member
				Tatui Member
				Tupi Member
				Pitanga Tillite
	Itararé Subgroup	Rio Bonito Fm.		
			Tietê Fm.	Jumirim Tillite
			Gramadinho Fm.	Mombuca Tillite Rafard Tillite
			Capivari Fm.	
			Itu Fm	Elias Fausto Tillite Saito Tillite

Stratigraphic classification of the Tubarão Group

The upper limit of the Passa Dois is generally marked by an a disconformity below the Mesozoic sandstones and lavas of the São Bento Group. In Rio Grande do Sul, however, the Late Paleozoic sequence is conformably superposed by the Rosário do Sul Formation (= Rio Pardo plus Santa Maria formation; Gamermann, 1970).

Tubarão Group

The rocks of the Tubarão Group (Rocha-Campos, 1967) undelie more than 1,000,000 square kilometers of the Brazilian portion of the Paraná Basin, covering parts of the states of Mato Grosso, Goiás, Minas Gerais, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul.

The group outcrops mainly in two belts on the eastern and western flanks of the basin. Equivalent sediments extend to the neighbouring areas of Paraguay, Argentina and Uruguay. The maximum

thickness is about 1,500 meters in southern Mato Grosso and southwestern São Paulo (Fig. 2 B, C and D).

During the excursion, the northern part of the eastern outcrop belt will be examined, for which the following stratigraphic classification shown on page 8 will be used (Rocha-Campos, 1967; Barbosa and Almeida, 1949; Barbosa and Gomes, 1958).

The classification and nomenclature are still unsatisfactory and a more adequate status may only be achieved after a careful mapping of these rocks. Rocha-Campos (1967) resumed the historical evolution of the stratigraphic knowledge of the unit.

The classification proposed by Barbosa and Almeida (1948) and modified by Barbosa and Gomes (1958), is rather based in reconnaissance stratigraphic survey, than in regional mapping and so, remains to be tested.

The upper contact of the Taquaral Member with the Tatuí Member was interpreted as discordant by Barbosa and Gomes (1958) who included the unit in the basal part of the Passa Dois Group, or as transitional by Mendes and Fúlfaro (1966). Excursionists will have the opportunity to examine those stratigraphical relationships in outcrops in southern São Paulo State.

The boundary between the glacial (= Itararé Subgroup) and post-glacial units (Itapetininga Formation) is also a matter of discussion. It is usually considered as transitional, but Soares (this Symposium) presents evidence of a disconformity separating the two sequences.

The contact between the Rio Bonito Formation and the Itararé Subgroup is also subject to debate and while Bigarella and Salamuni (1967), based on paleogeographic evidence, are in favour of an unconformable boundary, a conformable relationship is interpreted by others (Northfleet et al., 1969). In this case, the lower limit of the Rio Bonito is fixed at the base of the first sandstone bed above the uppermost diamictite horizon of the Itararé.

Although not definitely, there are indications of a time transgressive behaviour of this boundary (Rocha-Campos, 1967; Northfleet et al., 1969). All the other boundaries between formations or members of the Tubarão Group are interpreted as transitional.

Equivalent sediments of the western part of the Paraná Basin in Mato Grosso and Goiás are denominated Aquidauana Group (Rocha-Campos, 1967). Almeida (1954) considers the sequence younger than the Itararé because Aquidauana-like sediments in northern São Paulo area are correlated with the post-glacial sequence (Itapetininga Formation), a little south. Petrobrás geologists, however, are in favour of an older age for the Aquidauana based on palynological data (Northfleet et al., 1969).

