STRATIGRAPHY AND AGE OF FINI-PROTEROZOIC BASINS OF PARANÁ AND SANTA CATARINA STATES, SOUTHERN BRAZIL

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Key Words
Neoproterozoic; Cambrian; turbidites; volcanism.

RESUMO

As Bacias de Itajaí, Corupá, Campo Alegre, Guaratubinha, Camarinha e Castro representam, na porção norte da região sul-brasileira, o mais importante registro dos eventos geológicos ocorridos durante o período compreendido entre o final do Neoproterozóico e o início do Cambriano. As bacias de Itajaí e Camarinha são interpretadas como bacias de ante-país, enquanto as demais são classificadas como bacias extensionais tardi-colisionais. O vulcanismo presente nessas bacias está, espacial e geneticamente, relacionado com o magmatismo alcalino-peralcalino da Suite Serra do Mar. A fase principal de instalação dessas bacias está relacionada a eventos extensionais situados entre dois episódios compressivos: final do Neoproterózoico (~ 650-600 Ma) e início do Cambriano (550-530 Ma).

ABSTRACT

The Itajaí, Corupá, Campo Alegre, Guaratubinha, Camarinha and Castro basins are the most important register in the northern half of southeastern Brazil of geological events wich occurred at the end of the Neoproterozoic and beginning of the Cambrian. The Itajaí and Camarinha basins are thought to be foreland basins while the rest are late-collision extensional basins. The volcanism in these basins is related in time and genetically to the alkaline-peralkaline magmatism of the Serra do Mar Suite. The main phase of basin installation is related to extensional events which separate two compressive phases at the end of the Proterozoic (~650-600 Ma) and the beginning of the Cambrian (550-530Ma).

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INTRODUCTION

The Itajaí, Camarinha, Corupá, Campo Alegre, Guaratubinha and Castro basins are located in the eastern parts of the Paraná and Santa Catarina states (figure 1), and are important geotectonic marks of the evolution of the different geotectonic entities present in the region. They can be classified into two main groups according to their relationships with Neoproterozoic fold belts.

In the first group, the basins are directly related to the adjacent fold belt. Rocks in the Itajaí basin underwent the last deformational phases which also affected the supracrustal rocks of Dom Feliciano Belt. The same relationship is seen for the Camarinha Formation and adjacent Ribeira Belt. They are foreland basins (Allen et al, 1986) in which the border near the fold belts is much more deformed than the opposite border. This is specilally true in the Itajaí Basin, in which the northern border is in clear unconformity with the gneissic basement.

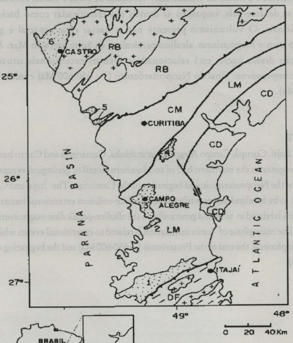

Figure 1 - Distribuition of Fini-Proterozoic basins of Shouthern Brazil. Legend:1- Itajai; 2-Corupa; 3-Campo Alegre; 4- Guaratubinha; 5- Camarinha and 6- Castro. DF- Dom Feliciano Belt; LM-Luis Alves Microplate; CD- Costeiro Domain; CM-Curitiba Microplate, and RB- Ribeira Belt (tectonic unities according to Basei et al, 1992).

The Basins of the second group do not present a direct relationship with the southern Brazilian fold belts. They are not folded, and were affected only by rigid (brittle) tectonics, which resulted in tilting of blocks along local faults. They represent extensional, late collision basins (IF and LL types, Kingston et al.,1983).

Analysis of the stratigraphy and the succession of depositional environments in the basins provided important elements for their geotectonic interpretation.The Itajaí and Camarinha foreland basins have predominantly epiclastic arenaceous sediments deposited in a range of environments from delta fans to distal turbidites. Conglomerates and pelitic horizons form an important part, volcanic rocks are subsidiary and limestones are absent. The extensional late collisional basins of Campo Alegre, Guaratubinha, Corupá and Castro have an important intermediate to acid volcanic component, represented by lavas, pyroclastics and subordinate dykes.

FORELAND BASINS

ITAJAÍ BASIN

The Itajaí basin (Fig.1, basin 1) occupies an area of more than 700 km² in the northeastern part of Santa Catarina, near the Itajaí River valley. It is elongated along N60E and is characterized by a thick epiclastic sedimentary succession with subordinated trachytic to rhyolitic volcanics and pyroclastics.

Pioneer studies of this basin started with Ferraz (1921), followed by Dutra (1926), Maack (1947) and Salamuni et al. (1961). The Itajaí series was divided into the basal Ibirama Formation, of quartzites and phyllite horizons grading upwards into massive and laminated slates with small conglomerate lenses. The upper Gaspar Formation contains a thickening-upwards sequence beginning with psammo-pelitic slates and ending with the thick Baú conglomerates.

Silva & Dias (1981) inverted this stratigraphy, placing the Gaspar formation, composed of psammitic sequences with minor conglomerates and vulcanic rocks, at the bottom. The pelitic and pelitic-psammitic rhythmites were grouped into the Campo Alegre Formation, and there correlated with similar rocks in another basin further north; they were placed at the top of the basin sequence.

