

# New occurrence of †Mawsoniidae (Sarcopterygii, Actinistia) in the Morro do Chaves Formation, Lower Cretaceous of the Sergipe-Alagoas Basin, Northeastern Brazil

## Nova ocorrência de †Mawsoniidae (Sarcopterygii, Actinistia) na Formação Morro do Chaves, Cretáceo Inferior da bacia de Sergipe-Alagoas, nordeste do Brasil

Valéria Gallo<sup>I</sup>

Marise Sardenberg Salgado de Carvalho<sup>II</sup>

Hugo Ricardo Secioso Santos<sup>III</sup>

**Abstract:** The goal of this paper is to describe a new occurrence of †Mawsoniidae in the Morro do Chaves Formation, Sergipe-Alagoas Basin. This stratigraphical unit is represented by an intercalation of coquina and shale beds, deposited in a lacustrine paleoenvironment during the Upper Barremian (Lower Jiquiá local stage). The description is accomplished on the basis of new and more complete material, represented by articulated bones of the palatoquadrate and lower jaw, as well as by gular plate. It was assigned to the genus *Mawsonia* based on the presence of a stout angular conspicuously ornamented with wrinkles and ridges, as well as palatoquadrate with a single strengthening ridge on its lateral surface. When this new occurrence of *Mawsonia* was compared with the other genera of Mawsoniidae occurring in Brazil (i.e., *Axelrodichthys* and *Parnaíbaia*), it was verified that it differs clearly from *Axelrodichthys* by the inclination of the suspensorium (obliquely oriented in *Mawsonia* versus vertically oriented in *Axelrodichthys*). Regarding *Parnaíbaia*, the ornamentation of the angular and gular plate is more delicate in this genus.

**Keywords:** †Mawsoniidae. Sergipe-Alagoas Basin. Lower Cretaceous.

**Resumo:** O objetivo deste estudo é descrever uma nova ocorrência de †Mawsoniidae na Formação Morro do Chaves, bacia de Sergipe-Alagoas. Esta unidade estratigráfica é representada por uma alternância de camadas de coquina e folhelho, depositadas em um paleoambiente lacustre, durante o Barremiano Superior (no andar local Jiquiá Inferior). A descrição foi efetuada com base em material inédito e mais completo, representado por ossos articulados do palatoquadrado e maxila inferior, bem como pela placa gular. Este espécime foi atribuído ao gênero *Mawsonia*, com base na presença de um robusto angular conspicuamente ornamentado com cristas e rugas, bem como pela presença de uma crista única, fortalecendo a superfície lateral do palatoquadrado. Quando esta nova ocorrência de *Mawsonia* foi comparada com outros gêneros de Mawsoniidae presentes no Brasil (i.e., *Axelrodichthys* e *Parnaíbaia*), verificou-se que ela difere claramente de *Axelrodichthys* pela inclinação do palatoquadrado (obliquamente orientado em *Mawsonia* versus verticalmente orientado em *Axelrodichthys*). Com relação a *Parnaíbaia*, a ornamentação do angular e da placa gular neste gênero é mais delicada.

**Palavras-chave:** †Mawsoniidae. Bacia de Sergipe-Alagoas. Cretáceo Inferior.

<sup>I</sup> Universidade do Estado do Rio de Janeiro. Instituto de Biologia. Departamento de Zoologia. Rio de Janeiro, Rio de Janeiro, Brasil (gallo@uerj.br).

<sup>II</sup> Universidade Federal do Rio de Janeiro. Instituto de Geociências. Departamento de Geologia. Rio de Janeiro, Rio de Janeiro, Brasil (marise.sardenberg@gmail.com).

<sup>III</sup> Universidade do Estado do Rio de Janeiro. Instituto de Biologia. Departamento de Zoologia. Rio de Janeiro, Rio de Janeiro, Brasil (hugouerj@yahoo.com.br).

## INTRODUCTION

Mawsoniidae is a fossil family of actinistians popularly known as coelacanths, being found in continental and marine paleoenvironments. It possesses a temporal range from the Middle Triassic (Ladinian) to the Late Cretaceous (Cenomanian), and a geographical distribution in the South and North Americas, Africa, and Europe (Schultze, 1993; Carvalho & Maisey, 2008; Miguel & Gallo, 2009a). The taxon was proposed by Schultze (1993) and, since then, some studies on its phylogeny in a cladistic context were accomplished. It is considered monophyletic in the most recent reviews and includes five unquestionable genera (*Axelrodichthys*, *Chinlea*, *Diplurus*, *Mawsonia*, and *Parnaibaia*), besides others with some taxonomical controversy (*Alcoveria*, *Gambergia*, *Indocelacanthus*, *Libys*, *Lualabaea*, and *Trachymetopon*). From these, only *Axelrodichthys*, *Parnaibaia* and *Mawsonia* are recorded in Brazil.