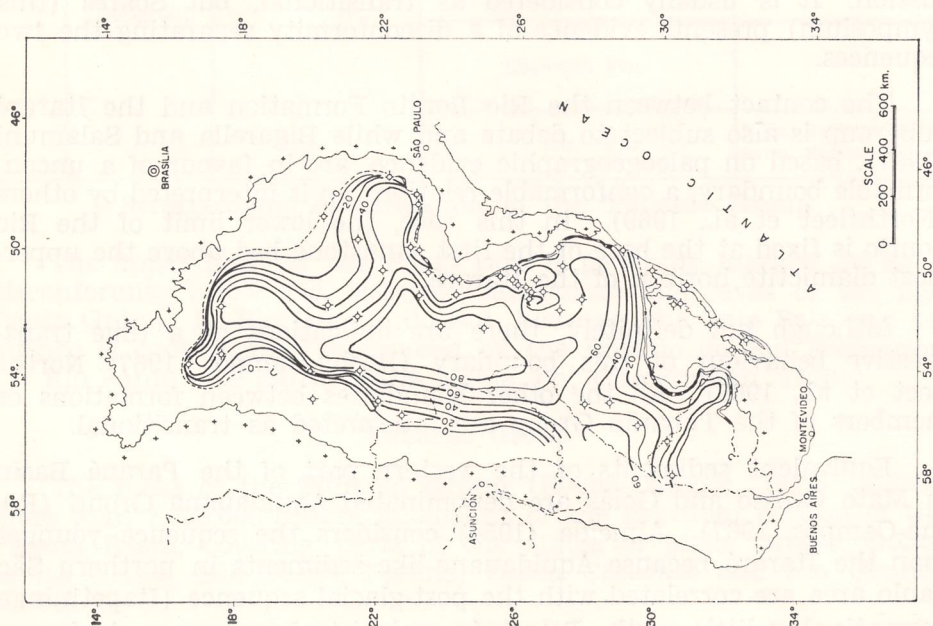
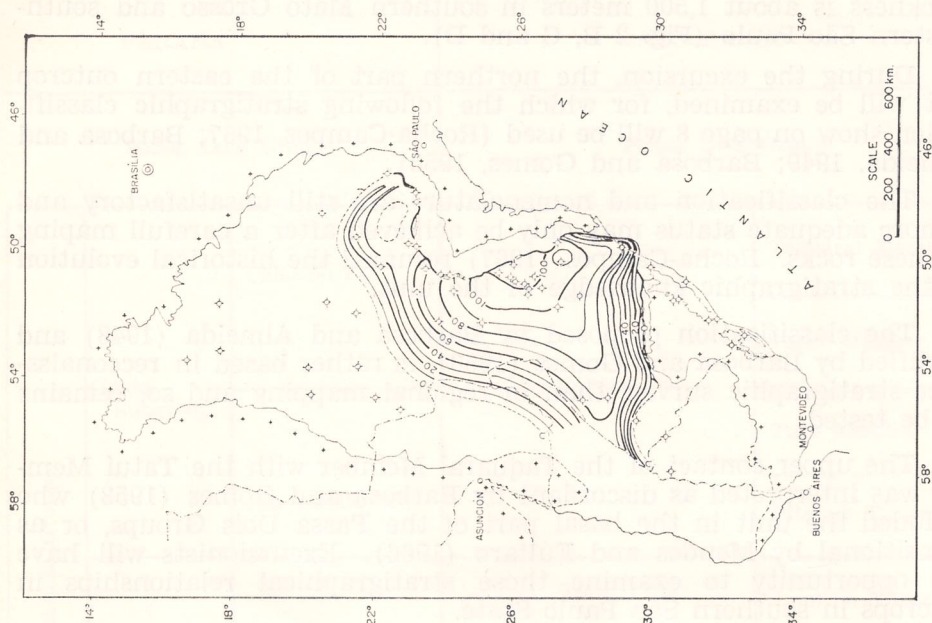
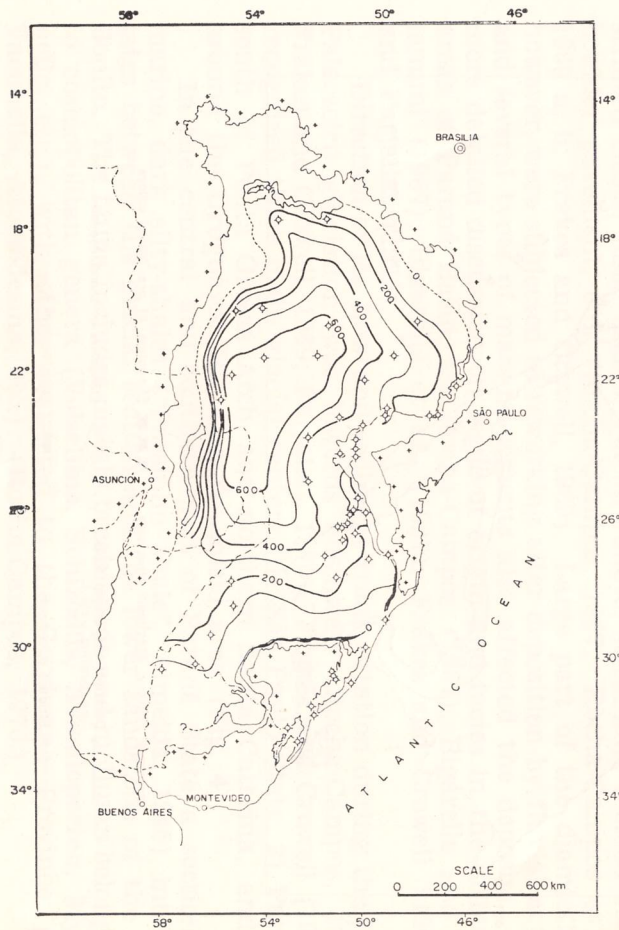
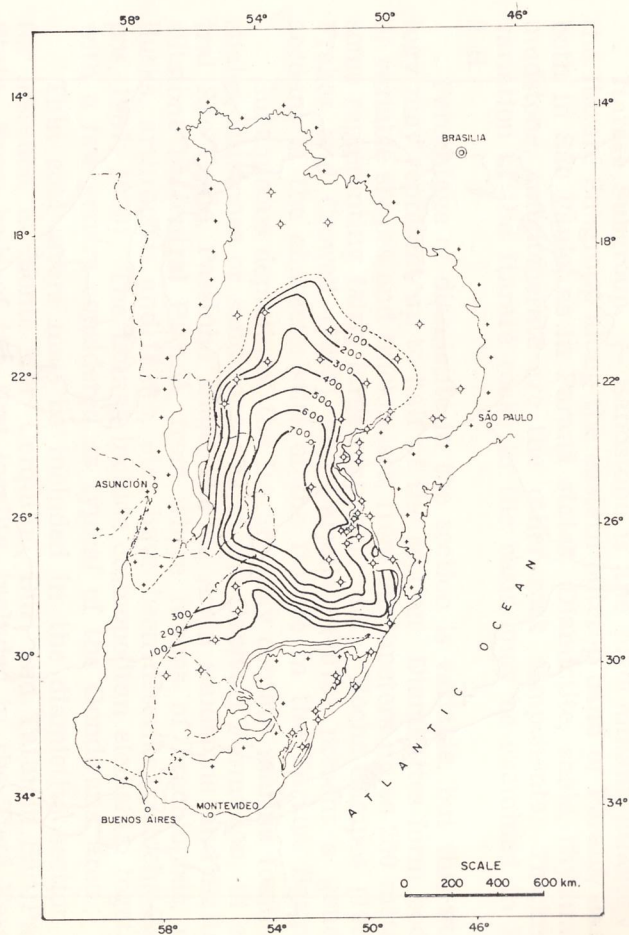


