THE GONDWANA FORMATIONS OF SOUTHERN BRAZIL: SOME OF THEIR STRATIGRAPHICAL PROBLEMS, WITH EMPHASIS ON THE FOSSIL FLORA

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INTRODUCTION

THE main purpose of this article is to present a brief summary of the geology of the Gondwana beds of Southern Brazil and to point out some of their stratigraphic problems with especial emphasis on the palaeobotanical data.

These beds constitute a large basin known as the Paraná Basin (TEXT-FIG. 1), covering a wide area of Southern Brazil, Uruguay and Paraguay, and which has been named in Brazil the " Santa Catarina System ", from their classical section in the State of Santa Catarina.

Their continuity into the " Paganzo System " (Gondwana) of Argentine has been suggested but not yet proved. There occurs in Argentine a *Rhacopteris* flora absent in Brazil, as well as marine phases with *Syringothyris* and *Eurydesma*, unknown in the Paraná basin.

The Santa Catarina system rests with disconformity and long hiatus on the fossiliferous marine Lower Devonian and is covered disconformably by terrigenous Upper Cretaceous beds. Its maximum thickness is around 2,000 meters and perhaps more.

The sole intra-Gondwana break of major importance yet proved occurs between the Upper Palaeozoic and the Lower Mesozoic (São Bento series, in Brazil), apart from obviously transgressive local disconformities.

The greater part of the sequence is non-marine, while truly marine phases are known only at the middle part of its Palaeozoic section.

The strata are nearly horizontal, dipping slightly almost everywhere in Brazil. There was no orogenetic folding affecting the " system " as has been the case with the Lafonian system of the Falkland Islands. Local disturbances due to basic eruptives (sills, laccoliths and dykes), however, are frequently reported.

Basic lava flows close the sequence, while certain sandy deposits of supra-lava position have been distinguished under the name Caiuá beds. If they still belong to the pre-Cretaceous sequence, or if they may be already referred to the Cretaceous series, is yet to be proved, because no palaeontological data are available in the case.

The lava flows make up wide plateaux, sometimes surrounded by rather steep escarpments, e.g. the so-called Serra Geral.

The Gondwana beds reach the Atlantic coast from Araranguá, State of Santa Catarina, and southward to Torres, State of Rio Grande do Sul.

The Gondwana of Southern Brazil, generally speaking, lacks stratigraphic details, while its fauna and flora ought to be more carefully studied; and until then their proposed correlation with Argentine, Africa, Australia and India is almost pure speculation. Aerial mapping is still backward.

WHITE'S STRATIGRAPHIC COLUMN AND ITS EVOLUTION

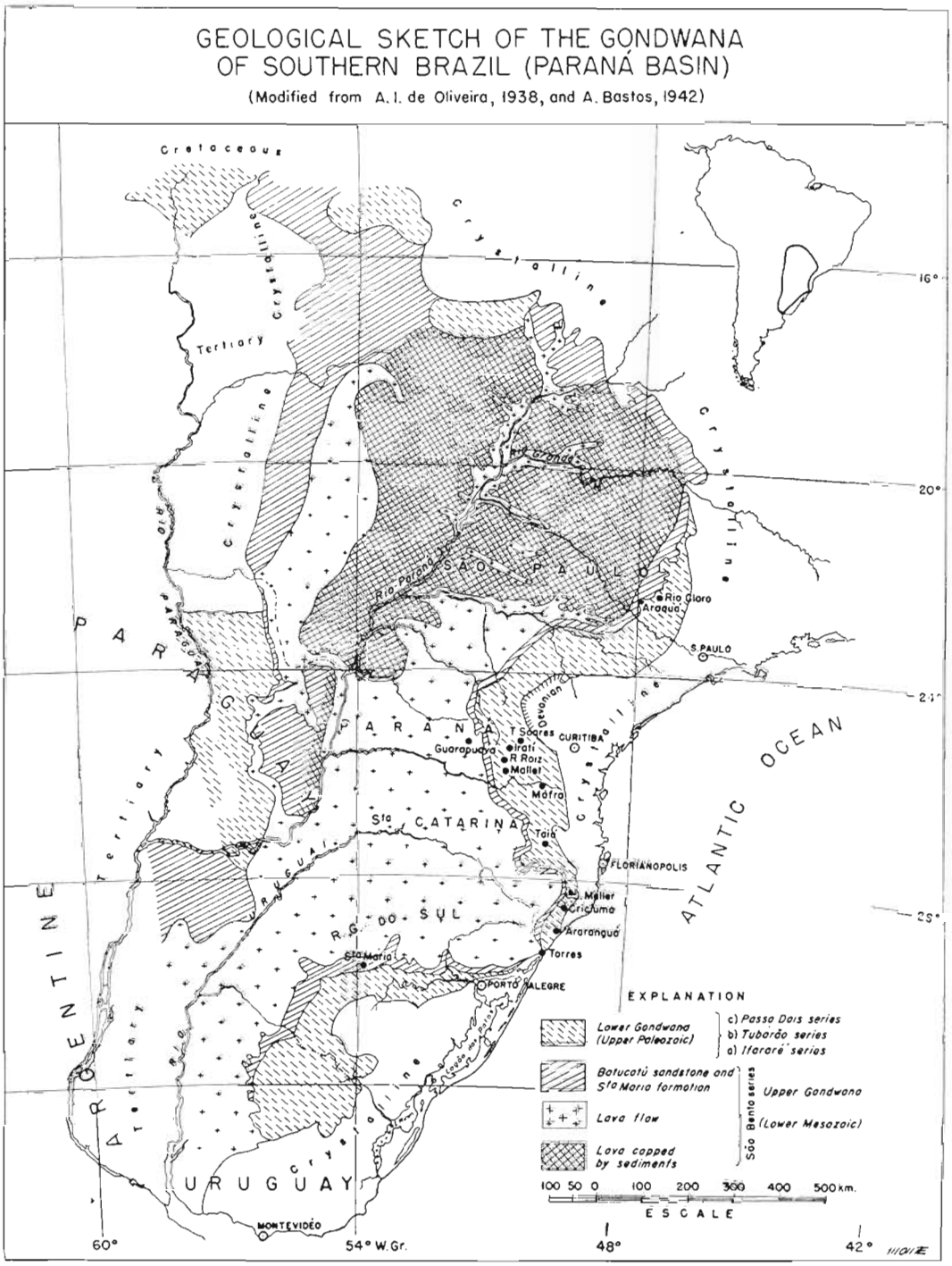
It seems that the first description of fossil plants from the Gondwana of the Paraná basin was given in 1869 by W. Carruthers[1], who published *Flemingites Pedroanus*, *Odontopteris Plantiana* and *Noeggerathia obovata* from the State of Rio Grande do Sul; the first reference to glacials is credited to Orville Derby in 1888.[2]