Basei (1985) and Basei et al., (1987) attributed a thickness of 7500 meters to the Itajaí Group. They showed that it has been affected by two deformational phases also present in the fold belt formed by the Brusque Group, and interpreted the structure as a monoclinal with vergence towards the granulite terrane to the northest. They proposed that it is composed of two main units, divided into four informal lithostratigraphic sub-units: (i) the lower psammitic unit, equivalent to the Gaspar Formation, with an arenaceous-conglomeratic subunit containing thick arkosic sandstones intercalated with lenses of polymitic conglomerates and volcanic tuffs, overlain by a rhythmic sandstone-silt subunit with microconglomeratic layers; and (ii) the upper silty unit, with a silty- arenaceous subunit with predominant silts at the base and a silty-pelitic unit of homogeneous clay- and silt-stones, containg small lenses of coarser material, at the top. Krebs et al. (1988, 1990) proposed a more complex stratigraphy with 12 lithofacies and 5 facies units, distributed from the edge to wards the centre of basin as follows (i) conglomerates of delta fans in which a clast-supported conglomerate facies predominates; (ii) sandstones of the delta front, often with sigmoidal geometry; (iii) platform sandstones and pelites; (iv) graded medium conglomerates of submarine fans; and (v) turbidites in the form of tabular sandstones and pelites.

Researches coordinated by Petrobrás were synthesized by Appi & Cruz (1990), Appi et al (1990) and Rostirolla (1991). A lower sequence closely corresponding to the Gaspar Formation, is formed of polymitic conglomerates with sandstone matrices and coarse continental sandstones deposited in alluvial and delta fans. The upper subaqueous sequence, deposited in marine or lacustrine environments, corresponds to the Campo Alegre Formation of Silva & Dias (1981), with varied rocks types including diamictites, conglomerates, graded and massive coarse sandstones, rhythmites of fine sandstones and laminated slates whose structures include those of subaquatic mass movements, channeled turbidites and clastic turbidites.

These authors elaborated a stratigraphic arrangement in of sedimentary systems tracts, identifying a lower sequence - the Gaspar Formation - formed by a low-level tract-and a transgressive sequence represented by a condensed distal system of rhythmic slates which formed from an eroded upper tract. Appi et al. (1990) believe that they have identified remnants of this upper tract, formed by prograding continental sequences at the southern border of the basin.

Citroni (1993), identified four main sedimentary facies associations, defined according to their depositional environment:
1) Turbiditic associations (1.1 sandstone-conglomerate dense turbidites; 1.2 thick graded dense turbidites; 1.3 Classic medium density turbidites; 1.4 Low density turbidites); 2) Basin associations (2.1 hemipelitic; 2.2 subaqueous slides); 3) Transitional associations (3.1 coastal plain sandstones; 3.2 fan delta; 3.3 shallow water); 4) Continental associations (4.1 ruditic alluvial fans; 4.2 Intercalated alluvial sandstones).

The sandstone-conglomerate dense turibidites of association 1.1 are characterised by the presence of orthoconglomerates with normal or inverse grading, graded conglomeratic sandstones and sandstones. Intraformational breccia are sometimes seen at the base of the sequence. This assotiation is interpreted as deposits formed in subaquatic channels in the median portions of the fan lobes (Walker 1984).

The graded dense turbidites of association 1.2 occur in small distribution channels or in the median parts of the lobes. They are identified by continuous gradation from conglomeratic sandstones to fining-upwards siltstones with Bouma T_{ABDE} or T_{BDE} sequences. This association usually occurs intercalated in association 1.1.

The classical turbidites of association 1.3 were deposited in the fringe lobes or in external fans. The most characteristic rocks are fine and medium graded sandstones and graded siltstones, forming complete or incomplete Bouma sequences.

The low density turbidites of association 1.4 are thick packets of silty-slates or siltstones and fine sandstones with rhythmic layers, which may have subordinate intercalations of coarse and fine sandstones. These were deposited on the fringe of the fan, or on the basin floor. They are associated with and similar to hemipelagic rocks, though they usually have less well-defined lamination, being composed mainly of massive pelites and shales.

The subaqueous sliding deposits of association 2.2 are breccias, sandstones to silty-mudstones and diamictites with sand-clay mudstone matrixes. They are commonly associated with rocks of associations 1.3 and 1.4.

The transitional facies between the continental and deeper marine environments are the coastal plain association 3.1, the delta fan association 3.2 and the shallow water association 3.3, all of which containing great thicknesses of coarse to fine sandstones. The different associations are characterised by the different sedimentary structures. The coastal plain sandstones have medium-scale cross-bedding and are associated with graded sandstones and siltstones with cross-bedding. Herring bone stratifications is also present. The cross-bedding is typically bimodal.

The delta fan deposits have typically sigmoidal layers of massive sandstone which contain ~ 1m thick cross bedded sigmoidal ortho-conglomerates with widths up to 2-3m. Their occurrence is restricted. The shallow water sandstones have small-scale (< 10cm) cross-bedding with climbing ripple and wave laminations, channeled profiles and very variable paleocurrent directions suggestive of reworking by wave action. Intercalations of massive or graded mediun sandstones are also present.