The monotypic genus *Axelrodichthys* occurs in the Lower Cretaceous of the Araripe Basin, being represented by almost complete and articulated specimens (Maisey, 1986), as well as by a juvenile specimen (Brito & Martill, 1999). Also, there is a record of an articulated skull of this genus in the Lower Cretaceous of the Grajaú Basin (Carvalho & Maisey, 1999), as well as isolated bones in the Upper Cretaceous of Africa (Madagascar; Gottfried *et al.*, 2004). In addition, Gee (1988) reported a coelacanth skull roof in the Lower Cretaceous of Africa (Niger), believed to be very similar to *Axelrodichthys*.

The monotypic genus *Parnaibaia* is restricted to the Late Jurassic of the Grajaú Basin and is represented by almost complete and articulated specimens, as well as by isolated bones, fin-rays, and scales (Yabumoto, 2008).

*Mawsonia* is found all along the Cretaceous of the South America and Africa, which allows the establishment of stratigraphical correlations between both continents, as well as biogeographical approaches. Ancient studies point out the existence of six species: four in Africa (*M. lavocati*, *M. libyca*, *M. tegamensis*, and *M. ubangiensis*) and two in Brazil (*M. brasiliensis* and *M. gigas*). However,

Carvalho & Maisey (2008) recognized only *M. gigas* and *M. tegamensis*, based on unequivocal morphological evidence, and synonymized the remnants species with *M. gigas*. This species possesses an abundant and wide record in Brazil, and is represented by an almost complete specimen, an articulated skull, fins, and several isolated bones from the Recôncavo, Tucano, Almada, Sergipe-Alagoas, Araripe, Iguatu, Grajaú, Sanfranciscana, and São Luís basins (see Carvalho & Maisey, 2008). *Mawsonia* is also represented in the Late Jurassic of the Araripe Basin, in the Brejo Santo and Missão Velha formations (Brito *et al.*, 1994; Malabarba & Garcia, 2000). In addition, there is an occurrence of *Mawsonia* in the Late Jurassic of the Tacuarembó Formation, Uruguay, being the southernmost record of the genus in South America (M. Soto, pers. comm., 2010).

Until now, there are only unpublished data of mawsoniids from the Morro do Chaves Formation, Barremian of the Sergipe-Alagoas Basin. Those are represented by an incomplete caudal fin and portions of fins referred to *Mawsonia* (Maffizzoni, 1998, and Ph.D. Dissertation by A. F. Maffizzoni, defended 2000, entitled "Paleoictiofauna da Formação Coqueiro Seco, Aptiano Inferior do Estado de Alagoas, Nordeste do Brasil"). The paleoichthyofauna of this stratigraphic unit is represented, besides mawsoniids (*Mawsonia* sp.), by semionotids (*Lepidotes alagoensis*), elopomorphs, clupeomorphs *sensu lato* and paraclupeids, gonorynchiforms (*Dastilbe* sp.), salmoniforms, cimolichthyids *incertae sedis* (*Atolvorator longipectoralis*), and enchodontids (*Enchodus* sp.) (Gallo & Coelho, 2008; Figueiredo, 2009; Gallo *et al.*, 2009a; Miguel & Gallo, 2009b). Also, tetrapods, invertebrates, microfossils, and palynomorphous are present (Antonioli *et al.*, 2004, 2009; Carmo *et al.*, 2008; Gallo *et al.*, 2009b).

The goal of this paper is to describe a new occurrence of Mawsoniidae in the Morro do Chaves Formation, on the basis of recently collected material, composed by articulated bones of the palatoquadrate, lower jaw, and gular plate.

## GEOLOGICAL SETTING

The Sergipe-Alagoas Basin is located in the coastal region of Northeastern Brazil (Figure 1). The northeastern part of this basin has a limit with the Pernambuco-Paraíba Basin represented by the Maragogi Structural High. To the southwestern, the boundary with the Jacuípe Basin is not so clear (Campos Neto *et al.*, 2007).