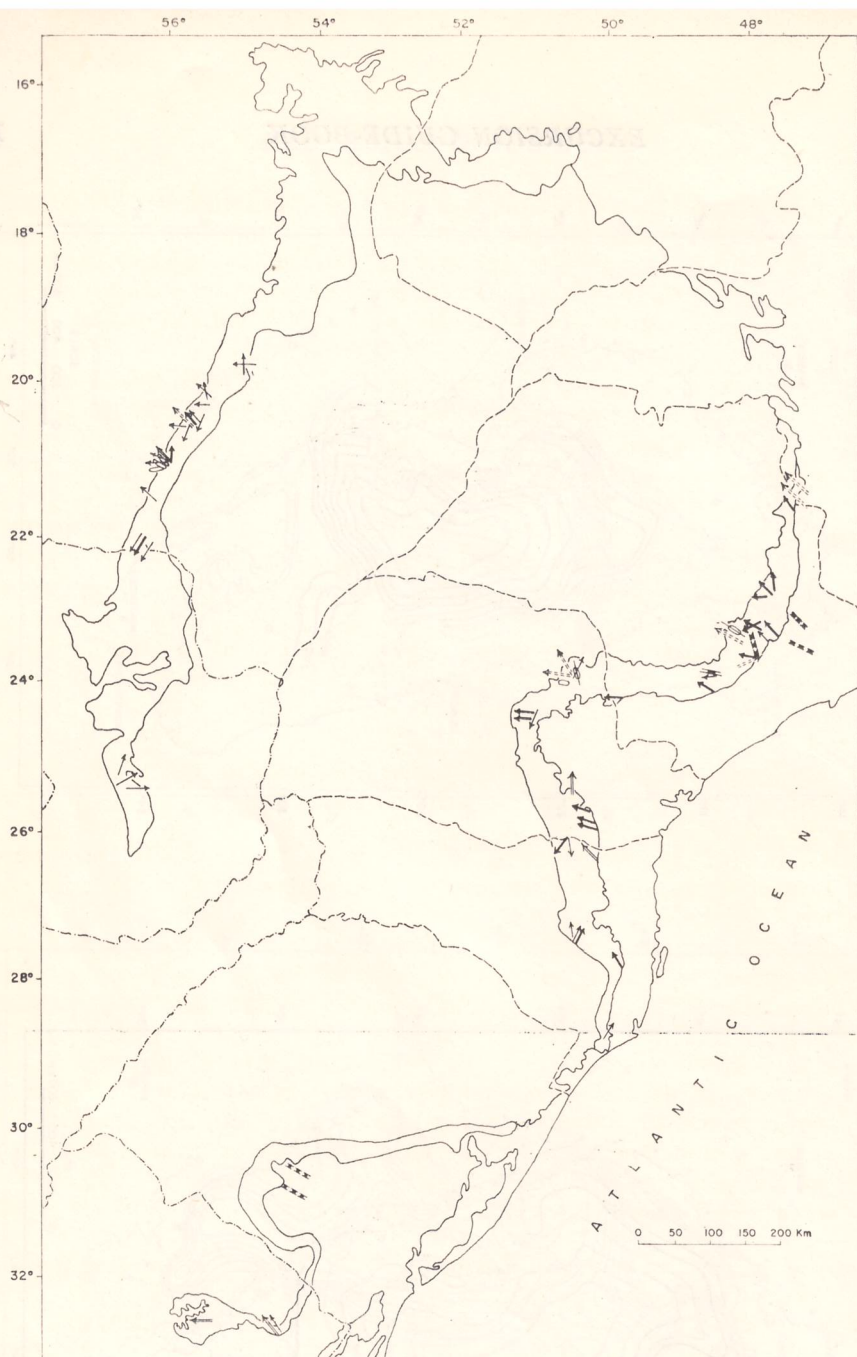
Fig. 3 — Isopach map of the Passa Dois Group. A: Irati Formation; B: Serra Alta Formation. Next page, C: Estrada Nova Formation; D: Rio do Rasto Formation. Interval in meters (Simplified from Northfleet et al., 1969).



