

PALEOGEOGRAPHIC DISTRIBUTION OF THE TERRESTRIAL SQUAMATE REPTILES FROM THE CRETACEOUS OF BRAZIL

DISTRIBUIÇÃO PALEOGEOGRÁFICA DOS RÉPTEIS ESQUAMATAS TERRESTRES DO CRETÁCEO DO BRASIL

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ABSTRACT: The terrestrial squamates from Brazil are the Early Cretaceous *Olindalacerta brasiliensis* and *Tijubina pontei* from Ceará State; the Late Cretaceous *Pristiguana brasiliensis* from Minas Gerais State, Ophidia indet. and Aniloidea from São Paulo State. Squamates were widespread in western Gondwana and Laurasia landmasses, and iguanids and mainly snakes widely distributed in southern South America.

KEYWORDS: Squamata. Paleogeographical distribution. Cretaceous. Brazil.

INTRODUCTION

The Early Cretaceous terrestrial basal squamate species *Tijubina pontei* and *Olindalacerta brasiliensis* from the Crato Formation in Araripe Basin (Ceará State, Brazil) are among the earliest known squamate lepidosaurs from South America. Accordingly, their paleogeographic position in Gondwana during the Early Cretaceous indicates a widespread Gondwanan distribution of squamates. Their phylogenetic position places them at or near the ancestry of squamates (BONFIM; MARQUES, 1997; EVANS; YABUMOTO, 1998). The Late Cretaceous squamate record consists only of *Pristiguana brasiliensis* from late Maastrichtian Marília Formation of Minas Gerais State, which has been regarded as a possible iguanid by Apesteguía; Agnolin; Lio (2005), Estes (1983), Estes; Price (1973) and Candeiro et al. (2007).

Recent studies have reported an expanded and considerably detailed record of Late Cretaceous continental squamate discoveries (APESTEGUÍA, 2005; APESTEGUÍA; AGNOLIN; LIO, 2004, 2005; MARTINELLI; FORASIEPI, 2004). The recently reported Ophidia from Turonian-Santonian Adamantina Formation of the São Paulo state (BERTINI, 1994). Other, more recently reported (ZAHER et al., 2003) squamate *Anguimorpha* from Adamantina Formation, São Paulo State, confirm serpent paleogeographic distribution in Brazil. This contribution reviews the paleogeographic position of squamate Brazilian Cretaceous records and the remarks of this group in Brazil.

In this contribution, I present an up-to-date list of Squamata taxa recognized in the Cretaceous of Brazil. Furthermore, I evaluate the

paleogeographical and chronostratigraphical distribution of this group in Brazil during the Cretaceous.

METHODOLOGY

The data on Squamata taxa for the present review are mostly based in literature sources as well as in the direct observation of the specimens.

Taxonomical treatment - In order to evaluate the taxonomic status of Squamata, I use information obtained from Reynoso; Callison (2000).

Institutional abbreviations: *Brazil* - DNPM, Departamento Nacional da Produção Mineral, Rio de Janeiro, Rio de Janeiro State; MPSC, Museu de Paleontologia de Santana, Universidade Regional do Cariri, Ceará State. *Japan*: KMNH, Kitakyushu Museum and Institute of Natural History, Fukuoka, Kyushu, Japan Province.

Geology - For the stratigraphic units in the Araripe Basin I follow the arrangement proposed by Martill (1993) and for the Bauru Basin used Fernandes; Coimbra (1996).

SQUAMATA BACKGROUND

The current record of squamates in the Cretaceous beds of Brazil is extremely limited: a few lizards and possibly two snakes. The first formally described Cretaceous lizard from this Brazil was *Pristiguana brasiliensis* from the Bauru Group (ESTES; PRICE, 1973). In addition, a well-preserved basal squamate was described from the Crato Formation (Ceará State; BONFIM; MARQUES, 1997; EVANS; YAMUBOTO, 1998). Unstudied materials of lizards and serpents are known from the Adamantina Formation of São Paulo State (BONAPARTE, 1978; BERTINI; BONFIM, 1998; ESTES; PRICE, 1973).