The alluvial sandstones of association 4.2 are composed of sandstones and massive clayey sandstones which rarely have cross-bedding and normally occur in association with rudaceous alluvial fans (Asso- ciation 4.1), with diamictites and chaotic orthoconglomerates as the dominant rock types, and less important intercalations of massive sandstones or graded rudites.

Citroni (1993) proposed that these facies could be grouped into a number of formations, according to their geographical distribution. In this article, we redefine this distribution into five formations whose space-time succession is a result of marine transgression. The basal unit of Itajaí basin, termed the Blumenau Formation, is thin, and is composed of the coastal plain sandstone association 3.1. An erosional discordance observed at the edges of the basin separates this Formation from the Baú Formation, composed of thick rudaceous alluvial fans of association 4.1, which are present in areas adjacent to adequate sources. In distal setting these fans include thick anastomosed arenaceous fluvial sediments of association 4.2.

At the top, the arenaceous Baú

Formation passes into transitional and shallow marine sedments of the facies associations 3.2 and 3.3, which are here grouped into the Gaspar Formation. This in turn passes into the deeper water environment of facies 1.1, 1.2, 1.3 and 2.2, now known as the Ibirama Formation. The fine sediments which are intercalated in the most distal parts of the turbidites become more abundant, and finally occupy the top of the sequence, above the Ibirama Formation. Citroni (1993) placed these sediments, of facies 1.4 and 2.1, into an independent stratigraphic unit, the Ribeirão do Espinho Formation. Even here, erosive channels filled by channalised turbidites are found.

Restricted thin (< 50 cm) levels or lenses of strongly recrystallised tuffs are inter-calated wlthin the Baú and Gaspar Formations. The tuffs are fine-grained light green coloured rocks composed of quartz and sericite. The lenses are more abundant in the Gaspar Formation, where they occur close to the southern edge of the basin. Predominantly acid volcanic and subvolcanic rocks are more abundant than the pyroclasts, and are intercalated within the sediments of the Ibirama and Ribeirão do Espinho Formations.

Clasts of acid volcanic rocks with diameters from 3mm to 40 cm are observed in all conglomerates. Subordinate basic and intermediate rocks also occur as late dykes.

CAMARINHA BASIN

Situated about 30 km west of Curitiba, and coverig little more than 100 km², the Camarinha basin (Fig1. basin 5) occupies two main areas, and is covered by rocks of the Paraná basin to the west. The Camarinha sediments are situated in the southern extremity of the Ribeira belt of supracrustal rocks, and was intimately involved in the final episodes of the evolution of this belt. The rocks were affected by regional folds which result in the development of schistosities, and also suffered faulting which led to the present division in small basins.

Described for the first time by Muratori (1966) and Fuck (1966) and in more detail by Muratori, et al. (1967) and Popp (1972), the sediments of the Camarinha basin belong to two facies, one predominantly coarse grained with conglomerates and subordinated arkoses, and the other pelitic with predominance of siltstones. According to Fuck (1966) and Muratori (1966), the conglomerates are intercalated with the siltstones.

Popp, (1972) observed in three sections that the siltstones occupy the base and the conglomerates, the top. He considered that the mineralogical immaturity of the arkoses indicates that deposition was fast, and the source area underwent intense erosion.

Soares (1988), on the other hand, attributes a lower position to the conglomerates, which pass gradationally upwards into the siltstones. This view was also followed by Ciguel & Gois (1989) who also recognized fining-upwards cycles in the siltstones. They also explained the presence of breccias formed by pelitic intraclasts at the top of the unit in terms of re-working of the pelitic units.

According to Ciguel & Gois (1989), rudaceous wedges intercalated with psammo- pelitic rhythmites were deposited in fans on a lagoonal coastline together with distal turbide facies and flood deposits. The conglomerates of the coastal and alluvial fans predominate at the base of the sequence, and are overlain by psammo-pelitic rocks deposited during deepening of the basin.

From ichnofossils of the Camarinha basin and overlyng Furnas Formation of the Paraná basin, and the metamorphic age of the basement Açungui Group, Ciguel et al. (1992) placed the sedimentation of the Camarinha rocks at the Neoproterozoic-Cambrian transition.

EXTENSIONAL LATE COLLISION BASINS

Campo Alegre Basin

The Campo Alegre basin (Fig. 1, basin 3) is mostly situated far north of Santa Catarina, covering about 475 km², but about 2 km² are in Paraná. It has a roughly triangular form, and is centered at the city of Campo Alegre.

The first authors to study this region (Dutra, 1926, Carvalho & Pinto, 1938 and Maack 1947) did not identify these rocks as new unit, eventually referring them as the "Itararé Series".Almeida (1949) was the first one to notice the presence of volcanic and piroclastic rocks in this region and used petrographical similarities between some of these rocks and others found in the Itajaí basin between Ibirama and Apiuna to attribute an "Eopaleozoic" age to them.

Daitx (1979a and b) and Daitx & Carvalho (1980), confirmed the stratigraphic column proposed by Ebert (1971), and identified five depositional sequences (all of them also observed in the Guaratubinha Group): 1) Lower sedimentary sequence; 2) Lower volcanic sequence;3)Intermediate sedimentary sequence; 4) Upper volcanic sequence; and 5) Upper sedimentary sequence.