3C



3D



EXPLANATION

- | | |
|--|--|
| → Primary directional structures | ▤▤▤▤ Elongation of pre-glacial valleys |
| → Deformations, (slump folds, ice pushing, etc.) | ○ Elongation of channel deposits |
| → Striated pavements | ▬▬▬▬ Elongation of eskers |
| ⋯⋯⋯⋯⋯⋯ Diamicite fabric | ○ Striae on clasts of diamicite |

Fig. 4 — Direction of Late Paleozoic glacial movement and sediment transportation in Paraná Basin Outcrop area of the Tubarão Group is limited by two coarser lines. Data from Rocha-Campos, 1967; Frakes and Crowell, 1969; Farjallat, 1970.

Itararé Subgroup. — Sandstone is the predominant lithology of the Itararé Subgroup along the eastern outcrop band of Paraná Basin, both in São Paulo, as in Paraná states. Diamictite, shale, rhythmite, mudstone, conglomerate are the other rock components. Thickness variation of the Itararé rocks in the basin may be examined in Fig. 2 B.

Percentage of diamictite in the section is variable, but this lithology may represent up to half of the section. Diamictites form bodies of variable shapes and thicknesses, from centimeters up to 200 meters, some representing fairly large mappable units. Rocha-Campos (1967), Frakes and Crowell (1969) and Farjallat (1970) present a general account of the characteristics of the Itararé in the Paraná Basin.