GEOLOGICAL SETTING

Ceará State

Araripe Group, Crato Formation

The Araripe Group (Crato, Ipubi, Batateiras, and Santana formations; Araripe Basin) is located in the west-central region of Brazil (Figure 1), covering Ceará and Piauí states. This group is an important paleontological area of Gondwana landmass due to its richness of Cretaceous vertebrate faunas. It is composed of intercalating marine, littoral and continental sediments (NEUMANN et al., 2003).

Within the Araripe Group, the fossils of *Tijubina ponteii* (BONFIM; MARQUES, 1997) and *Olindalacerta brasiliensis* (EVANS; YABUMOTO, 1998) were collected in the Crato Formation (Figure 1).

The Crato Formation was previously included in the Santana Formation (MARTILL, 1993). The Santana Formation was subsequently subdivided into the three members Crato, Ipubi, and Romualdo (BERTHO, 1990), later elevated to formations rank: the Crato, Ipubi and Santana Formations (the later being equivalent to the Romualdo Member) (MARTILL, 1993). Together with the Exu Formation, which consists mainly of coarse clastic sediments, these formations were included in the Araripe Group (MARTILL, 1993). The Crato Formation is the most basal of these formations and consists of organic rich mudstones and laminated micritic plattenkalk limestones possibly of marginally marine origin (BECHLY, 1998). The limestone sequence is about 30 m in thickness, showing considerable variations in the underlying topography (MARTILL, 1993). The age of the sedimentary sequence of the Araripe Group is uncertain due to lack of good stratigraphic marker fossils and lack of other geological evidence. It is generally cited as Early to mid-Cretaceous (Aptian, and/or Albian, and perhaps Cenomanian) (MARTILL, 1993). Berthou (1990) suggested a late Aptian to early Albian age based on sedimentological and palaeontological

correlations. This age assignment is supported by stratigraphic studies (DE LIMA, 1978; DOYLE, 1992; PONS et al., 1990).

Minas Gerais and São Paulo States

Bauru Group (Adamantina and Marília formations)

Within the Bauru Basin, is the Bauru Group (Figure 1), the most extensively studied unit. The Bauru Group is composed of the Adamantina (Turonian-Santonian), Uberaba (Turonian-Coniacian) and Marília (late Maastrichtian) formations. The Caiuá Group is composed by the Rio Paraná (Santonian-Maastrichtian), Goio Êre (Santonian-Maastrichtian), and Santo Anastácio (Aptian-Cenomanian) formations. Dias-Brito et al. (2001) discussed the age of Santo Anastácio, Adamantina, Uberaba, and Marília formations, Fernandes (1998) the for Goio Êre and Rio Paraná formations. The Bauru Group has a complex nomenclatural history (BARCELOS, 1984; FERNANDES; COIMBRA, 1996), partially due to the artificial division of the Upper Cretaceous strata in the flat areas of the Goiás, Mato Grosso do Sul, Minas Gerais ("Triângulo Mineiro"), Paraná and São Paulo states.

Both the Adamantina and Marília formations are chronologically correlated to the Upper Cretaceous strata from Argentina (HUENE, 1927, 1939). Within the Paraná Basin, the Adamantina and Marília formations have been described as Grez (GONZAGA DE CAMPOS, 1905), Series (FREITAS, 1955), Formation (ARID, 1967; DIAS-BRITO et al., 2001; MEZZALIRA, 1974) and Group (SOARES et al., 1980; SUGUIO, 1980). Other workers subdivided further these formations into more units (e.g., FERNANDES, 1998).

The recognition and description of the stratigraphical relationships among the various formations of the Bauru Basin allowed to better understanding of the extensive fossil collections in a chronostratigraphic context.