The lower sedimentary sequence was divided into two facies, one conglomeratic and the other arenaceous, with abrupt gradational passages between them. The authors did not identify the depositional environment, but noted that the packet is thick and fining-upwards, since rare siltstones and shales are present in the upper parts. The packet forms a near-continous basal unit around the perimeter of the basin. In the initial phases of deposition, therefore, the detritus was derived indiscriminately from sources all around the basin. Clasts in the conglomerates reflect the various rock-types found in the surrounding basement. Although clasts of acid volcanic rocks were not found, clasts of basic volcanic rocks are present around the northern margin of the basin.This may not demonstrate the contemporaneous nature of sedimentation and volcanism, since basic volcanic clasts present in the northern and northeastern conglomerates more closely resemble meta-basic and meta-ultrabasic rocks present in the gneissic basement, and are not so obviously related to the volcanics present in the basin sequences.

Arkoses of the arenaceous facies have small-scale tabular cross-bedding structures. Small conglomerate wedges are present. Rare pelitic lenses (up to 1.5 m long) are also present.

The passage from conglomerates to sandstones occurs both laterally and vertically, showing that there is an upward passage from proximal to distal conglomerate facies. This interpretation is reinforced by the presence of the restrict siltstones layers in the overlying lower volcanic sequence. This sequence, of basic to intermediate composition, is best developed between the lower and intermediate sedimentary sequences, although similar volcanic events are also registered during deposition of the intermediate sedimentary sequence.

The lower volcanic sequence is composed of basalts and andesites with rare dacites and more differentiated rhyodacites and quartz-trachytes as individual flows or lateral differentiates of more basic volcanics. The basic rocks commonly have closely-spaced decimetric vesicles and amygdales, whereas pyroclastic tuffs, mixed fine-grained tuffs and epiclastic siltstones are intercalated between the flows.

The intermediate sedimentary sequence consists mainly of pyroclastic and fine-grained epiclastic sediments. The pyroclastic rocks are intimately associated with basic volcanics, which occur at several levels in the sequence, but are more common at the base and the top. The predominantly pyroclastic deposits are con- centrated at the top of the sequence, and vary from fine-grained tuffs to coarse breccias. These breccias are sometimes found in gradational association with ignimbrites.

The pyroclastic rocks are commonly altered, making it difficult to distinguish them from the epiclastic sediments. Thin sections study shows, however, that the tuffs are predominantly acid with variable contributions from other sources, as originally described by Daitx & Carvalho (1980).

The acid volcanism commenced while basic activity was still in progress, reached an explosive peak, then evolved to the trachytic and rhyolitic flows of the upper volcanic sequence. Fluidal structures in some rhyolites suggest that they are ignimbrites, which may explain the wide distribution of the acid volcanics in the area.

The upper sedimentary sequence has a transitional contact with the underlying pyroclastic rocks. There is a predominance of fine-grained tuffs intercalated with less-abundant fine-grained epiclastic rocks, at the base. From base to top, the epiclastic rocks become more abundant, then predominant. The unit therefore records the waning of volcanic activity at the end of the evolution of the basin. The epiclastic sediments are mainly siltstones, but calcareous siltstones and mudstones are also present.

CORUPÁ BASIN

Located in the south of the Campo Alegre basin, and separated from it by a few km, the Corupá basin (Fig1. basin 2) occupies the NE-SW trending Corupá graben, developed in basement gneisses and associated younger granites.

The sedimentary filling is very similar to that of the Campo Alegre basin, but several authors (e.g., Ebert, 1971) noted that the rocks of this graben are more intensely deformed than those of the Campo Alegre basin, and therefore believed that the two basins have different ages. Movements along the marginal fauts of the Corupá graben may explain these structural differences. More detailed studies of the Campo Alegre basin have also shown evidence of stronger deformation than supposed by Ebert (1971) and Daitx & Carvalho (1980).

Daitx (1979b), Daitx & Carvalho (1980) and descriptions of drill cores by Valiat (1974) provide the most detailed analysis of the stratigraphy of the Corupá basin. With the exception of the lower volcanic sequence, all units of the Campo Alegre basin are present in the Corupá basin. In the graben the intermediate sedimentary sequence has a small pyroclastic component, whereas such rocks are common in the upper sedimentary sequence.

GUARATUBINHA BASIN

Originally described during the 1967-1969 studies the Paraná Geological Map Comission, (Fuck et al, 1967), this volcanosedimentary basin (Fig. 1, basin 4) is located 35km south of Curitiba. The name "Guaratubinha Group" comes from the river which cuts the area.

More detailed studies were reported by Daitx Carvalho (1980). The sequence occupies about 210 km² in a NNE-SSW belt northeast of the Campo Alegre basin. The sediments and associated intermediate to acid volcanic rocks are in angular unconformity with underlying migmatites and granites.

The basin was faulted and tilted, and the layers now mostly dip 24° to 45° SE, although in some places the beds are nearly vertical.

Daitx & Carvalho, (1980) identified three main unit, but the stratigraphic relationships were not defined: 1) sedimentary sequence; 2) acid-volcanic sequence; and 3) intermediate volcanic sequence. The sedimentary sequence covers an area of 70 km², in the northern part of the belt. Arkoses are predominant, siltstones and claystones form intercalations and conglomerates are present in isolated occurrences. The rudaceous rocks seem to occupy the base of the sequence, and are orthoconglomerates with clasts of a wide range of dimensions, derived from a wide variety of source rocks including acid volcanics, in an arkosic matrix with quartz, alkaline and plagioclase feldspars, opaque and other minerals. The conglomerates have poorly-defined stratification.