Subaqueous deposits of the Itararé may contain marine fossils in shales, siltstones or sandstones, as in the Capivari Formation, in central São Paulo, Passinho shale, Rio da Areia sandstone and Baitaca siltstone in central Paraná, from where faunas of brachiopods, mollusks, arthropods and fishes, etc., have been described (Rocha-Campos, 1967; 1970). The faunas include cosmopolitan elements, together with a few genera considered as typical of the Gondwana area.

Thin coal layers may be included in the diamictite section, as for instance, at Monte Mór, Cerquilha, Buri and Tatuí in São Paulo State. From beds of the first locality, included in the Tietê Formation, Millan (1972) described a florula with **Rhacopteris**, **Lepidodendron**, **Paracalamites**, **Gondwanidium**, **Adiantites**, etc., which he considered as Upper Carboniferous in age.

A glacial mode of origin for diamictites of the Itararé Subgroup is supported by the occurrence of striated floors, a "roche moutonnée", striated clasts, fossil eskers, glacial valleys, streamline molded forms, boulder pavement, etc. (Rocha-Campos, 1967; Rocha-Campos et al., 1969 a, b; Frakes and Crowell, 1969). Large part of the diamictites, however, were subjected to reworking after deposition by fluvial action and several types of mass-movements also affected the deposits. For more detailed discussion on mode of origin and facies in the different areas of Paraná Basin, see Rocha-Campos (1967), Bigarella and Salamuni (1967), Bigarella et al., (1967), Frakes and Crowell (1969), and Farjallat (1970).

Direction of ice flow and sediment transportation during the Late Paleozoic glaciation was towards northwest (Rocha-Campos, 1967; Frakes and Crowell, 1969; Farjallat, 1970). Frakes and Crowell (1969) recognized three main glacial centers: 1) São Paulo State, 2) Paraná south of Ponta Grossa Arch and northern Santa Catarina, and 3) around the Uruguayan-Rio Grande shield area (Fig. 4).

In the central and southern part of Paraná State a section of marine, dark silty-shales ("Passinho shale", Almeida, 1945) intercalates between the glacial section and the lower sandstone of the Rio Bonito. The fauna includes mainly brachiopods and mollusks belonging to cosmopolitan genera (**Volsellina**, **Schizodus**, **Aviculopecten**, **Myalinella**, etc.), with other restricted to the Gondwana Province (e.g. **Vacunella**, **Atomodesma**, etc.). (Rocha-Campos, 1970.)

Because of the relative rarity of suitable fossils, the age of the Itararé is not yet firmly established. Evidences have been presented for an Upper Carboniferous to Lower Permian age for the Itararé, on basis of marine megafossils (Closs, 1967; Rocha-Campos, 1966; 1970). Recent palynological work of Petrobrás (Daemon and Quadros, 1969) tends to interpret the age as ranging from Stephanian to Middle Permian (Kungurian).

Guatá Subgroup and Itapetininga Formation. — The post-glacial sequence in São Paulo area is known as the Itapetininga Formation (Barbosa and Almeida, 1949 = Tatuí Formation of Rocha-Campos, 1967).

The section is predominantly composed of sandstone, with subsidiary siltstone, shale and limestone.

Fossils are rare, except for sponge spicules, crustaceans and fish remains (Rocha-Campos, 1967).

The lower boundary with the Itararé Subgroup is generally interpreted as transitional, but Soares (this Symposium) considers it as unconformable.

The environment of deposition is subaqueous.

In the Paraná State the post-glacial sequence is subdivided into two formations, Rio Bonito and Palermo. Thickness variation of the Rio Bonito and Palermo formations and equivalent sequences in São Paulo is shown in Fig. 2 C, D.

The lower and upper thirds of the Rio Bonito are predominantly composed of fine sandstone. In its middle part, siltstone and argillites are the main components, together with limestone and coal beds (Northfleet et al., 1969). During the excursion the Gondwana coal beds and associated sediments from the lower part of the Rio Bonito Formation will be observed in coal basins of northeastern Paraná State.

