

## BIOSTRATIGRAPHY OF SOUTHERN BRAZILIAN MIDDLE-UPPER TRIASSIC

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**ABSTRACT** The rocks of Middle/Upper Triassic from Southern Brazil (Paraná Basin) can be divided in three major and clearly distinct biostratigraphic units from the basis to the top: 1) Therapsid Cenozoone, dominated by Dicynodonts and Cynodonts; 2) Rhynchosauria Cenozoone, with an expressive presence of Rhynchosaurs and absence of Dicynodonts and 3) *Jachaleria* Level, marked by the presence of the Dicynodont *Jachaleria*. This last one is here proposed as an informal biostratigraphic unit, once that the number of fossils collected until now is low and the occurrence of this fossil assemblage is very restricted. This biostratigraphic framework is very similar to that occurs in Argentinean Triassic. Besides, in both sedimentary sequences it is not observed any evidence of significant hiatus between the different fossil levels, just a change from an anastomosed to a braided fluvial system towards the top of the package.

**Keywords:** Triassic, Biostratigraphy, Paleovertebrates, Parana Basin;

**INTRODUCTION** The first proposal of a biostratigraphic zonation for the Triassic package that occurs in the southern portion of Paraná Basin was elaborated by Barberena (1977) and later enhanced by Barberena *et al.* (1985, 1991). In these last papers, the authors, looking for a larger geochronological resolution, characterized, to the south Brazilian Permo-Triassic package, seven Local Faunas, based on the faunal content from the rocks that outcrop in Paraná, Santa Catarina and Rio Grande do Sul States. Wilson (1950 in Simpson, 1971) introduced the concept of Local Fauna, as being a geobiotic unit constituted "by the totality of the species collected in some important outcrops or group of outcrops". To this definition, Simpson (*op. cit.*) added the following conditions: a) to be composed by organisms that lived in the same geologic time and in the same area; b) do not be representative of the totality of an extensive litho or chronostratigraphic unit.

Four of these faunas were included in rocks of Middle-Upper Triassic age and occurs in surface along an East-West strip (Fig. 1) in Rio Grande do Sul State: Pinheiros Local Fauna (Early Ladinian age), Chiniquá Local Fauna (Middle Ladinian age), Alemoa Local Fauna (Late Ladinian-Middle Carnian age) and Botucaraí Local Fauna (Early Carnian-Early Norian age).

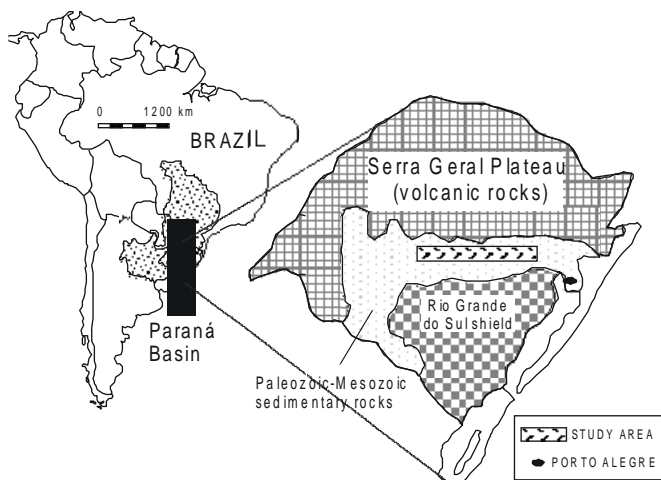


Figure 1-Geographic location of the studied area.

In spite the reached progresses, mainly regarding to the chronocorrelation among the tetrapod paleofaunas from Brazil, Argentina and South Africa, Local Faunas, of course, are parastratigraphic units and, in most of the cases, are not proper to formal biostratigraphic approaches (*vide* Barberena *et al.*, 1985). Its occurrence in isolated outcrops precludes the statement of biohorizons, as well as difficult the clear delimitation of the strata in what they are included. Using Local Faunas one can only identify and separate geographically different faunistic assemblages, which do not provide information about its lateral or vertical extension in the rock package (a Local Fauna can be found and defined in a single outcrop),

as well as the temporal relationships among them. Therefore, any attempt of using it in biostratigraphical correlation becomes, in most of the cases, inconclusive. However, the identification of chronocorrelated horizons in continental sequences, as in the case of the Santa Maria Formation, is very difficult (Scherer and Holz, 1993; Schultz, 1995). Barberena *et al.* (1993), Scherer (1994) and Schultz *et al.* (1994), based on the discovery of various new fossiliferous outcrops, returned to the perspective of a formal biostratigraphy, through the individualization of Cenozoones in the Medium-Upper Triassic package of Southern Brazil, as we will discuss to proceed.