The sedimentary succession which crops out in the São Miguel dos Campos Unit is the most significant exposure of the Morro do Chaves Formation in the basin. For this succession, the geologist Renato R. C. Ramos constructed a detailed stratigraphic, 75 meters thick column (Figure 2), summarized in Negrão & Cavalcanti (2009), as follows:

From base to top, the first 67 m are characterized by coquina beds ranging from decimeter to meter in thickness. These beds are generally amalgamated with horizontal stratification and trough cross-bedding. The coquina shells show variable grades of reworking and recrystallization, and most of them are very fragmented.

A remarkable characteristic is found from the upper half of the column: coquina beds with erosive bases and cross-bedded stratification, with granules and pebbles of quartz, feldspar, lithic fragments, and subrounded pebbles of more ancient coquinas. In this level, 16 strata of argillaceous shales were verified, with thickness varying from 2 to 95 cm, and possessing a high content of organic matter, abundant ostracods and fish remains. In the upper part of the stratigraphical column, some of these thicker pelitic beds show cracks on the top, which are filled with calcarenites or thin coquinas, interpreted as mud cracks. Another very interesting feature is the presence of massive and very solid calcrete, formed during periods of exposure of the former bottom of the lake for prolonged periods of time (Negrão & Cavalcanti, 2009).

According to Azambuja Filho *et al.* (1998), the deposits of the Morro do Chaves Formation were formed in saline to hypersaline shallow waters of a

lacustrine environment, under seasonal dry periods when extensive areas were exposed. The dark shales were formed in an anoxic environment during the high level water periods, allowing the preservation of the organic matter. The bivalves lived in shallow and oxygenated waters and their shells were reworked by storms and accumulated in banks and beaches.

Regarding the age of the Morro do Chaves Formation, Campos Neto *et al.* (2007) pointed out an Upper Barremian-Lower Aptian age. More recently, Antonioli *et al.* (2009), based on the associated occurrences of *Aequitriradites spinulosus*, *Transitoripollis crisopolensis*, and *Dicheiropollis etruscus*, recognized the palynozone *Dicheiropollis etruscus* in the lower portion of this stratigraphical unit, which suggests a Lower Jiquiá local stage (Upper Barremian).

## MATERIAL AND METHODS

In January 2009, the authors carried out extensive field work in the Morro do Chaves Formation, Sergipe-Alagoas Basin, specifically in the São Miguel dos Campos Unit (formerly known as Atol quarry), situated in the municipality of São Miguel dos Campos, State of Alagoas, Northeastern Brazil (Figure 3).

The material consists of bony elements of the palatoquadrate and lower jaw, as well as by gular plate. It was preserved in grey shale and was prepared mechanically only with the aid of steel and carbide needles. Methacrylate resin (Paraloid B-67) was used to consolidate and to protect the bones. Ethyl acetate was dropped on the surface of the fossils to enhance skeletal structures prior to observation under Nikon SMZ 800 and Leica Zoom 2000 stereomicroscopes. The drawings were made directly from the specimens by means of measurements, as well as from photographic magnifications.

The specimen is housed at the paleontological collection of the Departamento de Zoologia of the Universidade do Estado do Rio de Janeiro (UERJ).