Although some authors admit an unconformity separating the Rio Bonito from the Itararé, a practical way to establish the limit for mapping purposes, is to place it immediately at the base of the first sandstone bed of the post-glacial sequence. The same practical view has been used for separating the Rio Bonito from the Palermo, whose lower limit is choosed as the top of uppermost sandstone bed bellow the typical gray on greenish-gray siltstone (Northfleet et al., 1969).

A very interesting model of sedimentary deposition of the Rio Bonito Formation was proposed by Northfleet et al. (1969), who interpreted the basal sandstone as regressive and the upper as transgressive. The sandstones seem to represent extensive deltaic deposits (Ramos, 1967; Rocha-Campos, 1967). Marine, transitional and continental facies with coal measures may be discriminate in the formation.

Regarding the age of the Rio Bonito Formation, the paleobotanical evidence (*Glossopteris*-*Gangamopteris* elements), the occurrence of marine fossils, including typical Gondwana genera, at the middle part of the formation in central Santa Catarina (*Oriocrassatella*, *Myonia*, *Heteropecten* etc.) point out for a general Lower Permian age

(Rocha-Campos, 1967; 1970). The palynological data is interpreted as indicative of Upper Permian (Kungurian to Kazanian). (Daemon and Quadros, 1969.)

Siltstones predominates in the Palermo Formation, plus subsidiary fine sandstone and chert. Abundance of biogenic structures (tubes and mottled structure) are typical of the formation (Salamuni and Alessi, 1966).

Northfleet et al. (1969) interpret the Palermo as a marine facies deposited under very stable tectonic conditions, which substitutes the Rio Bonito towards the center of the basin. The formation is practically barren of fossils, except for plants (*Glossopteris*), arthropods and fish scales. Daemon and Quadros (1969) assigned an Upper Permian age (Kazanian) for the unit.

Passa Dois Group

In a manner similar to the Tubarão Group, the Passa Dois outcrops form a long band on the eastern flank of Paraná Basin, extending from São Paulo as far as Uruguay. On the western margin of the basin the group outcrops in two discontinuous bands, one covering parts of Goiás and Mato Grosso and the other in Paraguay (Mendes, 1967).

The area occupied by the Group in the basin is approximately the same as the underlying Tubarão Group (about 1,000,000 km²). Equivalent units are found in the subsurface of the Chaco-Mesopotamian region of Argentina (Padula and Mingramm, 1969 b).

In the area covered by the excursion the following subdivision of the group will be used (after Northfleet et al., 1969).

Passa Dois Group	PARANÁ	SÃO PAULO
	São Bento Group (K)	São Bento Group (K)
	Rio do Rasto Fm.	
	Estrada Nova Fm.	Estrada Nova Fm. (= Corumbataí Fm.
	Serra Alta Fm.	
	Irati Fm.	Irati Fm.
	Tubarão Group	Tubarão Group

In Fig. 3 A, B, C, and D isopach maps of the Passa Dois Group formations are shown.

The lower contact with the Tubarão Group is conformable (Mendes, 1967; Northfleet et. al., 1969) and the upper boundary is represented by a general unconformity below the Lower Cretaceous Botucatu sandstone.

The Irati Formation includes dark argillites, dark-gray, brown to black bituminous shales, gray, non-bituminous shales, limestone, dolomites and chert. The formation shows a marked lateral facies variation along the eastern margin of the Paraná Basin. Dolomite and limestone beds predominate in the area north of the Ponta Grossa Arch, where the sequence consists of rhythmic alternation of calcareous beds and shales. Calcareous beds are subsidiary in the south.

The formation is paleontologically famous for its remains of mesosaurid reptilians: *Mesosaurus brasiliensis* McGregor and *Stereosternum tumidum* Cope, but the second genus seems to be restricted to the northern part of the basin. The taxonomic relationship between the two species is still an open question (Barberena, this Symposium). *Brazilosaurus*, a third genus, has been recently proposed by Shikama and Ozaki (1968).

Other fossils occurring in this unit include insects, crustaceans, plant remains and bivalves (Beurlen, 1957; Mendes, 1967; Pinto, 1972).

The problem of the environment of deposition of the Irati Formation has been debated for a long time. In the absence of useful paleontological data, analyses of sedimentological features and ratio of isotopic carbon ($C^{13} : C^{12}$) indicate an anaerobic, marine to litoraneous environment (Padula, 1969; Keith, 1969; Runnegar and Newell, 1971). Amaral (1971) prefers to interpret the formation as being deposited in a lake with sea connection.