**GEOLOGICAL SETTING** The Paraná Basin was a site of extensive cratonic sedimentation during Paleozoic and most of Mesozoic times. It is situated in central/southeastern South America and comprises 1,100,000 square kilometers each of Uruguay, Paraguay and Argentina. Its lithologic record is constituted by an up to 8,000 meter-thick sedimentary and igneous package.

Two lithostratigraphic units compose the studied stratigraphical section: Santa Maria Formation (Ladinian-Carnian) and Caturrita Formation (Carnian-Norian). The Santa Maria Formation is divided into two members (Andreis *et al.* 1980): (1) Passo das Tropas at the base (fluvatile conglomerates and coarse to medium sandstones) and (2) Alemoa Member at the top (fluvatile mudstones and fine sandstones).

The basal Passo das Tropas Member eroded the underlying Sanga do Cabral Formation, forming incised valleys filled by lenticular sandstones and conglomerates with trough cross bedding and subordinate parallel lamination, besides complex cut-and-fill structures, suggesting a braided fluvial system (Faccini 1989).

Fonseca and Scherer (1998) and Scherer (2000) studied the Alemoa Member and the overlying Caturrita Formation in detail. The authors recognize three architectural elements: main channels (CH), crevasse splays (CS) and floodplain fines (FF). Lenses of fine sandstone with plane and trough cross-bedded sets and minor horizontal bedding form the element CH. At the margins of the channels fine sandstone and siltstone with climbing ripples occur, interpreted as levee deposits. The geometry of the channels cannot be identified, but they measure from 5 to 20 m of thickness and 50 to 100m's wide. These channels were ribbon-like at the base and more sheet-like at the top of the facies succession. In some channels, lateral accretion surfaces are identified. The element CH is sparse and separated by floodplain deposits at the base of the sequence, becoming abundant in the top. The general paleocurrent direction is northwards.

The element CS is formed by alternation of centimeter-thick layers of mudstone, siltstone and fine sandstone. Sandstone lenses, 1 to 3 meters thick, with cross bedding may occur. Bioturbation, rootmarks, desiccation cracks and paleosoils are common. The geometry is sheet-like, with hundreds of meters of width and up to 10m of thickness. The element CS is frequent in the lower part of the deposits (Santa Maria Formation), becoming rare towards the top (Caturrita Formation). The general orientation of the paleocurrents is perpendicular to the element CH, as visualized in several outcrops. The deposits of crevasse splays are interpreted as lateral avulsions of the main channels.

Siltstone and massive and laminated mudstone, with levels or nodules of caliche form the element FF. The presence of fossil vertebrates is also characteristic for this architectural element. The

geometry is sheet-like, with hundreds of meters of lateral extension and dozens of meters of thickness. The element FF is most frequent at the base of the succession, becoming rare in the top deposits.

The occurrence of deposits of ribbon-like channels (CH), isolated by deposits of floodplain and associated to deposits of crevasse splays (CS) indicates an anastomosed fluvial system for the Alemoa Member, with some meandering channels. The decreasing of elements FF and CS in direction to the top of the succession associated with the increase of the number of channels and with the greater abundance of the elements CS indicate a transition from an anastomosed to a braided fluvial system for the Caturrita Formation. The constant presence of desiccation cracks, paleosols and caliche horizons in the elements CS and FF suggest that the lacustrine bodies associated with the floodplain had ephemeral character, indicating a seasonal climate, characterized by the alternation of dry and humid seasons during times of deposition of the Alemoa Member.

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The Alemoa Member of the Santa Maria Formation and the Caturrita Formation present three major and clearly distinct fossil assemblages that follow one to another along the time: Therapsid Cenozoone, Rhynchosauria Cenozoone and *Jachaleria* Level (informal biostratigraphic unit). These Cenozoones present some variations of its components from one outcrop to another, but a more accurate formal biostratigraphic separation is still not possible.