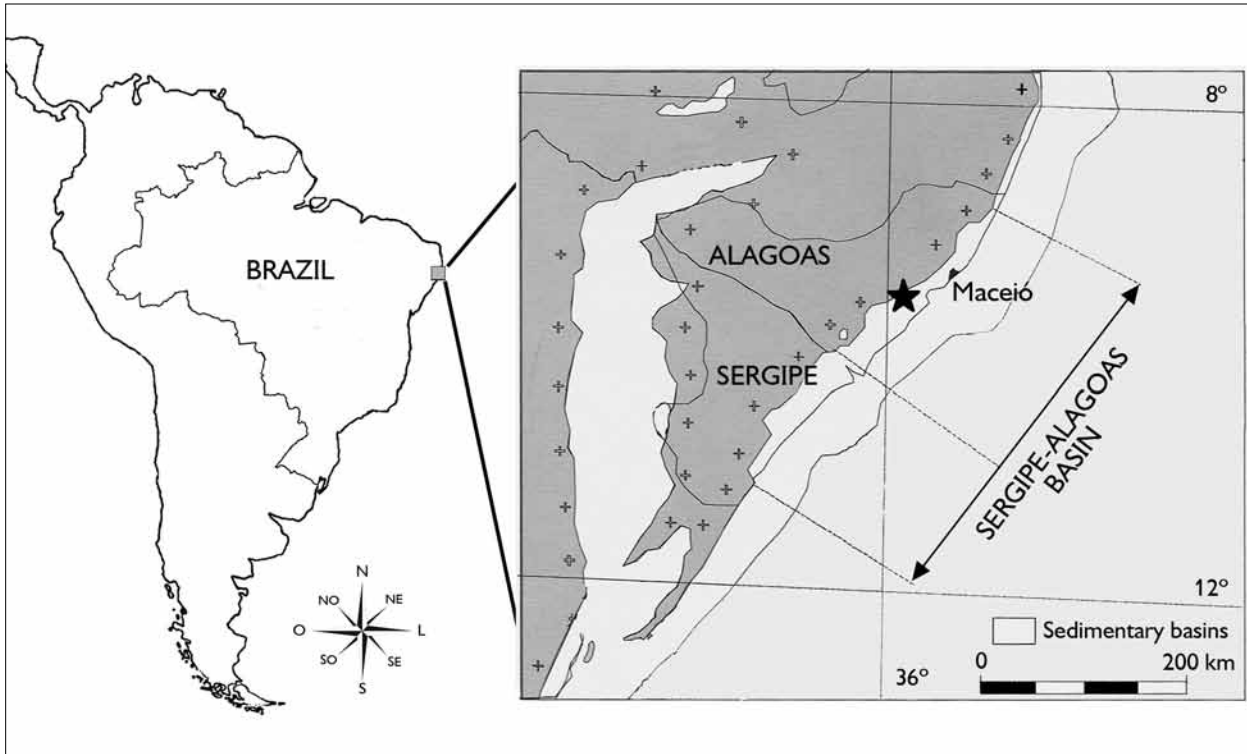


Figure 1. Location map of the Sergipe-Alagoas Basin, Northeastern Brazil. The star indicates the municipality of São Miguel dos Campos (modified from Souza-Lima *et al.*, 2002).

## DESCRIPTION

### SYSTEMATIC PALEONTOLOGY

Sarcopterygii Romer, 1955

Actinistia Cope, 1871

Coelacanthiformes Huxley, 1861

Latimerioidei Schultze, 1993

Mawsoniidae Schultze, 1993

*Mawsonia* Woodward in

Mawson & Woodward, 1907

*Mawsonia* sp.

Material: UERJ.MC 1 (Figures 4-7).

**Gular plate:** The well-preserved right gular plate (Figures 4 and 5) is an elongate, flattened, and spatulate bone. It possesses rounded extremities; the anterior is wider than the posterior. It is ornamented with remarkable ridges and furrows; those more conspicuous are obliquely

oriented. A piece of bone placed above the lower jaw was interpreted as the left gular plate preserved in inner view.

**Lower jaw:** Both left and right mentomeckelians (Figure 4) are anteriorly preserved, but displaced from their anatomical position. They are small, anteriorly and inwardly curved, ending in a swollen symphysis.

Since the right gular plate overlaps part of the lower jaw an accurate description of the dentary (Figure 4) was not possible. Its upper limb seems to be short and to contact the prearticular; the lower limb is not visible. Teeth were not observed.

The angular (Figures 4 and 6) is a very large and stout bone. The higher portion of the bone is situated in the middle of its length. At this point, there is a reduced dorsal process which contacts the principal coronoid. The angular is conspicuously ornamented with ridges and furrows producing a vermicular pattern. The mandibular sensory

