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Quasimodichthys gen. nov. (Neopterygii: Semionotiformes): A morphological and ontogenetic study

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ABSTRACT

Many *Lepidotes* species were recorded worldwide during most parts of the twentieth century, even in the Brazilian sedimentary basins. Among the Brazilian sedimentary basins, the Late Jurassic "*L.*" *piauhyensis* is one the best described, especially because the relatively great amount of well-preserved and articulated specimens. As suggested in the most recent phylogenetic analysis, *Lepidotes* should be restrict to the Lower Jurassic of Central Europe and all the *Lepidotes* species recorded beyond this interval belong to other genera. Herein "*L.*" *piauhyensis* was revised and presents new morphological and ontogenetic information, which allow us to propose a new genus, *Quasimodichthys*. This study reveals additional characters that *Quasimodichthys piauhyensis* shares with *Hoyasotes tanyrhis*, *Lepidohyas microrhis* and *Neosemionotus puntanus*. Additionally, four distinct ontogenetic stages were observed in *Quasimodichthys piauhyensis*, juvenile (1 and 2), sub-adult, and adult.

1. Introduction

Many *Lepidotes* species were worldwide recorded during most parts of the twentieth century, even in the Brazilian sedimentary basins (Gallo and Brito, 2004; Gallo, 2005; Paiva et al., 2013, 2014; Cavin et al., 2013). Among the Brazilian "*Lepidotes*", "*L.*" *piauhyensis* (Roxo and Löfgren, 1936) is the best described one, especially because of the relatively great amount of well-preserved and articulated specimens (Paiva, 2017).

"*Lepidotes*" *piauhyensis* is recorded in the Upper Jurassic of the Parnaíba Basin, Northeastern of Brazil. Despite the brief description furnished by Roxo and Löfgren (1936), Silva Santos (1945) and Schaeffer (1947) made extensive morphological studies and stated that "*L.*" *piauhyensis* is a Jurassic taxon, related to "*L.*" *congolensis* Hussakof, 1917 (Upper Jurassic of the Congo Basin, Africa), due to the strong similarity in scale morphology.

This relationship was also noted by Gallo-da-Silva (1998) and Gallo (2005) that redescribed "*L.*" *piauhyensis* and established comparisons with older studies, beyond a discussion about the relationships among the others Brazilian and African *Lepidotes* species. Additionally, two autapomorphies were established to "*L.*" *piauhyensis*: presence of bony lamina on the ventral portion of anterior ceratohyal, and dorsal and ventral hypohyals.

Although "*L.*" *piauhyensis* had been considered a well-known Brazilian "*Lepidotes*" representative, López-Arbarello (2012) argued that *Lepidotes* genus should be restrict to the Lower Jurassic of Central Europe. Additionally, López-Arbarello (2012) noted that all the *Lepidotes* species recorded beyond this interval belong to other genera or need to be revised. Therefore, herein we revise "*L.*" *piauhyensis*, adding new morphological and ontogenetic data. These new information complement the Gallo (2005) analysis and provide a new comprehension about Brazilian paleoichthyofauna and change the "*L.*" *piauhyensis* nomenclature, named here with a new generic epithet, *Quasimodichtys*.

2. Material and methods

The studied holotype (DGM-297-P) and paratype (DGM-295-P) are housed at the Museu de Ciências da Terra – Serviço Geológico do Brasil (CPRM), Rio de Janeiro, Brazil. These are almost complete specimens, with details of skull and fins. Additional material, analyzed by Gallo-da-Silva (1998) and Gallo (2005), is housed at American Museum of Natural History and paleozoological collection of the da Universidade do Estado do Rio de Janeiro. Except for *Callipurbeckia tendaguruensis*, *Camerichthys lunae* and *Pliodetes nigeriensis*, all comparative material was directly examined by the authors.

2.1. Institutional abbreviations

AMNH: American Museum of Natural History, New York, United

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States; **BMNH/NHMUK PV:** Natural History Museum (Paleontology vertebrates), London, UK; **DGM/MCT:** Museu de Ciências da Terra – Serviço Geológico do Brasil, Rio de Janeiro, Brazil; **FPH:** Fundação Paleontológica Phoenix, Aracaju, Brazil; **MGM:** Museo GeoMinero, Instituto Geológico y Minero de España, Madrid, Spain; **MN:** Museu Nacional, Rio de Janeiro, Brazil; **MNHN:** Muséum national d'Histoire naturelle, Paris, France; **Pz.UERJ:** Coleção Paleozoológica da Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil.