Therapsid and Rhynchosauria Cenozoones are both included in the Alemoa Member, but differ substantially in its fossil content. Therapsid Cenozoone (Fig. 2), which includes the Pinheiros and Chiniquá Local Faunas, presents the following ones percentiles of occurrence (Azevedo *et al.*, 1990): dicynodonts (61%), cynodonts (27%), thecodonts (11%), rhynchosaur (O, 7% - just two specimens)

and procolophonids (O, 3% - just one specimen). By its turn, Rhynchosauria Cenozoone (Fig. 3), which includes the Alemoa Local Fauna and part of the Botucaraí Local Fauna, is totally dominated by rhynchosaur (92%), being present also some cynodonts (2,7%), thecodonts (4,9%) and dinosaurs (O, 4%). New vertebrate fossils of all these groups have been founded in the last years, most of them have been still in study. Nevertheless, the only remarkable modifications on these rates are the increase of the number of cynodonts in the Therapsid Cenozoone and the discovery of some dinosaurs (Langer *et al.*, 1998 and Azevedo *et al.*, 1999) in the Rhynchosauria.

It is remarkable that the dicynodonts (mainly *Dinodontosaurus*), so abundant in Therapsid Cenozoone, are totally absent in Rhynchosauria Cenozoone. Rare and primitive forms in Therapsid Cenozoone ("Mariante Rhynchosaur"), becoming the dominant group in Rhynchosauria Cenozoone (Hyperodapedon and others) represent the rhynchosaur, for its time.

Based on the chronocorrelation with the Argentinean paleofaunas, an Early-Middle Chañarens age can be attributed for the Therapsid Cenozoone, while a Late Chañarens-Ischigualastense age is admitted for the Rhynchosauria Cenozoone.

At least in two outcrops of the Rhynchosaur Cenozoone, a peculiar form of rhynchosaur occurs: *Scaphonyx sulcognathus* Azevedo and Schultz, 1987. This taxon is known only in southern Brazil, and is not found associated to the typical Hyperodapedon-like forms which characterizes this Cenozoone. Instead, in all outcrops where *S. sulcognathus* occurs it was found in levels upper than those, existing a clear erosive surface between both rhynchosaur levels in one of the outcrops. So, it could be possible to subdivide the Rhynchosaur Cenozoone in two Subzones, but it would be necessary more paleontological and stratigraphical data to confirm it.