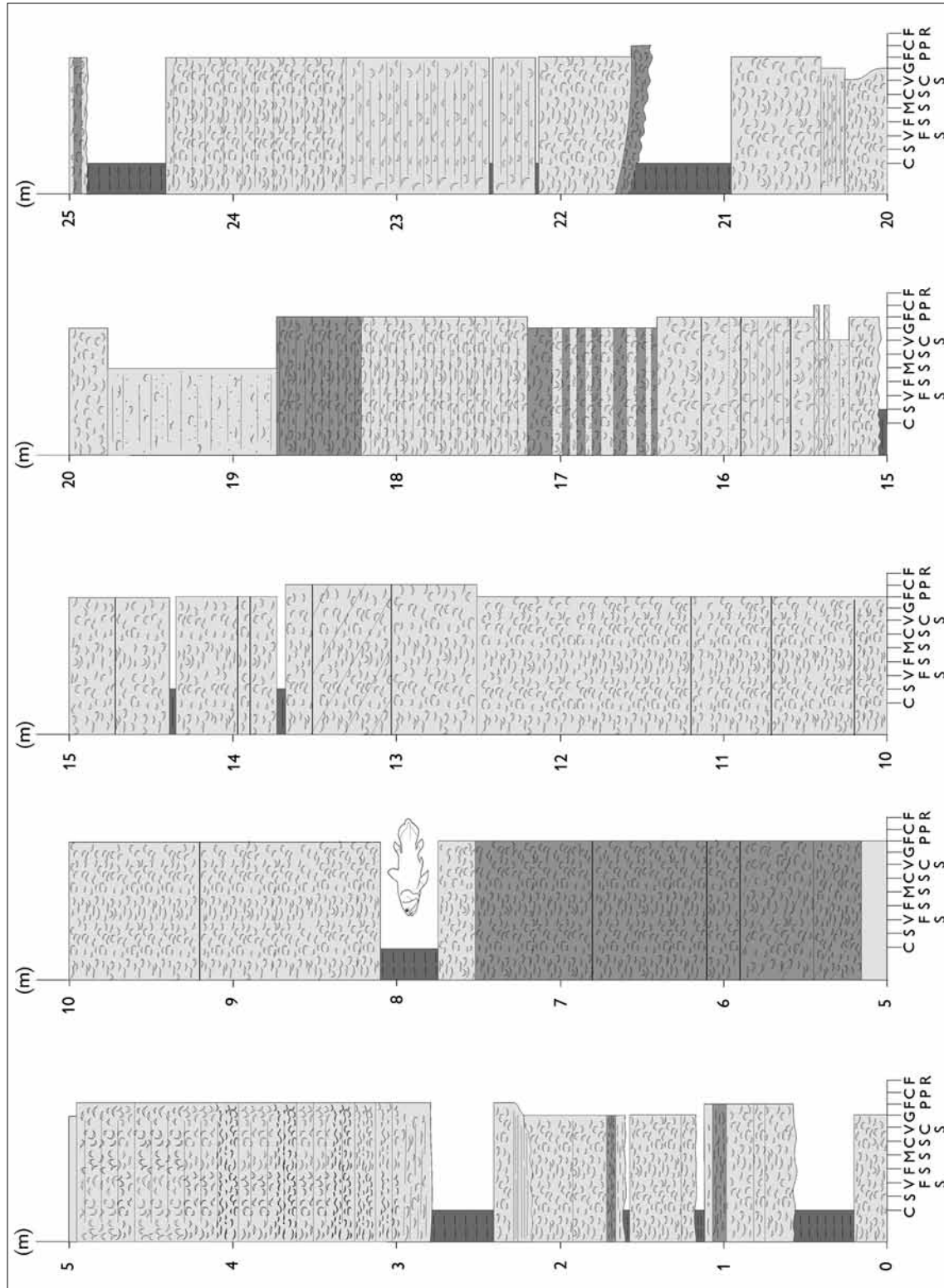