However, the first stratigraphic classification of these beds came in 1908, and was proposed by I. C. White[3], who measured a 1,403 meters thick section from Lauro

1. On the plant remains from the Brazilian coal bed with remarks on the genus *Flemingites*; Geol. Mag., 6, 151-5, Pl. V, VI, 1869.

2. In Waagen's Ueber Spuren einer Carbonen Eiszeit in Südamerika; Neues Jb. f. Min. Geol. u. Pal., Jg. 1888, B. 2, 172-6.

3. Report on the Coal Measures and associated rocks of South Brazil; Rio de Janeiro, 1908.


GEOLOGICAL SKETCH OF THE GONDWANA
OF SOUTHERN BRAZIL (PARANÁ BASIN)
(Modified from A.I. de Oliveira, 1938, and A. Bastos, 1942)
Cretaceous
Tertiary
Crystalline
Rio Grande
Rio Paraná
SÃO PAULO
Rio Claro
Araquá
S. PAULO
PARAGUAY
PARANÁ
Devonian
T. Soares
Guarapuava
Irati
R. Roiz
Mallet
Mafra
CURITIBA
Sta CATARINA
Taió
FLORIANOPOLIS
ATLANTIC OCEAN
Müller
Criciuma
Araranguá
Torres
RIO GRANDE DO SUL
Sta Maria
PORTO ALEGRE
Rio Uruguay
ARGENTINE
URUGUAY
MONTEVIDÉO
60°
54° W.Gr.
48°
42°
16°
20°
24°
28°
EXPLANATION
Lower Gondwana (Upper Paleozoic)
c) Passa Dois series
b) Tubarão series
a) Itararé series
Botucatú sandstone and Sta Maria formation
Lava flow
Lava capped by sediments
São Bento series
Upper Gondwana (Lower Mesozoic)
100 50 0 100 200 300 400 500 km.
ESCALE

TEXT-FIG. 1

TABLE I

			Meters		
Santa Catarina system	Sao Bento series	Serra Geral eruptives	600	900	Mesozoic (Triassic)
		Sao Bento sandstones, great cliffs of red grey, and cream-coloured sandstone	200		
		Rio do Rasto red beds, with fossil reptiles (*Scaphonyx*) and fossil trees	100		
	Passa Dois series	Rocinha limestone	3	223	Upper Palaeozoic (Permian)
		Estrada Nova grey and variegated shales with cherty concretions and sandy beds	150		
		Iraty black shales, *Mesosaurus* and *Stereosternum*	70		
	Tubarao series	Palermo shales	70	260	
		Rio Bonito shales and sandstones, Coal Measures, and *Glossopteris* (*Gangamopteris*) flora	158		
		Orleans conglomerate	5		
		Yellow sandstones and shales to granite floor	27		

TABLE II

Upper Gondwana (Lower Mesozoic)	Sao Bento series	Serra Geral eruptives
		Botucatu sandstone (= White's Sao Bento sandstones)
		Santa Maria beds, with *Scaphonyx* and other reptiles, *Zuberia*-like fossil plant, etc. (Known only in the State of Rio Grande do Sul)
Disconformity		
Lower Gondwana (Upper Palaeozoic)	Passa Dois series	Rio do Rasto beds
		Estrada Nova beds*
		Iraty shale
	Tubarao series†	Palermo group
		Bonito group (Coal Measures)
	Itarare series	Glacials and subglacials

* In the State of Sao Paulo the more or less corresponding sequence is named Corumbatai formation.
† The more or less corresponding sequence of strata is called in Sao Paulo, Tatui series; Palermo and Bonito groups, however, are not discriminated in this State.

Mueller to the top of the Serra Geral, in the State of Santa Catarina. White's column is as shown in Table I.

Except for a few changes, White's column is still adopted for the Gondwana strata of the State of Santa Catarina and its primary divisions as a generalization for the entire Paraná basin.

Many changes have been proposed, most of them, however, of no consequence. At the Lauro Mueller section (State of Santa Catarina) and in general in the States of Santa Catarina and Rio Grande do Sul, glacials are not so conspicuous as in the States of Paraná and São Paulo. Oliveira[4] has proposed their separation as an independent formation, designated by him Itararé series, maintaining the name Tubarão series *s.s.* for the higher sequence of strata containing coal and *Glossopteris* flora.