The arkoses are brownish- red or deep pink near the Guaratubinha river. They are predominantly fine-to medium-grained, with sub-angular grains of quartz, alkaline feldspar and plagioclase and rare iron-manganese minerals. Alteration of milimetric layers commonly confers a rhythmic appearence. Transition gradations from conglomerates to siltstones and claystones are common. Micro-cross-bedding and asymmetryc ripple marks are present. Associated thick layers of siltstones and mudstones commonly display rhythmic alternations of greenish layers with chlorite, pistacite and opaque minerals and lighter-coloured layers of quartz and feldspars. Pyroclastic tuffs and tuffites occur in finer-grained, quartz sandstones.

The intermediate volcanic sequence covers an area of 75 km^2, in the southeastern parts of the belt, and is composed of andesites and dacites. Although the stratigraphic position of this unit was not established, by analogy with the Campo Alegre basin it was believed that it overlay the basalt unit and underlies the acid flows. The majority of the flows of the intermediate volcanic sequence is composed of flows of vitrophyric or amygdaloidal andesites, some of which are porphyritic with milimetric phenocrystals of andesine, clinopyroxene, opaque minerals and quartz. Subordinate hypabyssal bodies are present.

The acid volcanic sequence includes lavas and pyroclastic rocks, and covers an area of about 65 km^2, in the central western portion of the basin, where it is responsible for the highest topography. Porphyritic rhyolites are predominant, but are accompanied by fluid-textured spherulitic rhyolites and microgranites. Rhyolitic breccias with associated tuffs are very common south of the Guaratubinha river. They are composed of angular to subangular fragments of a variety of acid volcanics contained in a greenish cryptocrystalline matrix formed by quartz and feldspars cemented by calcite. The tuffs are crystal and lithic tuffs with plane-parallel stratification.

Castro et al. (1994) established a stratigraphic sucession of five lithological association from base to top: 1) thick clastic association, the main body of epiclastic rocks, essentially formed of polimitic orthoconglomerates; 2) acid volcanic association, with rhyolites and alkali-rhyolites together with associated volcanoclastic rocks; 3) acid volcaniclastic association, consisting of pyroclastics including lapili-tuffs, agglomerates, ignimbrites, ash flow tuffs and rhyolites; 4) intermediate volcanic association, of andesites with subordinate rhyodacites; and 5) upper volcanoclastic association, with a fine-upwards succession of coarse volcaniclastic rocks. This considerably reduces the relative importance of the sedimentary sequence, and also provided the latter authors with stronger criteria for the setting-up of a stratigraphic column.

CASTRO BASIN

The Castro Basin (Fig. 1, basin 6) is situated in east-central Paraná, near the eastern border of the Paraná Basin. It outcrops in a triangular area of slightly more than 800 km^2. In the last century, (Derby, 1878) called the attention to the presence of acid volcanic rocks in this region. A stratigraphically defined Castro unit, was not recognized until 1943, when Oliveira & Leonardos included it in the Ribeira Series. The unit was re-defined as a Group in 1967 as a result of mapping by Trein & Fuck (1967). These authors divided the group into for units. At the base, an acid volcanic unit, which is overlain by a sedimentary sequence consisting of conglomerates, arenaceous arkosic-sandstones, siltstones, and claystones. Above the sedimentary unit, a second acid volcanic sequence with rhyolites, tuffs, agglomerates and volcanic breccias is covered by andesitic rocks of an intermediate volcanic sequence.

Arioli (1981) and Arioli & Moreton (1982) recognized that some of the rhyolites are in fact ignimbrites and also identified ash, pisolithic, crystal and lithic tuffs. Soares (1987, 1988) elaborated a facies scheme for these sediments, and identified piedmont deposits, alluvial plain sediments and marine fans. The eastern border of the basin is a normal fault with a dextral lateral component, the basin being situated in the lower block.

Moro et al (1992) and Moro (1993) presented a synthesis of the knowledge of the Castro Basin, and on the basis of a broad, regional scale study, a four-fold subdivision was established: 1) lower sedimentary association; 2) acid-intermediate volcanic association; 3) acid volcanic association; 4) upper sedimentary association.

Deposition of sandstones and pelites of the lower sedimentary association took place simultaneously in a fluvial-lagoonal environment, where flood plains, fluvial channels and distal lagoonal facies were found (Moro, 1993). The same author also situated the initial volcanic events, with products of intermediate to acid composition and comprising pyroclastic sediments, tuffs, ignimbrites, epiclastic breccias and associated conglomerates, at the base of the section. After intense erosion of the volcanics rocks, coarse sediments, including epiclastic-volcaniclastic types containing clasts of andesites and rhyolites in medium- to coarse-grained arkosic matrices, were deposited in an alluvial fan facies in the uppermost parts of the acid-intermediate volcanic association.