2.2. Comparative material

Araripelepidotes temnurus **(**Agassiz, 1841**):** DGM 1104-P (holotype), AMNH 11809, AMNH 11810, AMNH 11811, AMNH 11812, AMNH 11813, AMNH 11814, AMNH 11815, AMNH 11831, AMNH 11832, AMNH 11833, AMNH 11834, AMNH 11835, AMNH 12645, AMNH 12716, AMNH 13116, Pz.UERJ 039, Pz.UERJ 040, Pz.UERJ 041, Pz.UERJ 042, Pz.UERJ 043, Pz.UERJ 047, Pz.UERJ 102; ***Callipurbeckia minor*** **(**Agassiz, 1833**):** BGS. GSM 27975 (lectotype), NHMUK PV P 1118, NHMUK PV P 2006, NHMUK PV P 4989, NHMUK PV P 5591, NHMUK PV P 29393, NHMUK PV P 36080, NHMUK PV P 36081, NHMUK PV P 41157; ***Callipurbeckia tendaguruensis*** (Arratia and Schultze, 1999): MB. f7040a-b (holotype), MB. f7041a-b, MB. f7042, MB. f7043, MB. f7044, MB. f7045, MB. f7046, MB. f7047; ***Camerichthys lunae*** Bérmudez-Rochas and Poyato-Ariza, 2015: MGM-108C (holotype); ***"Lepidotes" alagoensis*** Gallo, 2000: FPH 0120-V (holotype), Pz.UERJ 446, Pz. UERJ 466, Pz.UERJ 467, Pz.UERJ 468; ***"Lepidotes" dixseptiensis*** Silva Santos, 1963: DGM 675-P (holotype), DGM 425-P, DGM 1130-P, MN 4377-V, MN 4378/1-V, MN 4378/2-V, MN 4378/3-V; ***Lepidotes elvensis*** **(**Blainville, 1818**):** MNHN JRE-545 (holotype), AMNH 7537, BMNH P 32421, MNHN 10527, MNHN 10528; ***"Lepidotes" mawsoni*** Woodward, 1888: BMNH P 5534 a, b (holotype), BMNH P 410, BMNH P 412, BMNH P 2280, BMNH P 7114, BMNH P 7712, BMNH P 7713, BMNH P 7718, BMNH P 7340, BMNH P 7341, BMNH P 7342, BMNH P 7343, BMNH P 7344, DGM 426-P, MN 4361/1-V, MN 4361/2-V, MN 4361/3-V, MN 4361/4-V, MN 4362-V, MN 4363/1-V, MN 4363/2, MN 4363/3-V, MN 4363/4-V, MN 4364-V, MN 4365-V, MN 4366-V, MN 4367-V, MN 4368-V, MN 4369/1-V, MN 4369/2-V, MN 4369/3-V, MN 4369/4-V, MN 4370/1-V, MN 4370/2-V, MN 4370/3-V, MN 4371/1-V, MN 4371/2-V, MN 4371/3-V, MN 4371/4-V, MN 4371/5-V, MN 4372-V, MN 4373-V, MN 4374-V, MN 4375/1-V, MN 4375/2-V, MN 4375/3-V, MN 4375/4-V, MN 4376-V, MN 4377-V, MN 4379/1-V, MN 4379/2-V, MN 4379/3-V, MN 4380/1-V, MN 4380/2-V, MN 4380/3-V, MN 4380/4-V, MN 4381/1-V, MN 4381/2, MN 4381/3-V, MN 4381/4-V, MN 4381/5, MN 4381/6-V, MN 4381/7-V, MN 4381/8-V, MN 4381/9-V, MN 4381/10-V, MN 4386/1-V, MN 4386/2-V, MN 4387-V, MN 4388-V; ***"Lepidotes"oliveirai*** Silva Santos, 1969: DGM 952-P (sintypes), MCT 1450; ***"Lepidotes" roxoi*** Silva Santos, 1953: DGM 423-P (holotype), DGM 422-P, DGM 429-P, DGM 430-P, DGM 431-P, MN 4383-V, MN 4384-V, MN 4385-V, MN 4386/1-V, MN 4386/2-V, MN 4387-V, MN 4388-V; ***Lepidotes semiserratus*** Agassiz, 1833: NHMUK PV P 3528; ***"Lepidotes" souzai*** Woodward, 1908: BMNH P 10603 (holotype), BMNH P 10566, BMNH P 10601, DGM 424-P, MN 4382/1-V, MN 4382/2-V, MN 4391/1-V, MN 4391/2-V; ***"Lepidotes" wenzae*** Brito and Gallo, 2003**:** MNHN-BCE 387 (holotype), MN 4791-V (paratype); ***Paralepidotus ornatus*** Agassiz (1833): AMNH 1029; ***Pliodetes nigeriensis*** Wenz, 1999: MNHN.F.GDF 127 (holotype); ***Scheenstia laevis*** (Agassiz, 1833): MNHN.F.JRE 370; ***Scheenstia mantelli*** (Agassiz, 1833): NHMUK PV P 6943, NHMUK PV P 6933; ***Scheenstia maximus*** (Wagner, 1863): AMNH 13097, MNHN 1885-19, MNHN 1878-116B, MNHN 1878-7, MNHN 1868-15, MNHN.F.JRE 369, MNHN.F.JRE 375.

2.3. Anatomical nomenclature

The anatomic description present in this work was compared with Wenz (1967, 1999), Thies (1989), Gallo-da-Silva (1998), Gallo (2005), López-Arbarello (2012), Bérmudez-Rochas and Poyato-Ariza (2015) and López-Arbarello and Wencker (2016).