Nevertheless, it is stated today that there occurs some intertillite coal.

Alex. du Toit[5] has proposed some modification in view of a palaeontological diagnosis of Cowper Reed's, recognized today as erroneous.

4. Geologia e Recursos minerais do Estado do Paraná; Bol. Ministerio da Agricultura, Industria e Comercio. Ano V, No. 1, Rio de Janeiro, 1916 (1st edition), Monogr. 6, Serviço Geologico e Mineralogico do Brasil, Rio de Janeiro, 1927 (2nd edition)

5. A Geological comparison of South America with South Africa; Carnegie Inst., Washington, Publ. 381, 1927.

It has been realized lately that White's Rio do Rasto beds have a composite character.[6] The Rio do Rasto beds *s.s.* of Santa Catarina are but lithologically similar to the pseudo-Rio do Rasto beds (better designated Santa Maria formation, from its type locality) of the State of Rio Grande do Sul with Triassic reptiles (*Scaphonyx*, etc.); Rio do Rasto beds *s.s.* from Santa Catarina are probably of an Upper Palaeozoic age and are conformable with the Passa Dois series with which they should be included.

Therefore, in the present state of geological knowledge, the Santa Catarina system may be presented in the manner as shown in Table II.

ITARARE AND TUBARAO SERIES

(Tubarao Series s.l., White, 1908)

(a) *Generalities* — I. C. White[7] has designated 280 meters thick basal strata of the section of Lauro Mueller, State of Santa Catarina, containing *Glossopteris* flora and coal, and including a glacial horizon at the very base, by the name Tubarão series (TEXT-FIG. 2).

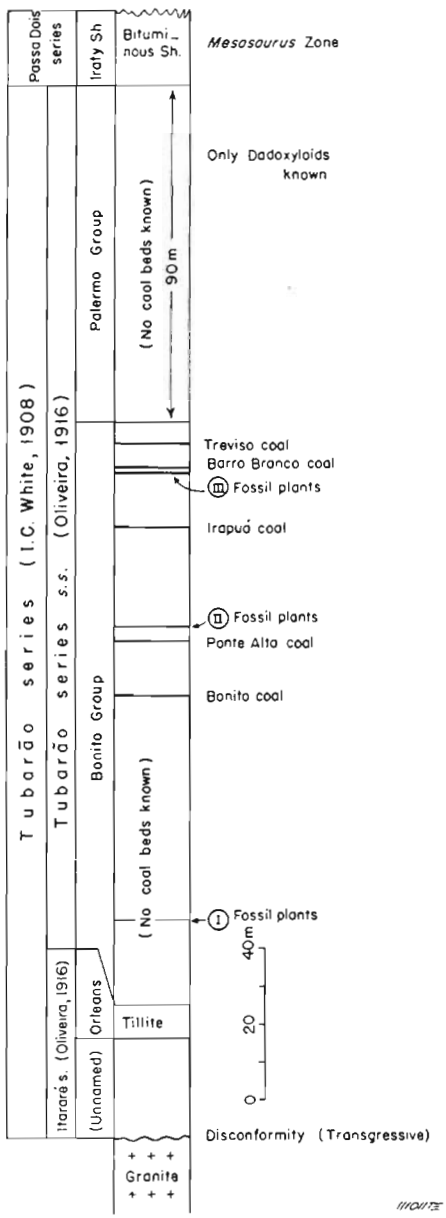
At that section the glacials are by no means conspicuous and its base is transgressive upon the pre-Devonian granite. Roughly speaking, glacials are not so well developed in the States of Santa Catarina and Rio Grande do Sul as in Paraná and São Paulo.

In 1916, Euzebio de Oliveira[8] proposed the designation Itararé series to include glacial and subglacial beds, retaining the name Tubarão series for the overlying coal-bearing sequence.

It has been recognized[9], however, that there are some intertillite coals, as shown in Text-fig. 3, and it is not unlikely that a *Glossopteris* flora also may be present.

In the State of Rio Grande do Sul only one tillite horizon has been observed; in the northern part of the Santa Catarina State only 2 or 3 of them are known; in the State of Paraná, 4 or 5 and in the State of São Paulo, 5 or 6. Besides the tillites, varve clays, fluvio-glacial sandstones, etc., are present in the Itararé series.

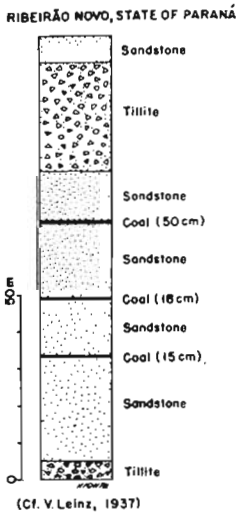
TUBARÃO SERIES AND ITS FOSSIL PLANTS HORIZONS
White's section, at Lauro Müller
State of Santa Catarina



(Columnar section organized according to I.C.White's data)

TEXT-FIG. 2

6. Mackenzie Gordon Jr.— Classificação das formações gondwânicas do Paraná, Santa Catarina e Rio Grande do Sul; Notas preliminares e estudos n. 38, Divisão de Geologia e Mineralogia, Rio de Janeiro, 1947.
7. Op. cit.
8. Op. cit.
9. L. F. de Moraes Rego: "A hulha em São Paulo"; Bol. Inst. de Engenharia de São Paulo 20, n. 109, 345-52, São Paulo 1934; also V Leinz: "Estudo Sobre a glaciação Permo-Carbonifera do Sul do Brasil"; Bol. Serviço do Fomento da Produção Mineral 21, Rio de Janeiro, 1937, etc.