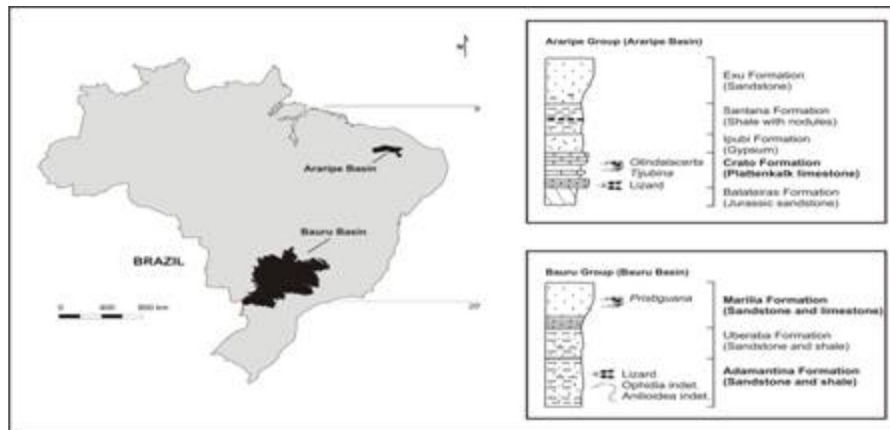


Figure 1. Distribution of Cretaceous continental Araripe and Bauru basins in Brazil (Adapted from MARTILL, 1993 and FERNANDES; COIMBRA, 1996).

PHYLOGENY OF SQUAMATA

The phylogenetic relationships of the Cretaceous squamates of Brazil are subjects of considerable interest. Recent studies on lepidosaur relationships have focused on traditional osteological comparisons (e.g. ALBINO, 1996; BONAPARTE, 1996) and cladistic analyses (e.g. CALDWELL, 1999; ESTES; DE QUEIROZ; GAUTHIER, 1988; EVANS, 2003; ESTES, 1983; LEE; 1998; REYNOSO; 1998; REYNOSO; CALLISON, 2000). The Brazilian *Tijubina* and *Olindalacerta* and the Early Cretaceous *Huehuecuetzpalli* from Mexico all retain certain osteological features that indicate relationship with Lepidosauria, with which they were contemporaneous. The other Early Cretaceous basal squamate (EVANS; 2003) are not known well enough to afford confident comparisons.

Recent taxonomic assignments and cladistic analyses have consistently recognized *Tijubina* and *Olindalacerta* as basal squamates (Confirm; BONFIM, 2001; BONFIM; AVILLA, 2002; BONFIM; MARQUES, 1997; EVANS; YABUMOTO, 1998).

PALAEOGEOGRAPHIC DISTRIBUTION OF SQUAMATA RECORDS

The following is a brief review of the institutional repository, locality information, stratigraphic distribution of Squamata from Cretaceous of Brazil (Figure 2; Table 1).

Systematic paleontology

Superorder Squamata Oppel, 1811

Species *Tijubina ponteii* Bonfim; Marques, 1997

Holotype: MPSC V010 an articulated specimen.

Locality, geology, and age. Nova Olinda municipality, Ceará State, Brazil, Crato Formation, Aptian/Albian age.

Remarks: The remains of the primitive squamate *Tijubina ponteii* from Early Cretaceous sediments was briefly described by Bonfim; Marques (1997) who referred it as a possible member of Teiidae. More recently, Bonfim (2001) and Bonfim; Avilla (2002) suggested *Tijubina* represents a basal squamate closely related to *Huehuecuetzpalli mixtectus* Reynoso, 1998 from the Aptian of Mexico. The results of a cladistic analysis by Bonfim; Marques (op. cit) places *Tijubina* and *Huehuecuetzpalli* in a basal position within Squamata where they comprise a sister clade to the crown-group squamates.

Olindalacerta brasiliensis Evans; Yabumoto, 1998
Holotype: KMNH VP 400, 001 an articulated specimen.

Locality, geology and age: Ceará State, the precise provenance-can you not get this information from the museum that the specimen is housed in KMNH is not reported by Evans and Yabumoto (1998), Crato Formation, Aptian/Albian age.