The acid volcanic association overlaps and cuts this sequence. Small rhyolite and quartz-latite flows, in same cases; ignimbritic, accompanied by predominant pyroclastic rocks, including lapilli ash vitric tuffs, together with restricted breccias with andesite and rhyolite fragments set in ash or lapilli matrices. The upper sedimentary association is composed of immature conglomerates deposited in the continental facies of alluvial fans. Although they contain clasts of the underlying units, the stratigraphic position of these conglomerates is uncertain.

GEOCHRONOLOGICAL STUDIES

The absence of fossils in all sedimentary units of these basins makes it impossible to stablish their ages of sedimentation. The best approximations were obtained by dating of the igneous rocks present. The first geochronological results obtained in the volcanic rocks were some K-Ar ages in whole rock from the Campo Alegre basin (Ebert, 1971). Later, Cordani (1974) presented a Rb-Sr whole rock isochron, obtained for acid flows of the Castro basin, with an apparent age of 425 ± 15 Ma. All the values fell in the 420-480 Ma range, therefore placing the age of the basins in the

Ordovician.

More recent Rb-Sr studies, excluding the Camarinha and Corupá basins (Basei, 1985; Basei & Teixeira, 1987; Reis Neto et al, 1994; Siga Jr., 1995) yielded ages in the 490-570 Ma range. The problems presented by the Rb-Sr methods are associated with the quite homogeneous compositions of the materials analysed. In many cases, Rb/Sr ratios are very close; they are sometimes very high (Guaratubinha, Castro and Itajaí), or very low (Campo Alegre). In addition, isotopic resetting may have occured during late magmatic transformations which are commonly observed in the volcanic rocks.

Two K-Ar age determinations were performed in fine-fractions extracted from siltstones from the Camarinha Basin. The ages (Ahrendt et al., in preparation) of 505 ± 10 (fraction <2mm) and 478 ± 10 (fraction <0.2 mm) Ma represent the time of the low grade metamorphism that affected the basin. In addition a K-Ar age of 534 ± 16 Ma was also obtained by the same authors dating fine-grained muscovite extracted from the mylonitic rocks of the Lancinha Shear Zone cutting the Camarinha sediments. This data represents the best age of the shearing and can be interpreted as a minimun age of the Camarinha basin deposition.

U-Pb analysis of zircon concentrates from volcanic rocks are available for the Campo Alegre (Fig. 2) and Guaratubinha (Fig. 3) basins, and yield ages in the range of 610 ± 20 Ma. For the Itajaí basin, a minimum age is provided by a U-Pb zircon age of 561 ± 42 Ma, (Fig. 4) obtained for the intrusive Subida granite. All the U-Pb analytical data are summarized in Table 1.

The radiometric data available for the granites and volcanic rocks related to these basins are presented in Table 2. The wide range in Rb-Sr ages compared with the more concordant U-Pb zircon ages leads to the conclusion that the zircon ages are more reliable and, are probably closer to the real age of the volcanism. Based on the U-Pb results, 600 ± 10 Ma is the best estimate of the age of the volcanism, and therefore of the initiation and filling of these basins. They are, therefore, late Precambrian.

CONCLUDING REMARKS

Since these basins differ in detail, it is difficult to establish with precision any mutual relationships. The following remarks should be treated as preliminary, since further work should provide progress in the understanding of many of these basins.

It appears to be extremely improbable that all these basins were once continous. The different orientations of the fault boundaries, especially of the Itajaí and Castro basins and the distances which separate some of them suggest that they are different tectonic entities. On the other hand, some of them, especially the Campo Alegre, Corupá and Guaratubinha basins (Fig. 1: basins 2, 3 and 4) may well have been connected.

In lithological terms, the majority of these basins have a coarse detrital lower unit, deposited in a fluvial environment, in which new volcanic material is not significant

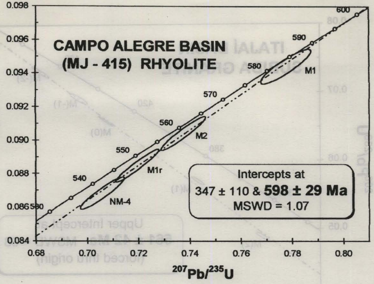

Figura 2 - Concordia plt for zircon fractions from rhyolites of the Campo Alegre Basin.

Two K-Ar age determinations were performed in fine-fractions extracted from siltstones from the Camarinha Basin. The ages (Ahrendt et al, in preparation) of 505 ± 10 (fraction <2μm) and 478 ± 10 (fraction <0.2 μm) Ma represent the time of the low grade metamorphism that affected the basin. In addition a K-Ar age of 534 ± 16 Ma was also obtained by the same authors dating fine-grained muscovite extracted from the mylonitic rocks of the Lancinha Shear Zone cutting the Camarinha sediments. This data represents the best age of the shearing and can be interpreted as a minimun age of the Camarinha basin deposition.

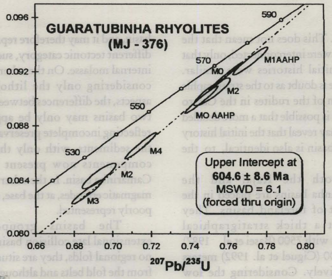

Figura 3 - Concordia plot for zircons from volcanic rocks of the Guaratubinha Basin. The upper intercept at 604.6 +-8.6 Ma is interpreted as the age of volcanic extrusion.