The third fossil assemblage (Fig. 4) occurs in a very restricted area,

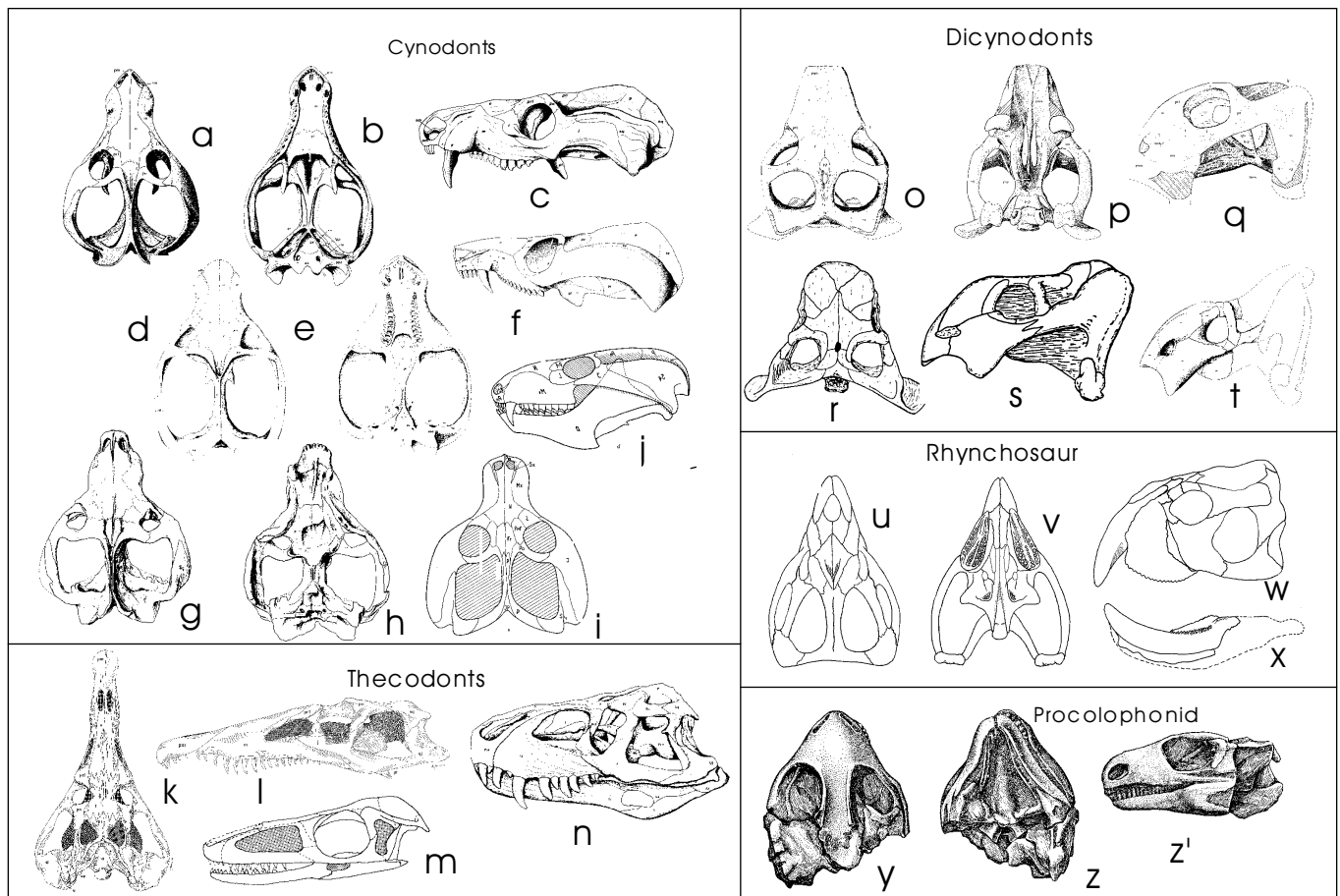


Figure 2-Faunal content of Therapsid Cenozoone (It does not represent the whole taxa of this Zone, but just the better-known genera). All are reduced approximately to the same size. a, b, c) *Massetognathus* (dorsal, ventral, lateral). Modified from Barberena, 1981. d, e, f) *Proelesodon* (dorsal, ventral, lateral). Modified from Teixeira, 1982. g, h) *Belesodon* (dorsal, ventral). Modified from Huene, 1942. i, j) *Traversodon* (dorsal, lateral). Modified from Huene, 1942. k, l) *Chañaresuchus* (dorsal, lateral). Modified from Dornelles, 1992. m) *Barberenasuchus* (lateral). Modified from Mattar, 1989. n) *Prestosuchus* (lateral). Modified from Azevedo, 1991. o, p, q) *Dinodontosaurus* (dorsal, ventral and lateral). Modified from Cox, 1965. r, s) *Stahleckeria* (dorsal and lateral). Modified from Cox, 1965. t) *Ischigualastia* (lateral view). Modified from Peruzzo, 1990. u, v, w, x) "Mariante Rhynchosaur" (dorsal, ventral, lateral, mandible). Modified from Schultz and Azevedo, 1990. y, z, z') *Candelaria* (dorsal, ventral, lateral). Modified from Price, 1947.