Remarks: *Olindalacerta brasiliensis* is known from an articulated skeleton of a juvenile and is the second lizard recovered from Crato Formation. According Evans; Yamuboto (1998) the position of *O. brasiliensis* within Squamata is uncertain, but it shares a general resemblance in body proportions to *Euposaurus* from the Late Jurassic of France. *Olindalacerta brasiliensis* is a fairly well-described basal squamate known of Brazil, but still requires a more comprehensive comparative study to understand its anatomy, identify taxonomically useful characters, and to test its relationship within Squamata.

Infraorder Iguania Cuvier, 1807--???

Family Iguanidae Gray, 1827

Species *Pristiguana brasiliensis* Estes; Price, 1973
Holotype. DGM 552: part of a disarticulated skeleton of a single individual.

Locality, horizon, and age. Peirópolis Site, Uberaba municipality, Minas Gerais State, Marília Formation, late Maastrichtian.

Remarks. *Pristiguana brasiliensis* was the first Mesozoic lizard to be described from South America (ESTES; PRICE, 1973). Estes (1983), Estes; Báez (1985) and Estes; Price (1973) indicate that *Pristiguana* might have iguanian affinities. However, this assignment was questioned by Borsuk-Bialynicka; Moody (1984) who believed it might be a teiid. Because of the controversial taxonomic position of this taxon among squamates, a re-analysis of *Pristiguana brasiliensis* in light of the new discoveries from the Cretaceous rocks of South America, is warranted.

Suborder Serpentes Linnaeus, 1758

Superfamily Anilioidea Fitzinger, 1826

Gen. et sp. indet. Zaher; Langer; Fara; Carvalho; Arruda, 2003

Material. MZ S/N: some articulated vertebrae and ribs.

Locality, horizon, and age. General Salgado municipality, São Paulo State; Adamantina Formation, Turonian-Santonian.

Comments. The snake record of Bauru Group only comprises the recent discovery by Zaher et al. (2003). This taxon is based on two specimens that include a few articulated vertebrae and some ribs. These anilioid fossils are characterized by their small size, and narrow, rather depressed, and elongated vertebrae (ZAHER et al., 2003). The Anilioidea briefly described by Zaher et al. (2003) represents the first Cretaceous snake reported in Brazil.

Other squamate remains. Bertini; Bonfim (1998) and Estes; Price (1973) and briefly reported isolated squamate remains from Adamantina Formation of the São Paulo State. Bertini (1994) mentioned a single vertebrae of *Ophidia* indet., but no additional information was made from the Adamantina Formation of the southwest of São Paulo State. In the Crato Formation at Ceará State, one indeterminate lizard was mentioned by Evans; Yabumoto (1998) which is larger than *Olindalacerta*, but this specimen had not yet been described.



Figure 2. Recent geographical distribution of Squamata records in Brazil.

Table 1. List of the Squamata records, their localities, and geological ages from Brazil.

Taxon	Locality	Geological Unit	Age	Selected Reference
Squamata				
<i>Tijubina ponteii</i>	Nova Olinda,	Crato Formation,	Aptian-Albian	Bonfim (2001)

Continua...

	Ceará State	Araripe Group		
<i>Olindacerta brasiliensis</i>	Ceará State	Crato Formation, Araripe Group	Aptian-Albian	Evans; Yabumoto (1998)
Squamata indet.	Ceará State	?	?	Evans; Yabumoto (1998)
Squamata indet.	São Paulo State	Adamantina Formation, Bauru Group	Turonian-Santonian	Bertini; Bonfim (1998)
Iguanidae <i>Pristiguana brasiliensis</i>	Peirópolis, Uberaba, Minas Gerais State	Marília Formation, Bauru Group	Late Maastrichtian	Estes (1998)
Ophidia Ophidia indet.	São Paulo State	Adamantina Formation, Bauru Group	Turonian-Santonian	Bertini (1994)
Anilioidea indet.	General Salgado, São Paulo State	Adamantina Formation, Bauru Group	Turonian-Santonian	Zaher et al. (2003)

DISCUSSION

Cretaceous lizards from Brazil were previously documented in scattered publications (see Introduction), but no synthetic studies have even been attempted, largely owing to lack of fossil specimens. However, over the past 8 years collections from Brazil and Japan have provided important specimens for undertaking the research reported in this paper. The geological distribution of these lizards is summarized in the form of two charts (Table 1).