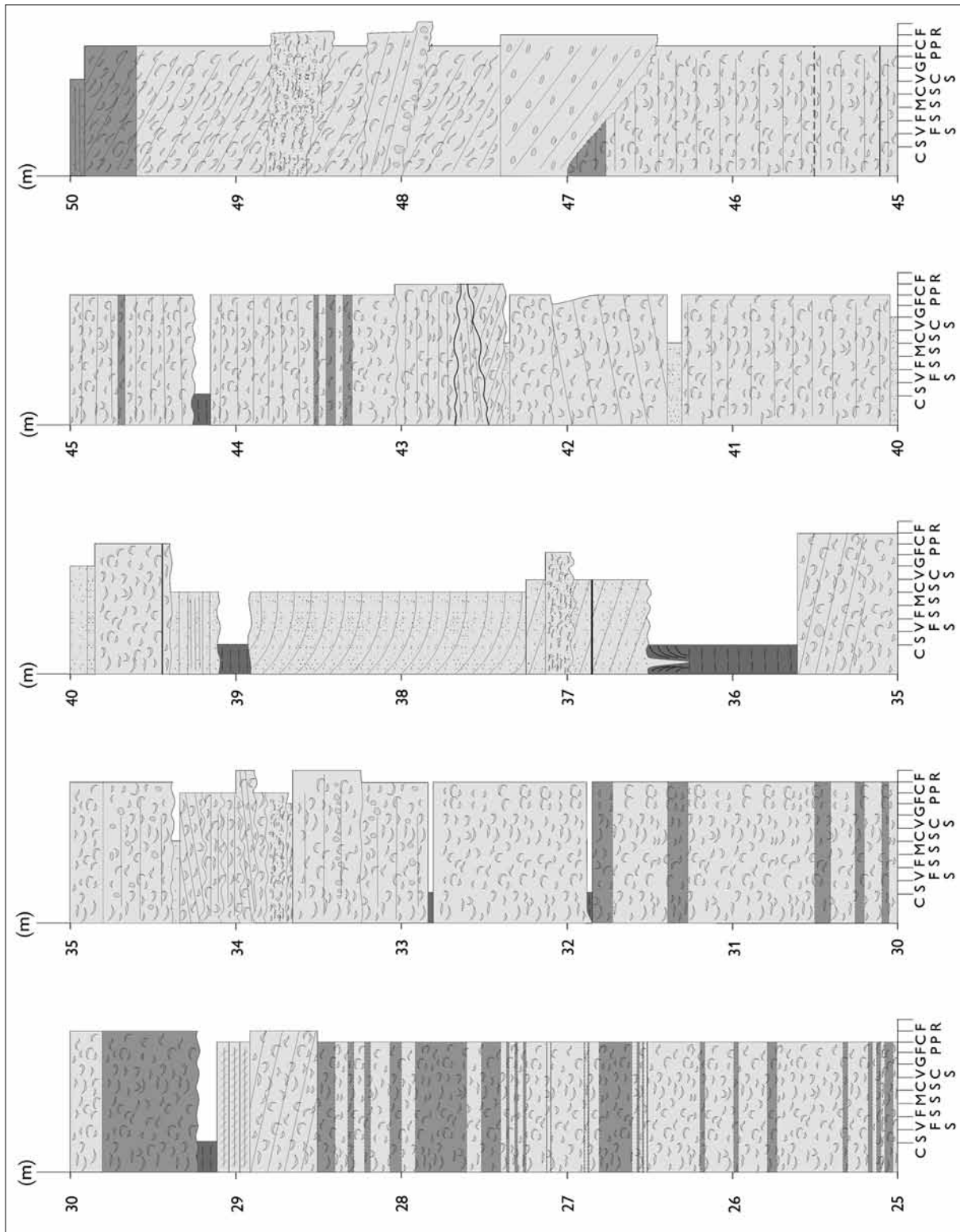