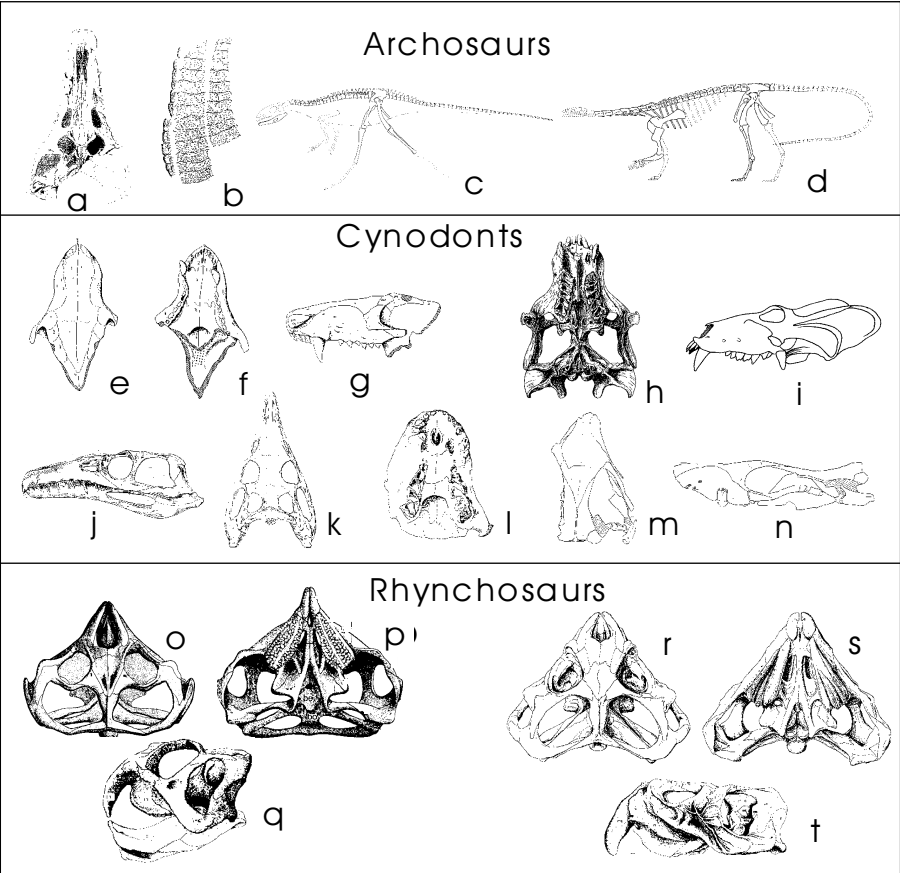


Figure 3-Faunal content of Rhynchosaur Cenozoone (It does not represent the whole taxa of this Zone, but just the better-known genera). All are reduced approximately to the same size. a) *Proterochampsia* (dorsal). Modified from Barberena, 1982. b) *Aetosauroides* (osteoderms). Modified from Zacarias, 1982. c) *Staurikosaurus* (reconstitution of the skeleton), modified from Colbert, 1970. d) *Saturnalia* (reconstitution of the skeleton). Modified from Langer et al., 1999. e, f, g) *Thrinaxodon brasiliensis* (dorsal, ventral, lateral). Modified from Barberena et al., 1987. This specimen is being re-studied by Bonaparte and Barberena (in prep.), which interpret it now as an ictidosaur (*Prozoostrodon*). h, i) *Exaeretodon* (ventral, lateral). Modified from Abdala and Barberena (in prep.). j-k) *Cerritosaurus* (lateral, dorsal). Modified from Dornelles, 1992. l) *Gomphodontosuchus* (ventral). Modified from Huene, 1942. m, n) *Therioherpeton* (dorsal, lateral). Modified from Bonaparte and Barberena, 1975. o, p, q) *Hyperodapedon* [*Scaphonyx*] (dorsal, ventral, lateral). Modified from Huene, 1942. r, s, t) "*Scaphonyx*" *sulcognathus* (dorsal, ventral, lateral). Modified from Azevedo and Schultz, 1987.

at the basis of the Botucaraí Mountain (11-km West in the Caturrita Formation. It is characterized by the presence of the tuskless dicynodont *Jachaleria candelariensis* Araújo and Gonzaga, 1980, archosaurian (probably dinosaurian) teeth (Dornelles, 1990), limbs and other fragments of the primitive prosauropod dinosaur *Guaibasaurus candelariensis* (Bonaparte and Ferigolo, 1999) and a lot of other fragmentary (not yet described) remains, including a probable phytosaur. However, the number of fossils collected until now, as well as its quite restricted occurrence, makes unfeasible the individualization of a cenozoone, so that Scherer (1994) proposed an informal biostratigraphic unit denominated *Jachaleria* Level. Besides, fieldwork developed by one of the authors (Scherer, 1994) in the Candelaria region indicates that one of the outcrops placed in the Botucaraí Local Fauna by Barberena *et. al*, 1985, in which were found *Proterochampsia nodosa* Barberena, 1982 and a splendid *Exaeretodon* skull (Abdala and Barberena, *in prep.*) is situated in a stratigraphic level further down that of *Jachaleria* and *Guaibasaurus*. So, this outcrop does not belong to the *Jachaleria* Level and should be correlated to the levels containing *S. sulcognathus*, in the upper portion of the Rhynchosaur Cenozoone.