From existing data on the paleogeographical and stratigraphical distribution of the squamata species, it is clear that Squamata ranged in an area roughly delineated by northern and central-Brazil. *Olindacerta brasiliensis* and *Tijubina pontei* species in Ceará State; *Pristiguana brasiliensis* specie in Minas Gerais State, and Ophidia and Anelloidea record in São Paulo State. The following are recorded to Albian-Aptian stage: *O. brasiliensis* and *T. pontei*; Turonian-Santonian: Ophidia indet. and Anilioidea indet.; Maastrichtian: *Pristiguana brasiliensis* (Figures 2-4; Table 1).

The occurrence of *Tijubina* and *Olindacerta* in the Early Cretaceous of Brazil

indicates with *Huehuecuetzpalli* from Albian of Mexico western Gondwana and Laurasia distribution (Figure 3). Considering the poorly and patchy global squamate record of the Early Cretaceous, the occurrence of the mentioned species are problematical; the simplest explanation of this obvious rarity could be related from lack of extensive or least systematic prospecting in the Early Cretaceous areas rather than from depositional or preservational events.

In contrast with the Early Cretaceous, squamates are very successful group distributed in Gondwana and Laurasia (EVANS, 2003). Upper Cretaceous localities in Argentina, Bolivia, and Brazil, contain a diversity of lizards and snakes (ALBINO, 1996; CALDWELL; ALBINO, 2002; CANDEIRO ET AL., 2007; ESTES; PRICE, 1973; GAYET et al., 2001; ZAHER ET AL., 2003). But, however, nothing of the systematic and phylogenetic approach of the Brazilian taxa. The new snake record from the Adamantina Formation suggests that Anilioidea were in Central Brazil and Argentina in the Late Cretaceous, and these accords with prediction based on dinosaurian studies (e.g. CANDEIRO et al., 2004).

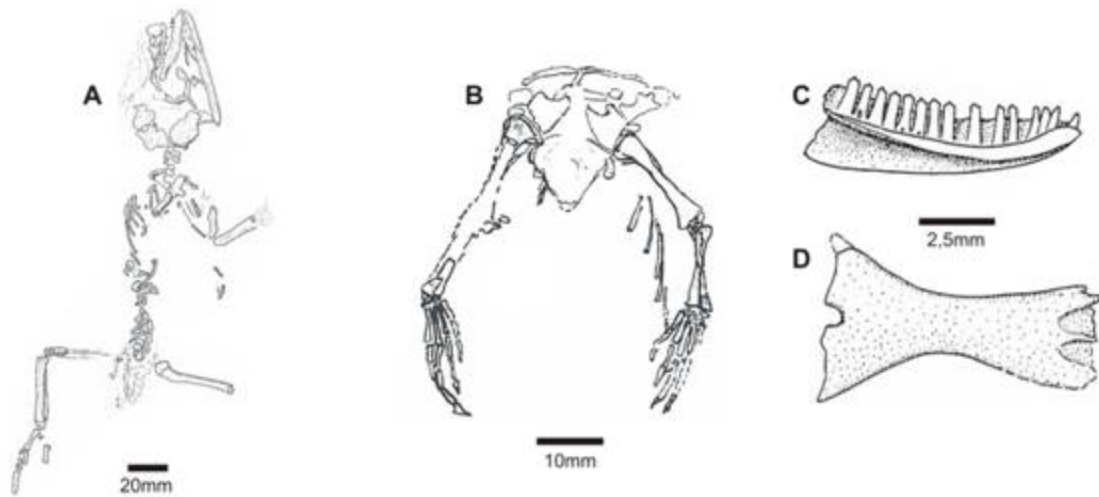
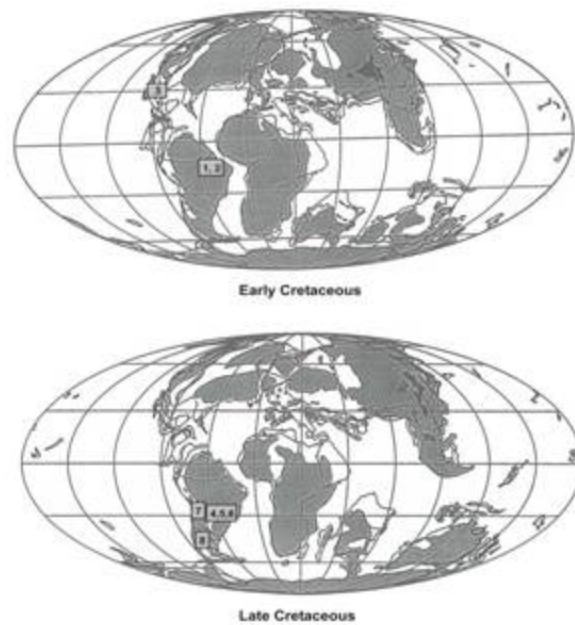