TEXT-FIG. 3

None of the borings so far described have cut *in toto* the Itararé series to its disconformable base upon the Lower Devonian. Recently a well opened at Araquá, State of São Paulo, showed about 1,000 meters of Itararé beds, reaching the granite basement apparently without presence of any Devonian strata; thus, its base therein is transgressive on rocks older than the Devonian and perhaps it is possible to find eventually somewhere else a greater thickness for the sequence.

(b) *Fossil Plant Levels* — From the stratigraphic point of view the three plant horizons from the Lauro Mueller White's section are the only ones well established. The collections have been studied by David White.[10]

Horizon 1 (Joaquim Branco Bed): *Rosellinites gangamopteroides* D. White, *Hysterites brasiliensis* D. White, *Phyllotheca Griesbachi* Zeiller, *P. Muelleriana* D. White, *P.* sp., *Glossopteris Browniana* Brongniart, *Vertebraria*? sp., *Gangamopteris obovata* (Carr.) D. White, *Arberia minasica* D. White, *Derbyella aurita* D. White, *Noeggerathiopsis Hislopi* (Bunb.) Feist., *Cardiocarpon Seixasi* D. White, *C. Moreiranum* D. White, *Voltzia*? sp.

Horizon 2: *Equisetites calamitinoides* D. White, *Schizoneura*? sp., *Sigillaria australis* D. White, *Sphenopteris hastata* McCoy, *Glossopteris indica* Schimper, *G. ampla* Dana, *G. occidentalis* D. White, *Noeggerathiopsis Hislopi* (Bunb.) Feistmantel, *Cardiocarpon*? sp.

Horizon 3: *Glossopteris Browniana* Brongniart, *Gangamopteris obovata* (Carr.) D. White, *Noeggerathiopsis Hislopi* (Bunb.) Feistmantel, *Cardiocarpon Moreiranum* D. White, *Vertebraria* sp.

Elsewhere the correlation of the coal-bearing strata is purely based on lithologic similarities and the fossil plant levels have an uncertain stratigraphic position.

At the present state of the stratigraphic knowledge of the Bonito group there is no one definite guide horizon established on the basis of plant forms or assemblages. Much more information is still needed.

To David White (1908)[11], Lundquist (1919)[12] and more recently Ch. Read (1940)[13] are due the most important palaeobotanical contributions.

The last-mentioned author has recognized in a lot of fossil plants coming from Teixeira Soares, State of Paraná, only forms belonging to the *Glossopteris* flora assemblage, and which he has referred to the top of the Itararé series. He writes[14]: "The assemblage is poor both in species and genera. These occurrences just above the tillites are essentials of the so-called *Glossopteris* flora with no complicating elements entering into association." And again: "In other words, the tillites are followed immediately by small floras of strictly southern types. These are evidently Pennsylvanian."

The forms identified by Read are the following:

Glossopteris indica Schimper, *G. Browniana* Brongniart, *G.* sp. (scales), *Phyllotheca* sp., *Brachyphyllum* cf. *australe* Feistmantel.

Nevertheless Oliveira[15] refers the same plant level to the Bonito group, i.e. within the Tubarão series (TEXT-FIG. 4).

David White[16] has expressed himself regarding the horizon 1 of the Lauro Mueller section as follows: "This flora is to be regarded as a purely southern or Gondwana flora, without contamination by northern

10. Report on the fossil flora of the Coal Measures of Brazil; in Relatorio Final da Comissão de Estudos de Minas de Carvão de Pedra, Pt. III, 337-617, Rio de Janeiro, 1908.

11. Op. cit.

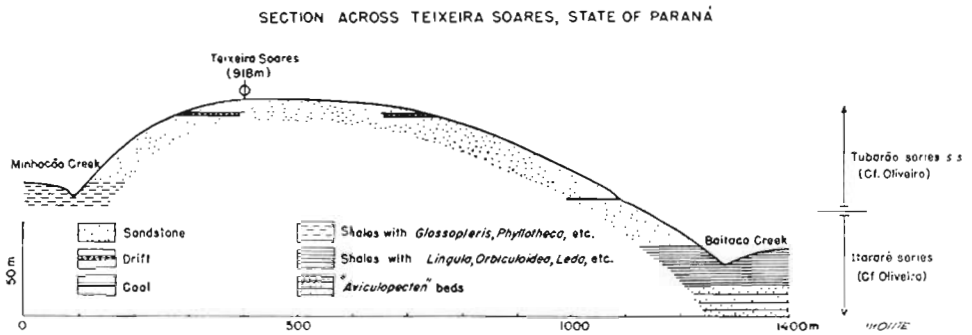
12. Fossile Pflanzen der *Glossopteris* Flora aus Brasilien Klg. Svensk Vetensk. Ac., Handl. 60, n. 3, 1-36, 2 pl., Stockholm.

13. Plantas fosseis do neo-Paleozoico do Paraná e Santa Catarina Monogr 12, Divisão de Geologia e Mineralogia, Rio de Janeiro, 1940.