U-Pb analysis of zircon concentrates from volcanic rocks are available for the Campo Alegre (figure 2) and Guaratubinha (figure 3) basins, and yield ages in the range of 610 ± 20 Ma. For the Itajaí basin, a minimum age is provided by a U-Pb zircon age of 561 ± 42 Ma, (figure 4) obtained for the intrusive Subida granite. All the U-Pb analytical data are summarized in Table 1.

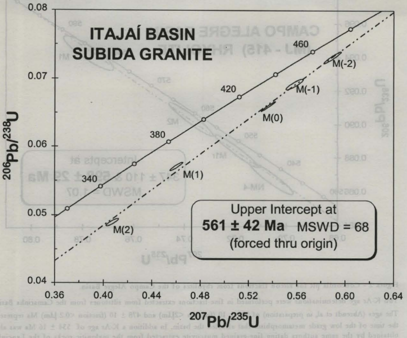

Figure 4 - Concordia plot for zircon fractions from Subida Granite (intrusive in the Itajaí sedimentary sequence). This age is interpreted as the time of granite emplacement.

(Fig. 5). This does not mean that the basins were interconnected, only that their initial histories were similar. As there is doubt as to the stratigraphic position of the rudites in the Castro basin, it is possible that a more detailed study may reveal that the initial history of this basin is also identical, to the others.

Both the Itajaí and the Camarinha basins are placed in the context of foreland basins. They present a thick stratigraphical column with 7500 (Basei et al. 1987) and 4000 (Ciguel et al. 1992) meters respectively. Considering the low quantity of volcanic rocks, their depositional histories appear to be simple. The Camarinha basin is more intensely deformed than the Itajaí basin, and it may therefore represent a different tectonic category, such as an internal molasse. On the other hand, considering only the lithological aspects, the differences between these two basins may only be apparent, reflecting incomplete preservation of the sediments, with only the basal components now present in the Camarinha basin. In the other basins, magmatic episodes, at the base, are also poorly represented.

The basins grouped as extensional late collision basins have no regional folds, they are situated far from the fold belts and although there are differences in composition, rock volumes and stratigraphic positions, all have characteristically large quantities of volcanic rocks. Different

FRACTION (1)	CONCENTRATION (2)		OBSERVED (3)	ATOMIC RATIOS (4)			AGES (5)		
	U(ppm)	Pb (ppm)	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
CAMPO ALEGRE RHYOLITES (MJ - 415)									
M(2)	113.7	14.83	230.77	0.09042	0.73745	0.05915	558	561	573
M(1)R	201.4	24.56	337.86	0.08848	0.71945	0.05898	546	550	566
NM(-4) AAHP	146.89	20.35	168.27	0.08804	0.74320	0.06122	544	564	647
M(1)	115.1	20.94	99.07	0.09442	0.77767	0.05973	582	584	594
GUARATUBINHA RHYOLITES (MJ - 376)									
M(3)	443.9	67.55	112.05	0.08316	0.68680	0.05990	515	531	600
M(4)	367.5	58.18	112.02	0.08657	0.71456	0.05986	535	547	599
M(0)	1658	186.9	832.36	0.09167	0.75859	0.06001	565	573	604
M(0) AAHP	195.8	28.63	147.81	0.08995	0.74628	0.06017	555	566	610
M(1) AAHP	731.0	52.76	84.35	0.09282	0.77177	0.06031	572	581	615
M(2)	499.6	87.04	59.43	0.08436	0.69290	0.05957	522	534	588
M(2)	418.4	96.16	55.34	0.09054	0.75178	0.06022	559	569	611
SUBIDA GRANITE									
M(O)	166.3	14.26	319.89	0.06602	0.53688	0.05898	412	436	566
M(-2)	115.4	11.18	283.02	0.07450	0.59604	0.05802	463	475	531
M(-1)	170.7	16.63	225.30	0.07142	0.57072	0.05796	445	458	528
M(1)	681.7	53.61	235.79	0.05771	0.46105	0.05794	362	385	528
M(2)	119.0	15.48	58.530	0.05021	0.40215	0.05808	316	343	533

Tabela 1 - U-Pb analytical data of the igneus rocks associated with the described Basins.

1: NM - nonmagnetic, M - magnetic, numbers in parentheses indicated tilte used on Frantz separator at 1.5 amp. power; HP - hand-picked;
2: Total U and Pb concentrations corrected for analytical blank
3: Not corrected for blank or non-radiogenic Pb
4: Radiogenic Pb corrected for blank and initial Pb; U corrected for blank;
5: Ages given in Ma using decay constants recommended by Steiger and Jäger (1977) and Ludwig Isoplot program (1993).