Figure 3. Cretaceous Brazilian squamates. A, *Olindacerta brasiliensis*; B, *Tjubina ponteii*; C, *Pristiguana brasiliensis* (Modified from EVANS; YABUMOTO, 1998 – A, BONFIM, 2001 – B, and ESTES, 1983 - C).



Brazil: 1, *Olindacerta brasiliensis*; 2, *Tjubina ponteii*; Mexico: 3, *HuehuetzpaW mixtecus*; Brazil: 4, *Pristiguana brasiliensis*; 5, *Ophidia indet.*; 6, *Anilioidea*; Bolivia: 7, Squamates (lizards and snakes); Argentina: 8, Squamates (lizards and snakes).

Figure 4. Paleogeographical distribution of Squamata records in western Gondwana and Laurasia landmasses (modified from HAY et al., 1999).

CONCLUSION

Recent discoveries of squamates have increased knowledge of the systematic and paleogeographical distribution of the Squamata. The occurrence of basal squamates *Tijubina* and *Olindalacerta* in the Albian-Aptian of Ceará State, Brazil and *Huehucuetzpalli* (Albian) indicate a western basal squamate on the world during the Early Cretaceous. The iguanian and serpentes record occurred in southern South America. Additionally, snake records from Argentina, Bolivia and Brazil presented paleogeographical distribution in the southern South America.

ACKNOWLEDGEMENTS

I wish to thank Dr. Victor Reynoso (Universidad Autonoma Mexico) for his direction and critical reading of the early manuscript. I appreciate the critical review of Dr. Andrew Newman (Royal Tyrrell Museum of Palaeontology, Alberta, Canada) and Dr. Randall Nydam (Midwestern University, Arizona, United States). I also grateful to the Dr. Oswaldo Marçal Júnior (Editor of the Bioscience Journal) and an anonymous reviewer who provided helpful critiques on the manuscript.

RESUMO: Os esquamatas terrestres do Brasil são conhecidos por registros do Eocretáceo por *Olindalacerta brasiliensis* e *Tijubina pontei* do estado do Ceará; do Neocretáceo por *Pristiguana brasiliensis* do estado de Minas Gerais, Ophidia indet. e Anilioidea do estado de São Paulo State. Os esquamatas foram amplamente distribuídos no oeste do Gondwana e Laurásia, os iguanídeos e principalmente o registro de serpentes estão distribuídos em uma vasta área do sul da América do Sul.

PALAVRAS-CHAVE: Squamata. distribuição paleogeográfica. Cretáceo. Brasil.

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