14. Ch. Read: op. cit., pp. 59-61 and p. 63.

15. Euzebio de Oliveira: op. cit.

16. Op. cit., pp. 366-368.



TEXT-FIG. 4

types. The absence of *Lepidophytes* or other elements belonging to the northern Permo-Carboniferous flora may be explained either on the hypothesis that the climate or other environmental condition had not yet become hospitable for the return of the contemporaneous northern flora or by the supposition that northern plants had not yet had time to recover the ground lost by themselves or their ancestors at the time of the refrigeration of the region." And again: " Evidence of the presence of *Lepidophytes* in the series is first found in the collection from the Bonito coal, where, at 120 meters above the granite, megaspores, probably Sigillarian, are met in layers forming a part of the coal. The same type of spore, together with fragments of cortex and leaves of *Sigillaria*, are met in a bed 135 meters above the granite and 40 meters below the Barro Branco coal near Minas [LAURO MUELLER]..." This is the horizon 2 in this section.

Concerning the evidence of a pure *Glossopteris* flora whether in the Itararé series or in the base of the Tubarão series it seems to be, at least at the present time, an open question. Long before Read, E. Oliveira[17] discovered a *Voltzia* specimen in the above-mentioned horizon from Teixeira Soares; it is possible, however, that it actually corresponds to a *Buriadia*. Recently, F. Almeida has collected at the same horizon and locality a specimen of *Sphenophyllum*[18]. O. Barbosa and F. Almeida[19], quite recently, have listed from levels supposed by them to be very low in the Itararé series, in the State of São Paulo, the following forms :

Phyllotheca sp., *Gangamopteris* sp., *G. cyclopteroides*, *Noeggerathia* sp., *N. Hislopi*, *Glossopteris* sp., *G. angustifolia*?, *Samaropsis* sp., *Lepidodendron Pedroanum*, *Sphenopteris* sp., *Psygomophyllum* sp., *Paranocladus* sp.

Even if their identifications or stratigraphy should eventually be revised, the existence of a pure *Glossopteris* flora in Southern Brazil is worthy of a re-examination. The plant collections made are very small and no systematic collecting has been carried out and the absence of " northern " forms might eventually be explained as the result of an unsatisfactory collecting.

" It might well be asked whether these latter are immigrants from the north or descendants of a pre-Gondwana stock which at that time had a distribution in both northern and southern hemispheres."[20]

On the other hand, the age of the Itararé and Tubarão series still remains an open question; they may have an Upper Carboniferous or Permian age.

For general information, the genera recognized by the different authors at the Tubarão (and Itararé) series are listed below:

Annularia, *Arberia*, *Asterophyllites*, *Baiera*?, *Brachyphyllum*, *Buriadia*, *Calamites*, *Cardiocarpon*, *Carpolithus*, *Chiropteris*, *Cordaites*, *Cyclopitys*?, *Dadoxylon*, *Derbyella*, *Equisetites*, *Gangamopteris*, *Glossopteris*, *Gond-*

17. Op. cit.

18. Episodio da ultima Epoca Interglacial Permo-Carbonifera no Paraná; Notas preliminares e Estudos, n. 27, Divisão de Geologia e Mineralogia, Rio de Janeiro, 1945.

19. Anais da Academia Brasileira de Ciências, t. 21, n. 1, 65-8, Rio de Janeiro, 1949.

20. H. S. Rao: *Lycopodiopsis Derbyi* Renault, with remarks on the Southern Paleozoic Lycopods; Proc. Indian Ac. Sc., 11, 5, Sec. B, 1940.

wanidium, Hysterites, Knorria, Lepidodendron, Lepidophloios, Lepidostrobus, Marchantites, Ottokaria, Paranocladus, Pecopteris, Phyllotheca, Psygmophyllum, Rosellinites, Samaropsis, Schizoneura, Sigillaria, Sphenophyllum, Sphenopteris, Stigmaria, Taeniopteris, Vertebraria?, Voltzia and *Zeilleria.*

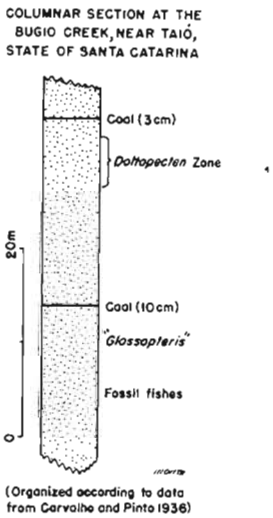
Readers interested in details of the Southern Brazil Gondwana flora will find at the end of this article a selected bibliography on it.

(c) *Marine Horizons* — Within the sequence of strata named by White *Tubarão*, three horizons of marine fauna have been noticed up to the present. One of them discovered by E. Oliveira bears a faunule with Brachiopods (*Lingula, Orbiculoidea, " Ambocoelia ", Chonetes*), Pelecypods (*Leda*), Gastropods and *Phyloblatta* wings. This horizon crops out at Teixeira Soares in the State of Paraná, and has been also noticed at several other points, the farthest known of which is Bela Vista, in the State of Santa Catarina, about 80 km. southward of the former locality. Its thickness is apparently quite variable: around 30 meters at Teixeira Soares and reaching only 2 meters at Bela Vista.

A few years ago, near Teixeira Soares, strata bearing *Aviculopecten*-like forms were found below the dark shale containing a small marine fauna. This material is not yet described. As these dark shales occur between tillites at Bela Vista, this marine horizon has been considered to be within the Itararé series. Just above the fauna level the already mentioned plant-bearing bed crops out and shows what has been supposed to be a " pure " *Glossopteris* flora, as well as a coal bed (*see* TEXT-FIG. 4).

The situation is rather confusing because, according to Oliveira, his Itararé series should include glacials and subglacials, while the coal-bearing strata with *Glossopteris* flora should be referred to the Tubarão series as re-defined by him. In fact, however, there occur intertillite coals (and quite likely also *Glossopteris* flora), and so it is easy to imagine how difficult it is to trace the boundary between the two formations as it is still a question whether their difference is to be considered one of facies or of age.