Basin related sedimentary and volcanic rocks					
	ITAJAÍ	CAMARINHA	CAMPO ALEGRE	GUARATUBINHA	CASTRO
W.R. isochrons	544 ± 20 (1)		499 ± 13 (2)	570 ± 10 (2)	490 ± 13 (3)
U-Pb zircons			598 ± 29 (5)	604.6 ± 8.6 (5)	
K-Ar	515 - 549 (6)	478-505 (8)	458 - 481 (7)		
Associated Alkaline-Peralkaline granitoids (Serra do Mar Suite)					
	SUBIDA GRANITE	CORUPÁ GRANITE	AGUDOS DO SUL GRANITE	MORRO REDONDO GRANITE	
W.R. isochrons	546 ± 10 (1)	550 ± 26 (2)	570 ± 22 (2)	524 ± 9 (2)	
U-Pb zircons	561 ± 42 (5)	585 ± 6 (4)	596 ± 26 (4)	589 ± 37 (2)	
K-Ar		533 - 523 (2)	585 - 541 (2)	565 (2)	

Tabela 2 - Available radiometric age determinations for the Neoproterozoic basins of Paraná and Santa Catarina States, Southern, Brazil.

References: 1) Basei, 1985; 2) Siga Jr., 1995; 3) Reis Neto et al., 1994; 4) Basei et al., 1995; 5) This work; 6) Macedo et al., 1994; 7) Ebert & Brochini, 1971; 8) Ahrendt et al., in preparation.

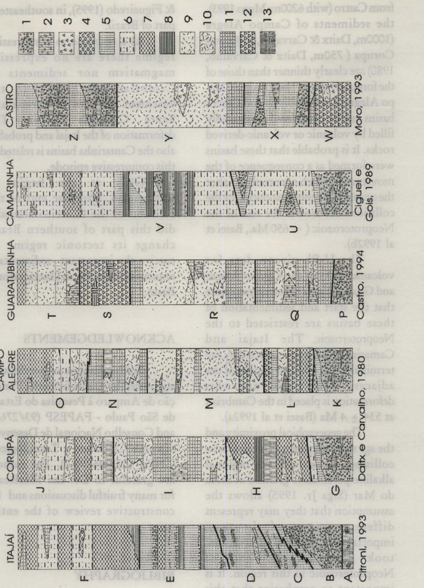

Figura 5 - Schematic comparative stratigraphic columns of the six eopaleozoic basins. Stratigraphic units: Itajaí basin: A) Blumenau Formation; B) Baú Formation ; C) Gaspar Formation (Mb. Jordão); D) Gaspar Formation (Mb. Garcia); E) Ibirama Formation; F) Ribeirão do Espinho Formation. Corupa basin: G) Lower sedimentary sequence; H) Intermediate sedimentary sequence; I) Upper volcanic sequence; J) Upper sedimentary sequence. Campo Alegre Basin: K) Lower sedimentary sequence; L) Lower volcanic sequence; M) Intermediate sedimentary sequence; N) Upper volcanic sequence; O) Upper sedimentary sequence. Guaratubinha Basin: P) Clastic association; Q) Acid volcanic association; R) Acid volcaniclastic association; S) Intermediate volcanic association; T) Upper volcaniclastic association. Castro Basin: U) Coarse grained facies; V) Pelitic facies. Camarinha basin: W) Lower sedimentary association; X) Acid-intermediate volcanic association; Y) Acid volcanic association; Z) Upper sedimentary association. Litologies: 1 - Orthoconglomerates; 2 - Conglomeratic sandstones; 3 - Breccia; 4 - Ryolithic lavas; 5 - Sandstones; 6 - Siltites; 7 - Argilites; 8 - Slate; 9 - Trachytic lavas; 10 - Acid tuffs; 11 - Ignimbirtes; 12 - Basaltic lavas; 13 - Rhyodacitic lavas.

from Castro (with 6200m; Moro 1993), the sediments of Campo Alegre (1000m, Daitx & Carvalho, 1980) and Corupa (750m, Daitx & Carvalho, 1980) are clearly thinner than those of the foreland basins. The Corupá, Campo Alegre, Guaratubinha and Castro basins may be considered as essentially filled by volcanic or volcanic-derived rocks. It is probable that these basins were formed as a consequence of the movements which occurred just after the crustal thickening produced for the collisions occured at the end of the Neoproterozoic (~ 650 Ma., Basei et al 1992b).

The U-Pb zircon data for volcanic rocks in the Campo Alegre and Guaratubinha basins demonstrate that the start and sedimentation of these basins are restricted to the Neoproterozoic. The Itajaí and Camarinha basins were affected by the terminal stages of the evolution of the adjacent fold belts, and this deformation is placed in the Cambrian at 534 ± 4 Ma (Basei et al 1992a).

The geographical proximity and the age similarity between these late-collision basins and the regional alkaline-peralkaline granites of Serra do Mar (Siga Jr. 1995) allows the assumption that they may represent different aspects of the same important distensional episode that took place at the end of Neoproterozoic in this region. It is important to emphasize that this episode was succeeded, during almost all Cambrian times, by a compressive regime related to the collision of the Costeiro Domain (550 ± 50 Ma, Basei et al 1992b and Siga Jr. 1995). This collision has the same age as, and was probable related to, the Rio Doce Orogeny described by Campos Neto & Figueiredo (1995), in southeastern part of Brazil.

As a response to compressive regime there are no expressive magmatism nor sediments of Cambrian age known in the basement terranes of Paraná and Santa Catarina States. The deformation of the Itajaí and probably also the Camarinha basins is related to this compressive episode.

Only at the begin of Ordovician, after the end of the collision of the Costeiro Domain, did this part of southern Brazil change its tectonic regime to receive the important sedimentary sequences of the Paraná Intracratonic Basin.

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