



The Lissamphibian Fossil Record of South America

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Received: 28 September 2021 / Revised: 5 April 2022 / Accepted: 12 April 2022
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Abstract

Anurans, along with urodeles and caecilians are the extant representatives of the clade Lissamphibia. Nowadays, lissamphibians are widely distributed in all continents, except Antarctica, but are particularly diversified in South America, where almost 3,000 species are found. This huge biodiversity is directly related to the complex geologic history of South America, which includes key events like the Gondwanan breakup, its isolation during parts of Mesozoic and Cenozoic, the Andean uplift, and the formation of the Panamá isthmus. Here, we present the most comprehensive bibliographic review of fossil lissamphibians from South America to date, covering unpublished (e.g. theses and dissertations) and published data (i.e. peer-reviewed scientific papers, book chapters, monographs, and conferences abstracts). We use a mixed approach, both qualitative (with brief comments on each taxon and specimen) and quantitative (including scientometric parameters). Compared to the latest published reviews with similar scope, our results indicate that approximately 85.4% of the records correspond to specimens new to science or older ones that have been revisited. These materials come from 164 different fossil-bearing localities, spread over eight of the twelve South American countries, and range from the Early Jurassic to the Quaternary. In total, we compile 273 records, mostly anurans (~97.6%), followed by indeterminate caecilians (~1.4%) and urodeles (~1%). Additionally, we discuss issues directly related to those fossil occurrences, such as their temporal and geographic range, as well as the presence of putative biological and taphonomic biases. Finally, we also provide calibration constraints for several anuran taxa.

Keywords Anura · Caudata · Gymnophiona · Vertebrate · Taphonomy · Fossil Calibration

Introduction

General Remarks

Among numerous taxa of non-amniotic tetrapods, Lissamphibia are the only one that still contains extant representatives. With approximately 8,000 modern species, it encompasses four subgroups (i.e. Anura, Urodela, Gymnophiona, and Albanerpetontidae, the last known only by fossil specimens) (Gardner and Rage 2016; Frost 2021). Lissamphibians emerged during the Permian (Marjanović and Laurin 2008; Hime et al. 2021), although some authors

consider an even older origin (see San Mauro 2010). The lissamphibian fossil record is relatively sparse but includes some remarkably well-preserved specimens, whose study allowed significant advances in the understanding of evolution, ontogeny, systematics, biogeography, and many other aspects related to lissamphibian biology, with a direct impact even on the knowledge of modern taxa (Estes and Reig 1973; Schoch 2014).

In South America, lissamphibians are particularly diversified. Almost 3,000 species are known, which corresponds to around 37.5% of the global diversity of lissamphibians (AmphibiaWeb 2021; Frost 2021). Most of them are anurans,

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although the relative quantity of gymnophionans is also considerable (AmphibiaWeb 2021; Frost 2021). Urodeles, however, are quite uncommon, whereas fossils of albanerpetontids are unknown so far (Gardner and Böhme 2008). Based on the living species and the fossil records, it is possible to infer that the palaeodiversity of Lissamphibia in South America is even richer than the observed in extant species (Fara 2004). However, clues for this evolutionary history are limited to a few specimens, mostly anurans (Sanchiz 1998) and some isolated records of caecilians and urodeles (e.g. Gayet et al. 2001). This scarcity is mainly due to the fragmentary and delicate nature of bones of lissamphibians (Wang and Gao 2011), but also related to the climatic conditions of moist environments occupied by these animals, which are susceptible to a high degree of decay and bioerosion of organic matter (Sanchiz and Roček 1996; Davis 1997; Trueman and Martill 2002; Gardner and Walker 2009), hampering fossil diagenesis and preservation.

South America has experienced a series of complex geological and environmental events (Ortiz-Jaureguizar and Cladera 2006; Rangel et al. 2018) that turned it into one of the most climatically and biologically diverse continents on the planet (Fig. 1). The geological history of this continent is deeply related to the other Gondwanan landmasses, to the orogeny of Andes, and to marine transgressions and regressions (Hernández et al. 2005; Hoom et al. 2010). Such geological events are linked to the evolutionary history of amphibians, which cannot be fully understood if studied separately. Whereas South America currently constitutes a world hotspot of Lissamphibia diversity (Jetz and Pyron 2018), their fossils are poorly represented, corresponding to less than 1% of the Lissamphibia's global fossil record (world fossil record compiled from Paleobiology Database 2021).