Another marine horizon of controversial stratigraphic position was discovered in 1929 at Taió, in the State of Santa Catarina. It comprises a sandstone bearing *Deltopecten* and some other Pelecypods and a few



TEXT-FIG. 5

Brachiopods. The material consists of internal casts and poorly preserved impressions and its age, attributed to the Permo-Carboniferous by Cowper Reed[21], should be revised in the light of larger collections. Its correlation with the lower and upper marine beds of Australia, as Reed suggested, ought to be reconsidered.

Concerning its stratigraphic position, Oliveira[22] infers that it is just above the horizon with *Lingula*, etc., and yet within the Itararé series.

However, that " lowest " marine horizon has not yet been proved at any place below the Taió *Deltopecten*-bearing beds which, according to P. F. Carvalho and E. A. Pinto[23], remain about 120 meters below the Irati shales (*Mesosaurus* zone) and within the Bonito group (Coal Measures); coal beds are present below and above the *Deltopecten* zone (TEXT-FIG. 5), the glacials coming out far down in the valley.

Quite recently, at Capivari, in the State of São Paulo, another marine occurrence has been found with Brachiopods (*Crurithyris*

21 F. R. Cowper Reed: A new Permo-Carboniferous fauna from Brazil, Monogr. 10, Serviço Geologico e Mineralogico do Brasil, Rio de Janeiro, 1930.

22. Euzebio de Oliveira: Conferência na Associação Brasileira de Educação: 75, Rio de Janeiro, 1930

23. P. Franco de Carvalho & E. Alves Pinto: Reconhecimento Geologico no Estado de Santa Catarina; Bol. 92, Serviço Geologico e Mineralogico, Rio de Janeiro, 1938.

and *Rhynchopora*) and *Aviculopecten*-like Pelecypods. Material is not yet described and its stratigraphic position is still uncertain.

As it has been shown, the relations between the marine horizons are not clear; however, with the progress of the investigation they certainly will prove to be of the greatest value as guide horizons to Southern Brazil Gondwana stratigraphy.

PASSA DOIS SERIES

No less complex problems are presented by the sequence of beds so far referrable to the Palaeozoic and succeeding to the Tubarão series. At the Lauro Mueller section, in the State of Santa Catarina, they reach a thickness of 330 meters, according to White's data.

Sequence begins with the Iratí shales, which lithologically are somewhat variable and, roughly speaking, include chiefly black shales, often bituminous and sometimes associated with magnesian limestones. Chert nuggets are also characteristic. The diagnostic fossil is a small free-swimming reptile, *Mesosaurus brasiliensis* MacGregor; frequently there are also *Liocaris* and other crustaceans. J. Maniero has described a small silicified tree under the name *Dadoxylon Whitei*.[24]

Iratí beds are apparently constant from Uruguay to the southern part of the States of Goiás and Mato Grosso and represent a very important guide horizon.

Some of the Brazilian geologists, nevertheless, sometimes over-estimate the lithologic " diagnostic " characters in recognizing this horizon. Occurrence of *Mesosaurus* should be obviously of a higher importance as characterizing a biozone.

The transition between the Tubarão series (below) and the Iratí shale is apparently gradual and this certainly reinforces the importance of the demonstration of a *Mesosaurus* zone. Similarly the uppermost beds of the Iratí formation pass to the Estrada Nova beds without any known disconformity.

The Iratí facies is at present under discussion. While it shows a certain uniformity along wide areas suggesting an interior sea or a paralic basin, there are no supporting arguments from the palaeontological point of view.

The succeeding formations, i.e. Estrada Nova (called, in São Paulo, Corumbataí) and Rio do Rasto beds, consist chiefly of variegated shales and some limestones and sandstones. It should be clear that White's Rio do Rasto have a composite character. The Santa Catarina Rio do Rasto beds *s.s.* do not bear Triassic reptiles like *Scaphonyx*, etc., which occur in the pseudo-Rio do Rasto beds of Rio Grande do Sul (Santa Maria formation), there being only superficial lithologic similarities. Because of this the Rio do Rasto beds *s.s.* are now admittedly referred to White's Passa Dois series. White's Rocinha limestone is recognized today as a local member with no major stratigraphic meaning.

Unfortunately no fossil collections have been described from White's Lauro Mueller section, which makes correlation very difficult.

Several other localities, however, have furnished Pelecypoda, fossil plants and fish remains besides small Crustacean and Gastropods. The recent Brazilian geological literature distinguishes the following groups within the Upper-Palaeozoic supra-Iratí sequence in the State of Paraná:

b) Rio do Rasto formation { Esperança mb. / Serrinha mb.
a) Estrada Nova formation { Terezind mb. / Serra Alta mb.

The facies of the sequence is still controversial. K. Holdhaus[25], F. R. Cowper Reed[26] and L. R. Cox[27] have recognized marine Pelecypod genera like *Solenomorpha*, *Sanguinolites*, *Myophoria*, *Pachycardia*, *Palaeoneilo*, etc. The second author has even described *Cephalopod* remains and referred to an undetermined *Radiolarian* (which no doubt should confirm the presence of a marine facies) and has attributed the fauna to an Upper Triassic age (Carnic). On the other

24. *Dadoxylon Whitei* n. sp., Universidade de São Paulo, Faculdade de Filosofia, Ciências e Letras, Bol. 45, Geologia no. 1, 107-12, São Paulo, 1944.