As pointed out by Benton (1986), rhynchosaurs would be had extinct at the end of Carnian, while some groups of mammal-like reptiles would have survived to the closing of the Triassic period. The extinction of rhynchosaurs, associated to the effective return of dicynodonts to the paleoenvironment, would reflect climatic changes occurred in Pangea (Scherer and Holz, 1995, Holz and Scherer, 1999).

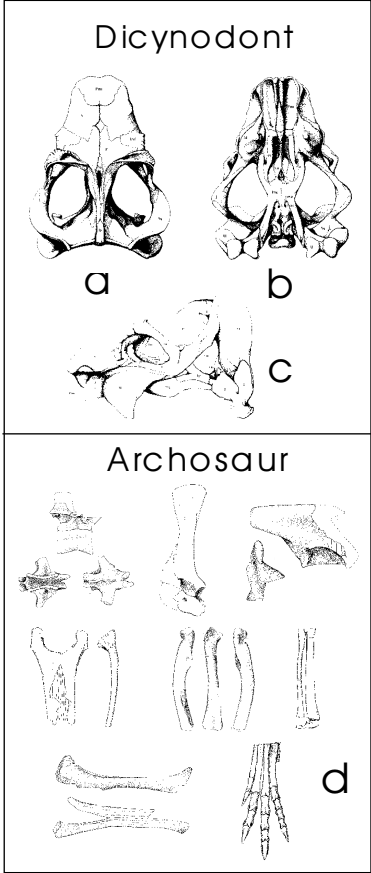


Figure 4-Faunal content of the *Jachaleria* Level (It does not represent the whole taxa of this unit, but just the better-known genera). All are reduced approximately to the same size. a, b, c) *Jachaleria* (dorsal, ventral, lateral). Modified from Araújo and Gonzaga, 1980. d) *Guaibasaurus* (parts of the skeleton). Modified from Bonaparte and Ferigolo, 1999.

Regarding to the temporary relationships between *Jachaleria* Level and Rhynchosauria Cenozoone, neither the faunal comparison with Argentina (Fig. 5), nor the stratigraphic studies accomplished by Scherer (1994) furnished any evidence of a significant hiatus. It is

STAGE	REPTIL AGE	LOCAL FAUNAS		CENOZONES	LITOSTRATIGRAPHY		DEPOSITIONAL SEQUENCE
	ARGENTINA	ARGENTINA	BRASIL	BRASIL	ARGENTINA	BRASIL	BRASIL
RHAETIC						MATA	III
		LA ESQUINA					
NORIAN	COLORADENSE				LOS COLORADOS		
			BOTUCARAÍ	Jachaleria Level		CATURRITA	
CARNIAN	ISCHIGUALASTENSE	ISCHIGUALASTO	ALEMOA	RHYNCHOSAURIA	ISCHIGUALASTO		
						SANTA MARIA	II
LADINIAN	CHANIARENSE		CHINIQUÁ		LOS RASTROS		
		LOS CHANARES	PINHEIROS	THERAPSIDA	LOS CHANARES		

Figure 5-Chronocorrelation between Brazil and Argentina, based on Paleoherpetafaunas.

observed, both in Brazil and Argentina, a faciologic change, marked by a progressive increase of the sandstone/mudstone ratio towards the top of the sedimentary packages, reflecting a transition from an anastomosed/meandered to a braided fluvial system (Holz and Scherer, 1999).

**CONCLUSION** Although the uniformity of the Middle/Upper Triassic lithofacies (Santa Maria and Caturrita formations) from

Southern Brazil, it is possible to divide this sequence in, at least, three different biostratigraphic units, on basis on its paleoherpetofauna (specially using rhynchosaurs and dicynodonts). This zonation, as well as the faunal content of each these zones, is very similar to that occurs in Argentina. Besides, there is no evidence of significant hiatus among the Zones in both countries, but just an increase in the ratio sandstone/mudstone towards the top of the sequences, reflecting a change in the depositional system.

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