Many works have compiled the fossil record of lissamphibians for different regions around the world (see Table 1 for a summary of these studies). The latest reviews of the fossil record of South American lissamphibians were published over the past half-century (e.g. Estes and Reig 1973; Báez and Basso 1996; Báez 2000; Cione and Báez 2007), but none of these previous works are thorough reviews of the South America Lissamphibia fossil record, in part, because those reviews were limited to anurans. Beyond that, the knowledge concerning this subject continues to be substantially updated and, in some cases, revised. Compared to these old reviews, our estimates indicate that 85.4% of the records compiled here concentrate on materials new to science or older ones that were revisited in the 21st Century. Here, we provide the first comprehensive bibliographic review focused on the lissamphibian fossils from South America, and we discuss the evolutionary history of this taxon on the continent, the putative biological and taphonomic biases related to the preservation of such remains, and present useful fossils as calibration-points for divergence-time estimates.

Brief Research History

The earliest descriptions concerning lissamphibian fossils from South America are of frogs, dating from the second half of the 19th Century (i.e. Günther 1859; Liais 1872; Ameghino 1899). In the pioneering work of Günther (1859) fossil skull and limb bones of *Ceratophrys cornuta* were described, both from the Pleistocene of Lagoa Santa locality, Minas Gerais, Brazil. Liais (1872) mentioned an enigmatic fossil representative of *Pipa* sp. from the Late Pleistocene–early Holocene of Vale do Rio das Velhas locality, Minas Gerais, Brazil. This material constitutes a skull; however, it was never described nor illustrated, and is currently lost (Delfino and Sánchez-Vilagra 2018). Ameghino (1899) described *Saniwa australis* from the lower Miocene Sarmiento Formation, Gran Barranca locality, Chubut, Argentina, and also *Ceratophrys prisca* from the lower Pliocene Monte Hermoso Formation, Monte Hermoso, Buenos Aires, Argentina.

From the 20th Century onwards, several works were published covering the description of new fossil frogs and other aspects of their palaeobiology (Sanchiz 1998, and references therein). The morphological descriptions of Jurassic stem taxa, such as *Vieraella* and *Notobatrachus* (Casamiquela, 1961), allowed a better understanding of the evolution of the anuran bauplan. Eventually, these and other fossil specimens were coded and included in phylogenies, and the knowledge of anuran palaeontology began to be integrated into the paradigm of phylogenetic systematics (e.g. Báez and Basso 1996).

Regarding caecilian remains, the first valid species ever described based on a fossil specimen was *Apodops pricei* Estes and Wake, 1972, based on a small and fragmentary pre-cloacal vertebra found in Brazil. For decades, this was the only known caecilian fossil. Other isolated vertebrae were also found in Bolivia and Colombia, but they were not assigned to any particular species, only to *Gymnophiona* indet. (Rage 1991; Hecht and LaDuke 1997; Gayet et al. 2001). These records, despite being sparse, show the potential of the region for new findings. However, since then, no new materials assigned to caecilians have been described from the continent.

Considering salamanders, a taxon in which even the modern representatives are uncommon in the continent, their fossil record is even more sparse and limited to a single species, *Noterpeton bolivianum* Rage et al., 1993, known from isolated vertebrae found in the Late Cretaceous and early Paleocene of Bolivia (Rage et al. 1993; Gayet et al. 2001). Since these works, no new material assigned to South American urodeles has been described.