25. Sobre alguns lamelibrânquios fosseis do sul do Brasil, Monogr. 2, Serviço Geologico e Mineralogico do Brasil, Rio de Janeiro, 1918.

26. Triassic fossils from Brazil. An. Mag. Nat. Hist., Series 2, v. 10: 39-48, 1928, Triassic faunas from Brazil. Monogr. 9, Serviço Geologico e Mineralogico do Brasil, Rio de Janeiro, 1929; Some new triassic fossils from Brazil. An. Mag. Nat. Hist., s. 10, v. 10: 479-87, 1932; Some Triassic Lamellibranches from Brazil and Paraguay. Geol. Mag., v. 72. 33-42, 1935.

27. Triassic Lamellibranches from Uruguay. An. Mag. Nat. Hist., s. 10, v. 13: 264-73, 1934.

hand, the presence of Leaia-like *Conchostraca*[28] and some *Lycopods* (*Lycopodiopsis Derbyi* and *Sigillaria*) suggests an Upper Palaeozoic age. Marine forms like Corals or Brachiopods, etc., are unknown. A recent revision[29] of Reed's "Myophoria" and "Pachycardia" has demonstrated that these forms actually belong to new and very distinct genera (*Jacquesia* and *Pinzonellopis*). Reed himself and Holdhaus (and Cox in Uruguay) have ascribed several other forms to new genera (*Pinzonella*, *Ferrazia*, *Plesiocyprinella* and *Terraia*) which points out very clearly the high endemic character of such a fauna. Holdhaus's "*Solenomorpha*" and "*Sanguinolites*" have been proved quite recently to belong to something else: *Leinzia* Mendes, *Terraia* Cox and *Holdhausiella* Mendes (as yet unpublished), Reed's cephalopods and Radiolarian remains, on the other hand, are not convincing; a "*Dentalium*" described by Rego[30] really seems to be a fish spine (*Elasmobranchia*).

Thus Reed's chronology has no validity, nor has du Toit's idea of an intra-Passa Dois hiatus, to explain the occurrence in the sequence of both Palaeozoic and Lower Mesozoic fossils. At least at present there are no palaeontological reasons to show definitely a marine environment for the Pelecypoda fauna, while these strata are apparently so extensive as to require an internal marine basin or a paralic basin.

Their mollusc fauna requires a more detailed study both in taxonomy and biostratigraphy. There are no well-established foreign genera, and no forms of a definite marine type have been found yet.

Before a careful study of the mollusc fauna is undertaken, stratigraphic correlations must be rather precarious. Lately, however, detailed stratigraphic studies have been in progress at the Rio Claro region in the State of São Paulo.

Lycopodiopsis Derbyi is the first fossil plant to be described from the supra-Iratí sequence which is found in a level just above the *Pinzonella-Plesiocyprinella* zone, at least in the Rio Claro region.[31]

Rao (1940)[32] has given a good paper on this plant, summarizing the discussion concerning its taxonomic position, etc.

Tietea singularis (apparently a *Psaronius* relative) was described in 1913 by Solms-Laubach[33]; its stratigraphic position is still doubtful.

Sigillaria (?) *muralis* and *Dadoxylon nummularium*, described by D. White[34], have also no precise stratigraphic position.

In a place known as Serrinha, near Malé, State of Paraná, from a horizon just above a bed containing *Terraia* (HOLDHAUS "*Solenomorpha altissima*") and *Leinzia* (HOLDHAUS "*Solenomorpha similis*") a few plant remains have been obtained. These were recognized by Zeiller[35] as *Glossopteris Browniana*, *G. angustifolia*, *Taeniopteris* cf. *Feddeni*, *Pecopteris* sp., *Cladophlebis* sp., and fragments of Equisetaceae (only listed). It could be remarked that the Serrinha beds are considered as belonging to the top of the Passa Dois series, i.e. to the Rio do Rasto formation.

Another florule has recently been described by E. Dolianiti[36] from a horizon likewise referred to the Rio do Rasto beds which lies about 20 meters above Reed's "*Palaeoneilo*" faunae of Santo Antonio da Platina, Northern Paraná, and, according to that author, it includes:

Sphenozamites sp., *Podozamites*? sp. and *Equisetites* remains.

Reed's "*Palaeoneilo*" has not yet been revised, but probably will prove to correspond to some other genus or genera and is associated with "*Estheria*", Ostracods and some small Gastropods.

28. F. R. Cowper Reed: New Phyllopoda from Brazil, Bol. 34, Serviço Geologico e Mineralogico do Brasil, 1929.

29. J. Camargo Mendes: Lamelibrânquios triássicos de Rio Claro; Univ. São Paulo, Fac, Fil. Ciên. Letr., Bol. 45, Geologia 1, 41-75, São Paulo, 1944; Novos lamelibrânquios fosseis da Serie Passa Dois, Sul do Brasil, Bol. Divis. Geologia e Mineralogia n. 133, Rio de Janeiro, 1949; see also for a discussion of the age of the Estrada Nova formation, by the same author: Consideraçoes sôbre a estratigrafia e idade da formação Estrada Nova, Bol. Fac. Fil. Ciên. Letr., 50, Geologia 2, 27-34, 1945.

30. L. F Moraes Rego: Contribuição ao estudo das camadas superiores da Serie Passa Dois, An. Ac. Bras. Ciên., v. 8, n. 1, 41-52, 1936.

31. J. Camargo Mendes: Posição estratigrafica de *Lycopodiopsis Derbyi* Renault, An Ac. Bras. Ciên., v. 16, n. 2, 137-8, Rio de Janeiro, 1944.