The Serra Alta consists of badly stratified, dark-gray shale, quite similar to the non-bituminous shales of the underlying Irati Formation. It has in fact been considered as a facies of the overlying Estrada Nova Formation (Mendes, 1967). Fossils are rare, except for bivalves and crustaceans (Mendes, 1967).

The Estrada Nova Formation includes green or greenish-gray, silty-shales, finely interbedded with gray to greenish-gray siltstone, together with chert and calcareous oolitic bands. Mendes (1967) recognized four main facies or lithosomes in the formation (including the Serra Alta Formation) which may recur vertically.

The paleontological content of the Estrada Nova Formation is richer and includes a very typical bivalve fauna (*Pinzonella neotropica*-*Jacquesia brasiliensis*, *Leinzia similis*-*Terraia altissima*, *Pinzonella illusa*-*Jacquesia elongata*, *Leinzia froesi* - *Barbosaia angulata* assemblages, Mendes 1952a; 1954; 1954b; 1962; 1963; Mezzalira, 1957; Runnegar and Newell, 1971), together with leiaiid conchostracans, fish remains (paleoniscoid and coelacantid), glossopterid plants (*Glossopteris*, *Gangamopteris*), lycopsid (*Lycopodiopsis*, *Lycopodio-*

phloios) conifers, silicified trunks of gymnosperms, etc. (Mendes, 1967, Yoshida, 1970; Rigby, 1970).

The fine, slightly undulated stratification, flaser structure, micro-cross-lamination, superposition of mudcracked laminae, and presence of bands of oölitic-limestone, geochemical isotope determinations and also the paleontological interpretation of the bivalve fauna points out a shallow water environment. This has been also interpreted as representing extensive tidal flats and slightly brackish to brackish environment (Salamuni, 1963; Northfleet et al., 1969; Keith, 1969).

The uppermost unit of the group to be examined during the excursion corresponds to the Rio do Rasto Formation red beds. It is a thick sequence of red-maroon sandstone, shale and siltstone, locally greenish-green or variegated. Sedimentary structures and the fossil content (plant remains, conchostracans) indicate a continental, flood plain environment, (Mendes, 1967; Bigarella and Salamuni, 1967; Northfleet et al., 1969). This has been corroborated by isotope ratio determination (C^{13} - C^{12}) which indicated a fresh water environment (Keith, 1969).

Investigations towards a model of environmental evolution of the Paraná Basin during the Passa Dois time indicate its progressive confinement and continentalization, which terminates with the deposition of the Rio do Rasto red beds. A modern analogue of this geological history, in terms of sedimentary processes and faunal development, was found by Runnegar and Newell (1971) in the Cenozoic evolution of the Baltic region.

The age of the Passa Dois Group is still a matter not entirely settled. The Group rests conformably on the Tubarão Group, from where Permian marine faunas have been described (Rocha-Campos, 1967; 1970) and underlies the Santa Maria beds with Middle to Upper Triassic reptile and plants (Gordon and Brown, 1952; Cox, 1968).

The occurrence of Glossopterids, leaiid conchostracans, arborescent lycopods and ctenacantid fishes are indicative of a pre-Triassic, probably Permian age. The endemic bivalve fauna of the Estrada Nova Formation is difficult to compare with other faunas because of its unique history. Runnegar and Newell (1971), however, consider that its closest similarity is to the Permian marine faunas from the Gondwana Province. New findings of fossil insects in the Irati Formation (Pinto, 1972) also corroborate this age interpretation.

Based on preliminary palynological zonation of Late Paleozoic strata of Paraná Basin, Daemon and Quadros (1969) interpreted the age of the Passa Dois Group as Kazanian.

Arguments for an younger age for the upper part of the group have been advanced by some geologists, based on the lack of a distinct discordance between the Passa Dois Group and Santa Maria beds in Rio Grande do Sul (Gammermann, 1970), notable physical break before deposition of the lower part of the Botucatu sandstone and possible misinterpretation of Cretaceous basic sills as lava flows (Fúlfa-ro, this Symposium).