In the 21st Century, the number of published descriptions of fossil lissamphibians increased considerably (69% of the total records are new descriptions and approximately 16.4% are revisions). This was achieved due to the availability of new technologies, e.g. μ CT-Scanning, that allows the recognition

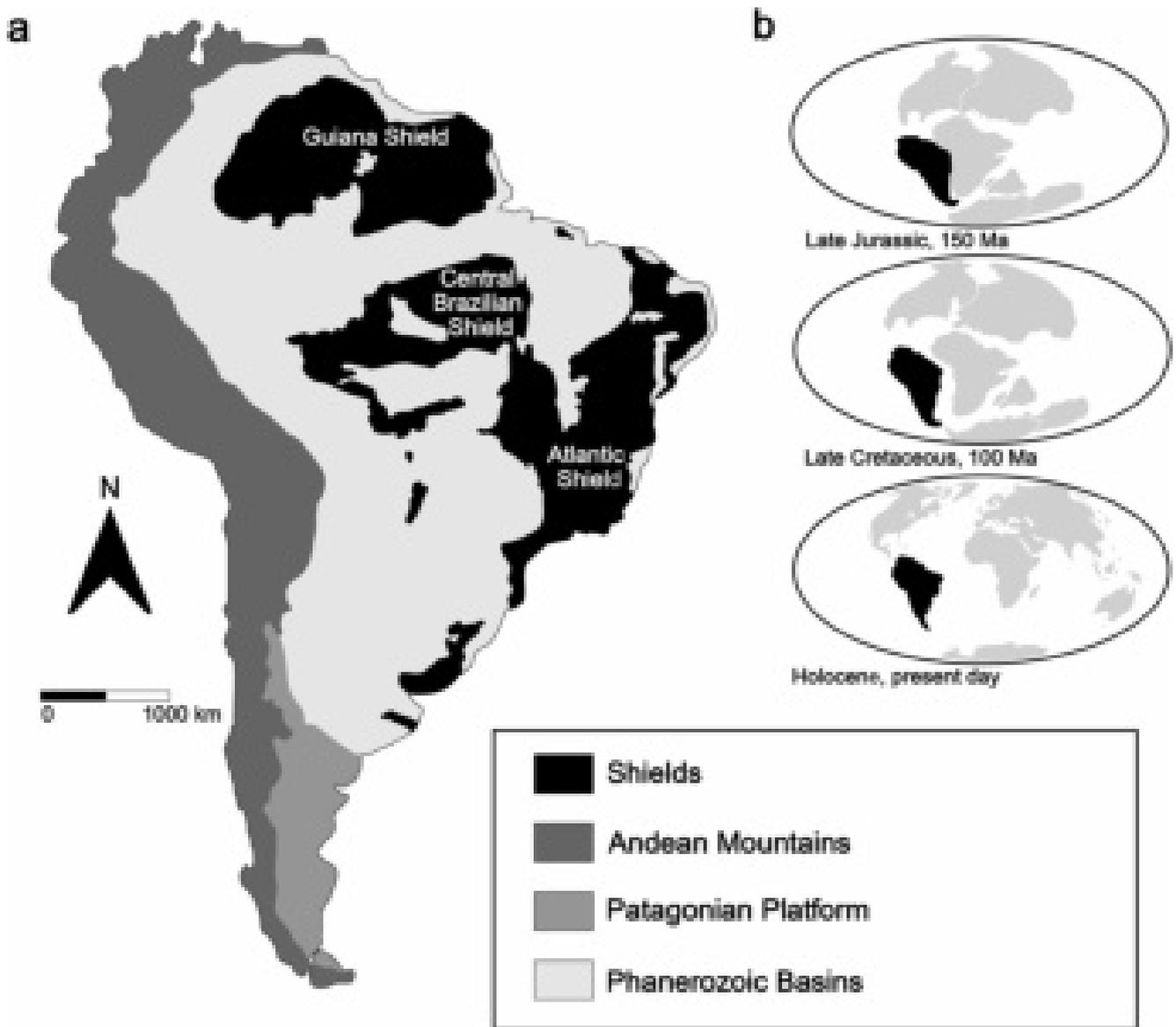


Fig. 1 Simplified geological map of South America. **a** Major South American geological units and features; **b** Position of South America at different intervals in the history of Earth. Modified from de Alkmim (2015) and Britannica (2021)

of the whole anatomy of the fossil without damaging it (Matthews and du Plessis 2016), and the necessity to understand the evolution of lissamphibians in South America, a world hotspot for extant species, through the fossil record.