32. Op. cit.

33. *Tietea singularis*. Ein neuer Pteridinenstamn aus Brasilien, Zeits. f. Botanik, V, n. 9, 673-700, 1913.

34. Op. cit.

35. *In* Oliveira's Posição estratigrafica dos lamellibranchios descritos na memoria do Professor Holdhaus; Serv. Geol. Min. Brasil, Monogr. 2, 25-32, Rio de Janeiro, 1918.

36. Um novo elemento na flora fóssil do Brasil, *Sphenozamites* Brongniart, Divisão de Geol. e Mineralogia, Notas preliminares e estudos n. 26, Rio de Janeiro, 1946.

J. Maniero[37] has described recently *Dadoxylon Roxoi* from the Corumbataí beds (± = WHITE'S Estrada Nova group) of the State of São Paulo.

Some other casual references to "*Dadoxylon*", "*Glossopteris*", "*Lepidodendron*", *Sagenopteris* and "*Walchia*" have been made, but, in general, the above may be considered as summarizing the present state of knowledge concerning the supra-Iratí flora.

No disconformity is yet known between the Tubarão and Passa Dois series, and it seems that there are no arguments from the palaeontological point of view to consider the sequence younger than Permian. Arguments on the basis of the presence of *Mesosaurus* do not seem to be decisive, at least at the present, to establish chronology, because the age of White's band is still questionable.

SAO BENTO SERIES

The São Bento series is made up of the Santa Maria formation (below), the Botucatú sandstone (= WHITE'S São Bento sandstone) and the basic lava flows (on top).

The Santa Maria formation, probably about 100 meters thick, is a sequence of sandstones, argillites and siltstones and has been erroneously correlated by White with his Rio do Rasto beds of Santa Catarina. It is only known in the State of Rio Grande do Sul, showing a reptilian faunule with *Scaphonyx fischeri*, *Stahleckeria potens* exhaustively studied by Woodward[38] and Von Huene[39] and recently by Price[40], besides silicified trunks of Coniferales. Quite recently some plant remains including *Zuberia*-like forms have been discovered. These latter are not yet described. The age of this formation after its reptilian fauna is attributed to the Upper Triassic.

Then follows the Botucatú sandstone which, according to du Toit[41], rests conformably on the Santa Maria beds, while Gordon[42] maintains that there is a disconformity.

The name Botucatú has priority over White's São Bento sandstone, since the former was proposed in 1904 by G. Campos.

The maximum thickness of the series is around 200 meters, and its chief lithological component is an eolian cross-bedded sandstone. Some reptilian footprints have been reported, as well as worm tubes and, quite recently, Ostracods and Estherioids have been collected from thin argillaceous partings.

Outside of the restricted area of the Santa Maria formation, the Botucatú sandstone rests either directly on the Passa Dois series or on older groups.

A supposed fluvial facies of the dominantly eolian Botucatú has been described under the name " Piramboia beds ".

An important fact, if general, is the occurrence of a disconformity between the Botucatú sandstone and the first lava sheets of the Serra Geral formation, meaning an erosional hiatus previous to the large extrusion. Some sandstone beds are known to intercalate the lava sheets.

Sandy deposits covering the topmost lava sheet have been distinguished as Caiuá formation[43]; if they actually belong to the São Bento series, or if they represent a separate series, or else if they belong already to the Cretaceous Baurú formation, is still doubtful. Regarding the Botucatú sandstone and the basic extrusive chronology, it is only possible to say that their age lies between the Upper Triassic (Santa Maria formation) and the Upper Cretaceous (Baurú formation).

The uppermost fossiliferous strata constitute the Baurú formation, which contains a reptilian faunule attributed to the Upper Cretaceous, and rests unconformably on the uppermost lava sheet where no Caiuá deposits are to be found.

The reader interested in the geology of the lava flow of Southern Brazil will find a good recent paper on the subject by V. Leinz.[44]

37. Uma nova madeira fóssil do Brasil Meridional; Revista do Inst. Adolfo Lutz, VI, n. 1, 65-76, São Paulo, 1946.

38. A. Smith Woodward: On some reptilian bones from the State of Rio Grande do Sul; Geol. Mag., V, n. 528, 251-5, 1908.

39. F. von Huene: Gondwana Reptilien in Südamerika, Pal. Hung., v. 2, fasc. 1, 86-102, Budapest, 1926; Eine Cynodontier aus der Trias Brasilien, Centb. f. Min. Geol. u.s., Jg. 1928, 257-70, Die fossilen Reptilien des südamerikanischen Gondwanalandes Ergebnisse der Sauriergrabungen in Südbrasilien 1928-29, Lief I, 1-92, Tübingen 1935; Lief II, 93-159, 1936.

40. L. Ivor Price: Sôbre um novo Pseudosuquio do Triássico superior do Rio Grande do Sul, Bol. n. 120, Divis. Geologia e Mineralogia, Rio de Janeiro, 1946; Um procolofonideo do Triássico do Rio Grande do Sul, Bol. n. 122, Divisão de Geologia e Mineralogia, 1947.

41. Op. cit.

42. Op. cit.

43. Chester Washburne: Petroleum Geology of the State of São Paulo; Com. Geografica e Geologica de São Paulo, Bol. 22. São Paulo, 1930.

44. Contribuição à Geologia dos derrames basálticos do Sul do Brasil, Fac. Fil. Ciên. Letr., Bol. n. 103, Geologia n. 5, Univ. São Paulo, 1949.

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