Figure 2. Stratigraphic column of the outcrop from the São Miguel dos Campos Unit, State of Alagoas (kindly provided by Renato R. C. Ramos, 2009). A coelacanth outline indicates the level of the shales in which *Mawsonia* sp. was collected. Scale: 1:25,000. Abbreviations: C, clay; S, sand; VFS, very fine sand; FS, fine sand; MS, medium sand; CS, coarse sand; VCS, very coarse sand; G, granule; FP, fine pebble; CP, coarse pebble; FR, fine rudite.

(Continued)





(Continued)

Figure 2.



Figure 2.



Figure 3. Outcrop (in a 360° view) of the São Miguel dos Campos Unit, State of Alagoas. Arrow points to the level of the shales in which *Mawsonia* sp. was collected.

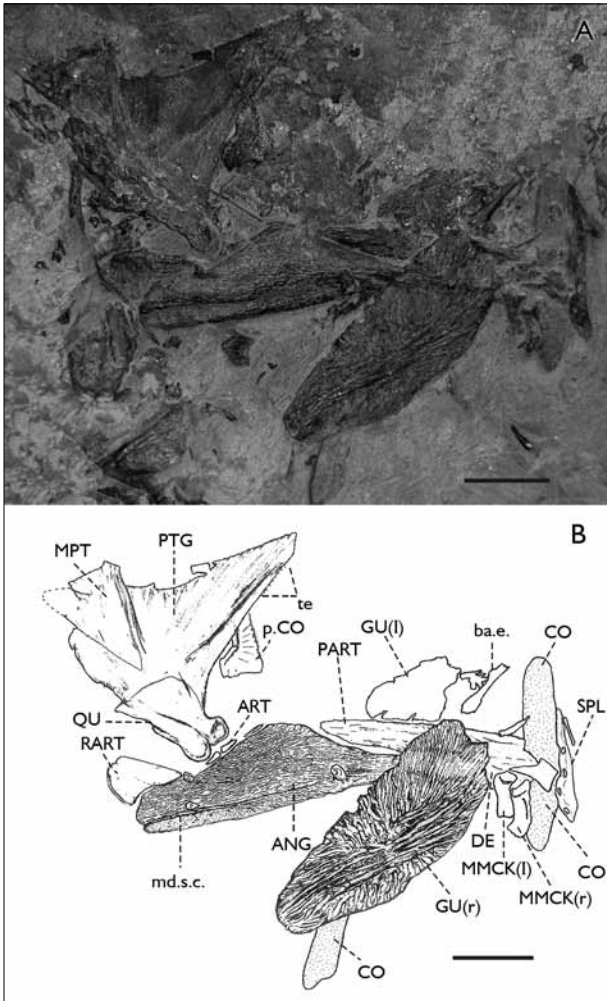


Figure 4. *Mawsonia* sp. from the Morro do Chaves Formation. A, photograph; B, line drawing. Anatomical Abbreviations: ANG, angular; ART, articular; ba.e., branchial arch element; CO, coronoid; DE, dentary; GU, gular plate; l, left; md.s.c., mandibular sensory canal; p.CO, principal coronoid; MMCK, mentomeckelian; MPT, metapterygoid; PART, prearticular; PTK, pterygoid; QU, quadrate; r, right; RART, retroarticular; SPL, splenial; te, teeth. Scale bars equal 20 mm.

canal runs in a groove near the ventral border of the bone. Above the groove the ornamentation is obliquely oriented, whereas below the groove it does not show any orientation.

The principal coronoid (Figure 4) is displaced from its anatomical position. It is a triangular bone showing an articular facet to the dorsal process of the angular.

The prearticular (Figure 4) is a laminate bone extending from the dorsal process of the angular to dentary. Its anteriormost part is overlapped by the right gular plate.

Fragments of the articular (Figure 4) are found lying on the angular.

The retroarticular (Figure 4) is sited in the posterior portion of the lower jaw and is articulated to the angular. The retroarticular and articular participate to the double articulation of the lower jaw, which receives the condyles of quadrate.

The splenial (Figure 4) is displaced from its anatomical position. It is an elongate and narrow bone, being broader posteriorly and tapering forward. It is longitudinally crossed by the mandibular sensory canal, represented by four sensory pores.

Three coronoids (Figure 4) are preserved, displaced from their anatomical position. They are long and flattened rod-shaped bones, bearing a pad of minute teeth.

Branchial arches: A single rod-like bone preserved near the anterior portion of the lower jaw was interpreted as an element of branchial arches (Figure 4).

Palatoquadrate: The palatoquadrate (Figure 7) is triangular and remarkably obliquely oriented. It is composed of pterygoid in the central region; quadrate in the ventral region; and metapterygoid in the dorsal region.



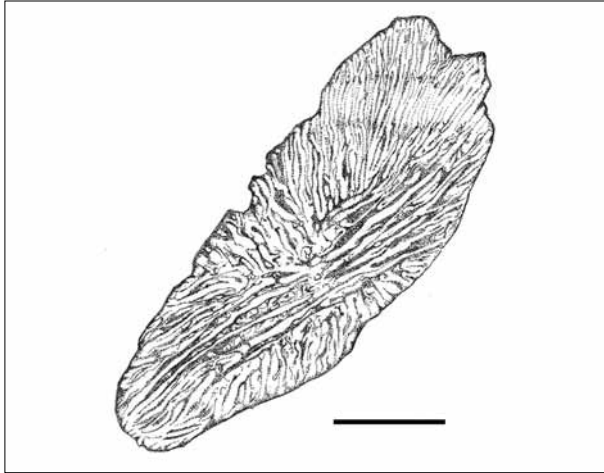


Figure 5. Right gular plate of *Mawsonia* sp. Scale bar equals 20 mm.

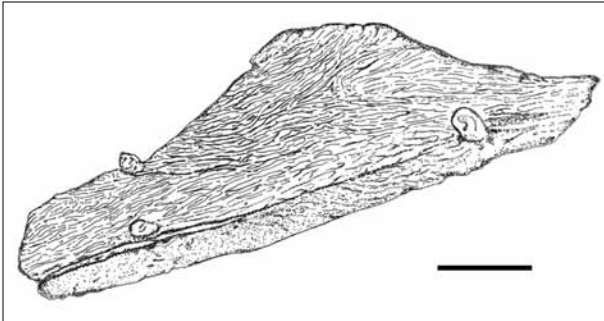


Figure 6. Angular of *Mawsonia* sp. in right lateral view. Scale bar equals 20 mm.