Geological and Palaeogeographical History of South America

South America was formed after the complex breakup of the southern landmasses of Pangea (i.e. Gondwana) and detached from the African landmass around 100 Ma (Veevers 2004; Granot and Dymant 2015; Lomolino et al. 2017). After the separation from Africa, South America remained attached to Antarctica until 35 Ma, with South America acting as a centre of diversification during the Cretaceous-Paleogene (Poole and

Cantrill 2006). However, after the opening of the Drake Passage between the Antarctic Peninsula and Tierra del Fuego (Barker and Burrell 1977; Lodolo et al. 2006), South America remained isolated from any other landmasses until the uprising of the isthmus of Panama, which bridged South America to Central and North America several times between 23–2.7 Ma (Hoorn et al. 2010; Bacon et al. 2015) and allowed the exchange of organisms between these continents (Antonelli et al. 2018).

After the splitting of South America from Africa, the former has undergone some relevant geological events (e.g. orogeny of the Andes, denudation and rifting of its southeastern region), and climatic events (e.g. sea-level rise and fall forming marine transgressions and regressions, respectively) that shaped its topography, shores, hydrographic basins, etc. (Donato et al. 2003; Hoorn

Table 1 List of published reviews about the lissamphibian fossil record

Work	Taxon	Geographic scope	Defined time interval
Estes (1965)	Caudata	Worldwide	No
Lynch (1971)	Anura	North, Central and South America	No
Spinar (1972)	Anura	Central Europe	Yes (Paleogene)
Estes & Reig (1973)	Anura	Worldwide	No
Báez & Gasparini (1977)	Anura	South America	Yes (Cenozoic)
Báez & Gasparini (1979)	Anura	South America	No
Estes (1981)	Caudata and Gymnophiona	Worldwide	No
Báez (1986)	Anura	Argentina	Yes (Tertiary)
Roček (1994)	Urodela	Europe	No
Van Dijk (1995)	Lissamphibia	Africa	No
Báez & Basso (1996)	Anura	South America	Yes (Jurassic)
Sanchiz (1998)	Salientia	Worldwide	No
Báez (2000)	Anura	South America	Yes (Tertiary)
Milner 2000	Caudata and Albanerpetontidae	Worldwide	Yes (Mesozoic and Tertiary)
Roček (2000)	Anura	Worldwide	Yes (Mesozoic)
Roček & Rage (2000)	Anura	Worldwide, except South America	Yes (Tertiary)
Holman (2003)	Anura	North America	No
Holman (2006)	Urodela	North America	No
Cione & Báez (2007)	Anura	South America	Yes (Cenozoic)
Gardner & Böhme (2008)	Albanerpetontidae	Worldwide	No
Dong et al. (2013)	Anura	China	Early Cretaceous
Skutschas (2013)	Caudata and Albanerpetontidae	Middle Asia, Kazakhstan, and Siberia	Mesozoic
Roček (2013)	Anura	Laurasia	Yes (Mesozoic and Tertiary)
Gao et al. (2013)	Urodela	China	Yes (Jurassic to Cretaceous)
Gardner & DeMar (2013)	Lissamphibia	North America	Mesozoic and Paleocene
Schoch (2014)	Lissamphibia	Worldwide	No
Gardner (2016)	Anura (only tadpoles)	Worldwide	No
Gardner & Rage (2016)	Lissamphibia	Africa, Madagascar, and Arabia	No
Moreira (2016)	Anura	Worldwide	Mesozoic
Rage et al. (2020)	Lissamphibia	India	Yes (Upper Cretaceous)
Santos et al. (2020)	Gymnophiona	Worldwide	No
Gómez & Turazzini (2021)	Ceratophryidae	South America	No
Delfino & Georgalis 2021	Urodela and Anura	Greece	No

et al. 2013; Malumian and Nájuez 2011; Souza et al. 2019, 2021). Regions with elevated topographies present an important role in species diversification (Ruggiero and Hawkins 2008; Antonelli et al. 2009; Rangel et al. 2018). Mountain ranges can favour allopatric (Janzen 1967; Antonelli et al. 2009), parapatric, and sympatric speciation (Vences and Wake 2007). The uplift of the Andes Mountain complex occurred during the Neogene (~23–2.5 Ma), favoured biological diversification (e.g. Ruggiero and Hawkins 2008; Antonelli et al. 2009; Rangel et al. 2018), and is recognised as an important source for the whole South America biodiversity (Antonelli et al. 2009; Hoorn et al. 2013; Rangel et al. 2018). The Andean uplift, also played an important role in the formation of the South American dry diagonal (Hoorn et al. 2010), comprising the Caatinga, Cerrado, and Chaco

biomes (Fig. S1 in Supplementary Data 1; Vanzolini 1963; Ab'Saber 1977).