Ontogenetic study followed Cloutier (2010), beyond a comparison with *Paralepidotus ornatus* ontogenetic sequence (Tintori, 1996; Gallo et al., 2002).

2.4. Anatomical abbreviations

ACh, anterior ceratohyal; **Ang,** angular; **Ao,** antorbital; **Apal,** autopalatine; **Art,** articular; **asc.proc.Psph**, ascending process of the parasphenoid; **Br,** branchiostegal ray; **Cl,** cleithrum; **Dpal,** dermopalatine; **Dpt,** dermopterotic; **Dsph,** dermosphenotic; **D,** dentary; **Ecpt,** ectopterygoid; **Enpt,** endopterygoid; **Exc,** extrascapula; **fr,** fin ray; **Fr,** frontal; **fr.f.,** fringing fulcra; **Hm,** hyomandibula; **Hy,** hypohyal; **Io,** infraorbital; **io. s.c.**, infraorbital sensory canal; **Iop,** interopercle; **md.s.c.**, mandibular sensory canal; **Mpt,** metapterygoid; **Na,** nasal; **Op,** opercle; **Pa,** parietal; **Part,** prearticular; **Pcl,** postcleithrum; **PCh,** posterior ceratohyal; **Pmx**, premaxilla; **Pop,** preopercle; **pop.s.c.,** preopercular sensory canal; **Ps,** parasphenoid; **Pt,** posttemporal; **Qu,** quadrate; **Sang,** surangular; **Scl,** supracleithrum; **So,** supraorbital; **so.s.c.,** supraorbital sensory canal; **Sob,** suborbital; **Sop,** subopercle; **Vo,** vomer.

We also analyzed the phylogenetic relationships of the Brazilian "*Lepidotes*" among Ginglymodi. The matrix was built on Mesquite 3.10 (Maddison and Maddison, 2016) and analyzed on Tree Analysis using New Technology (TNT) 1.5 (Goloboff and Catalano, 2016). The data were submitted to parsimony algorithm Traditional Search, with randomic adition of 2000 replicates, 10 obtained trees on each step and TBR (Tree Bisection Reconnection).

The characters used on this study were the same of López-Arbarello (2012), updated on López-Arbarello and Wencker (2016). The characters list and the matrix are on the appendices (Appendix 1). The inner group was formed by 33 genera: (*Adrianaichthys* Meunier et al., 2016; *Araripelepidotes* Silva Santos, 1990; *Atractosteus* Rafinesque, 1820; *Callipurbeckia* López-Arbarello, 2012; *Camerichtys* Bérmudez-Rochas and Poyato-Ariza, 2015; *Dentilepisosteus* Grande, 2010; *Herreraichthys* Alvarado-Ortega et al., 2016; *Hoyasotes* Poyato-Ariza and Martın-Abad, 2016; *Isanichthys* Cavin and Suteethorn, 2006; *Kyphosichthys* Xu and Wu, 2012; *Lepidotes* Agassiz, 1832; *Lepidohyas* Poyato-Ariza and Martın-Abad, 2016; *Lepisosteus* Lacépède, 1803; *Lophionotus* Gibson, 2013; *Luoxionichthys* Wen et al., 2012; *Macrosemiocotzus* González-Rodíguez et al., 2004; *Macrosemius* Agassiz, 1833; *Macrosemimimus* Schröder et al., 2012; *Masillosteus* Micklich and Klappert, 2001; *Neosemionotus* Bocchino, 1973; *Notagogus* Agassiz, 1833; *Obaichthys* Wenz and Brito, 1992; *Occitanichthys* López-Arbarello and Wencker, 2016; *Oniichthys* Cavin and Brito, 2001; *Paralepidotus* Stolley, 1920; *Pliodetes Wenz, 1999*; *Propterus* Agassiz, 1833; *Sangiorgioichthys* Tintori and Lombardo, 2007; *Scheenstia* López-Arbarello and Sferco, 2011; *Semiolepis* Lombardo and Tintori, 2008; *Semionotus* Agassiz, 1832; *Thaiichthys* Cavin et al., 2013; *Tlayuamichin* López-Arbarello and Alvarado-Ortega, 2011). The chosen outgroup was *Perleidus sinensis*. "*L.*" *dixseptiensis*, "*L.*" *mawsoni* e "*L.*" *oliveirai* were excluded of phylogenetic analyzes, because they presented more than 50% of missing data on the firstly catalogued bibliographic data, according Wilkinson and Benton (1996) methodology.

3. Geological setting

All the analyzed specimens of this study were collected in Fazenda Muzinho, Pastos Bons Formation (Piauí State, Brazil). The strata of Pastos Bons Formation (Fig. 1) are composed of green sandstones and grey to green siltstones (Vaz et al., 2007).

These sediments are fluvial-lacustrine, deposited in an arid and seasonal paleoenvironment during the Late Jurassic (Oxfordian) (Vaz et al., 2007; Petra and Gallo, 2012). Additionally, Petra (2006) and Petra and Gallo (2012) argued that the Fazenda Muzinho could be related to a saline lake, in which the water temperature could vary from