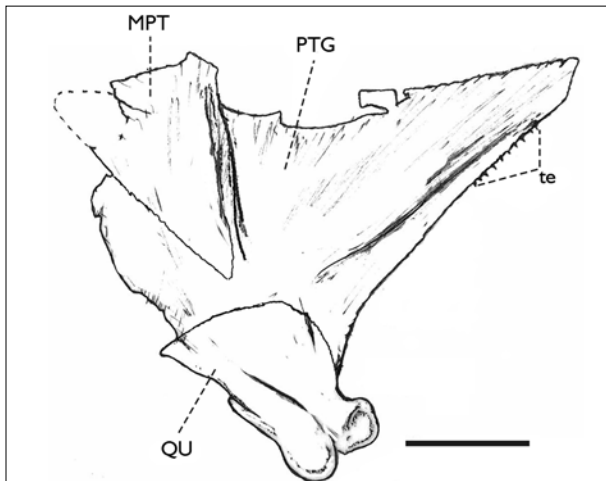


Figure 7. Palatoquadrate of *Mawsonia* sp. in right lateral view. Anatomical Abbreviations: MPT, metapterygoid; PTG, pterygoid; QU, quadrate; te, teeth. Scale bar equals 20 mm.

The pterygoid (Figure 7) is the most distinctively element in the palatoquadrate. It is a triangular and very high bone, bearing a conspicuous bony ridge in the lateral region which bounds the anterior edge of the metapterygoid, reaching the anterodorsal limit of the quadrate. The pterygoid is sutured to the quadrate and possesses a posterior vertical arm which articulates with the metapterygoid dorsally. Its anterior portion bears a row of minute teeth in the oral border.

The quadrate (Figure 7) is a deep and robust bone obliquely orientated. It ends in a large double condyle for articulation with the lower jaw. The two condyles are asymmetric, the inner being large than the outer. This asymmetry is typical in coelacanth fishes and allows a perfect fit with the lower jaw.

The metapterygoid (Figure 7) is a triangular bone, placed in the dorsalmost part of the palatoquadrate. Its articular dorsal surface is sinuous and provides the contact with the ventral surface of the antotic process of the basisphenoid (not preserved).

## DISCUSSION AND CONCLUSIONS

The new occurrence was assigned to the genus *Mawsonia* based on the presence of a stout angular conspicuously ornamented with wrinkles and ridges, as well as a palatoquadrate with a single strengthening ridge on its lateral surface. When we compare it with the other genera of Mawsoniidae which occur in Brazil, we verify that it differs clearly from *Axelrodichthys* by the inclination of the suspensorium (obliquely oriented in the new occurrence *versus* vertically oriented in *Axelrodichthys*; see Maisey, 1986, p. 27, figure 26). Regarding *Parnaíbaia*, the ornamentation of the angular and gular plate in this genus is more delicate (see Yabumoto, 2008, p. 332, figure 3).

Although certain diagnostic features (e.g., the presence of a very high pterygoid) can be suggested as putative autapomorphies, this new occurrence is assigned provisionally to *Mawsonia* sp. until more complete material is known.

The occurrence of *Mawsonia* and *Axelrodichthys* is recorded in the stratigraphical sequences of the Rift Valley system of Eastern Brazilian and Northwestern Africa. The disjunction of these genera can be explained by vicariant events related to the opening of South Atlantic Ocean, during the Early Cretaceous. In the Late Cretaceous, mawsoniids were reported to Northeastern Brazil (*Mawsonia*; Carvalho & Maissey, 2008), Southeastern France (*Mawsonia*-*Axelrodichthys* complex; Cavin *et al.*, 2005) and Madagascar (*Axelrodichthys*; Gottfried *et al.*, 2004). Due to the scarcity of these records, the distribution pattern is still for discussion. The Late Jurassic genus *Parnaíbaia*, from Northeastern Brazil, is restricted to South America. However, regarding the more recent phylogeny of Mawsoniidae (Yabumoto, 2008), the presence of *Parnaíbaia* may be expected in Africa.

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