The Atlantic Forest Domain was shaped by a complex geological process that occurred between 130 and 70 Ma and resulted in a fragmented mountain range (i.e. Serra do Mar and Serra da Mantiqueira; Souza et al. 2019, 2021). During the southeastern continental rift event, (~70–55 Ma), the mountain range was fragmented, forming the Serra do Mar and Serra da Mantiqueira (Salgado et al. 2016). Sediments eroded off these mountains, creating some fossiliferous Paleogene basins (e.g. Itaboraí Basin, Aiuruoca Basin, Taubaté Basin; Souza et al. 2019, 2021). Another important factor for explaining species richness in South America is the glaciations events, which were unequally distributed across the continent, and created climatic refuges that

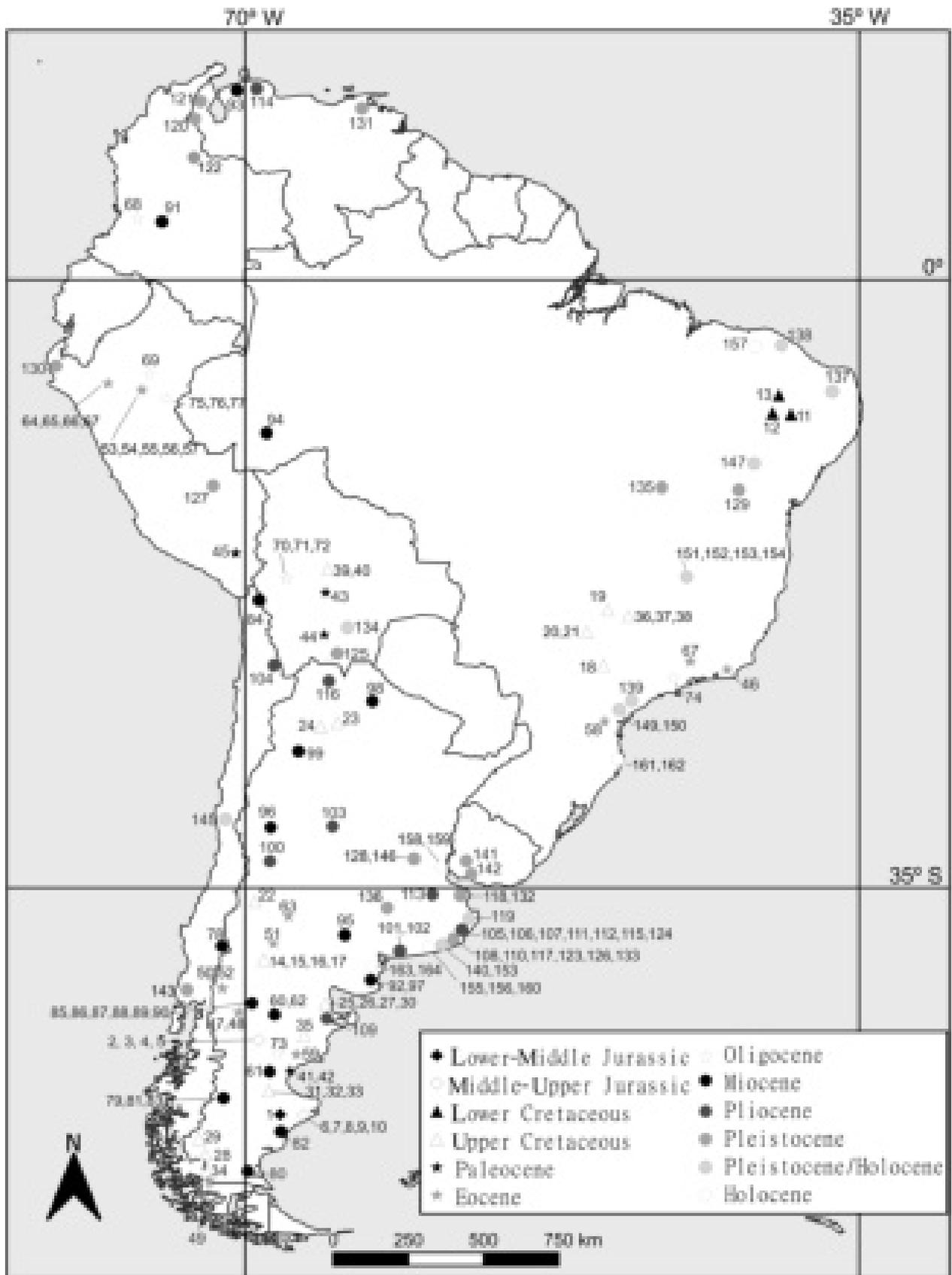


Fig. 2 Map of South America showing localities (numbered according to our locality/taxonomic accounts section) that have yielded lissamphibian fossils

were somewhat stable in certain regions (Carnaval and Moritz 2008; Carnaval et al. 2009; Lomolino et al. 2017).

Material and Methods

In this survey, we aim to review the fossil record of Lissamphibia from South America and explore the correlated information of those records. This is a bibliographic review, and thus our goals do not encompass the revision of systematic assignments or morphological descriptions of all records, although in some cases we have adopted a more conservative approach than the original works, in order to minimise potential biases in our quantitative data analysis (e.g. the earlier records assigned to *Leptodactylidae lato sensu*, a taxon well-known for uniting a wide assemblage of distinct species, are treated here as *Neobatrachia indet.*) All of these modifications are indicated throughout the text and are also summarised in Supplementary Data 2. We present the status of the specimens (e.g. holotype, paratype), mention the remains preserved, and the institutional number when those data were reported. We thoroughly surveyed both published (i.e. peer-reviewed scientific papers, book chapters, and conference abstracts) and unpublished (i.e. undergraduate, MSc, and PhD theses and dissertations, field notes, and correspondence) fossil records of South American lissamphibians up to January 2022. But we may have missed some records mentioned in more obscure publications (e.g. conference abstracts from regional/local events). We follow the original descriptions and taxonomic assignments of all authors but try to include additional and/or conflicting information from the literature where we consider this necessary. The standardised acronyms for institutional resource collections are listed in our Appendix and follow those presented by Sabaj (2019, 2020). Regarding the anatomical terminology of frogs, we follow Sanchiz (1998).

Remarks on the fossil-bearing localities

We report the occurrence of lissamphibian remains from 164 localities in South America (Fig. 2). Following a similar approach used in the review of Gardner and Rage (2016), here the term “locality” refers to a specific outcrop or deposit. We provide the inferred depositional environment for each locality included in our review. However, due to the limited knowledge of the palaeoenvironmental conditions for most of them, such information may refer to the stratigraphic unit as a whole. Furthermore, as the processes related to the deposition of sediments can vary over time, the same unit may have different palaeoenvironments. Even so, due to the importance of this information for different topics of our discussion (i.e. palaeobiogeographic and palaeoecological aspects, and possible taphonomic biases of the fossil record), we chose to still present this data similarly to other past works (e.g. Van Dijk

1995; Gardner and Rage, 2016). We employ the extent-of-occurrence polygons provided by the International Union for Conservation of Nature (IUCN 2021) in Quantum Gis (2021) version 3.20.1 to generate the maps with the distribution of extant and extinct specimens.

Regarding the localities in the Araripe Basin, the records from this unit are divided into three different localities in our review. The Triunfo and Pedra Branca mines are the two well-known fossiliferous localities, whereas Locality 13 (referred to simply as “Undetermined source locality”) was created for our review to include all records without more specific origin data. It is worth noting that the fossils from the Araripe Basin are often targeted by international fossil trafficking (Cisneros et al. 2021), which is one of the main reasons for the lack of accuracy of their origin.

Some fossil-bearing localities from the Pleistocene-Holocene of South America are known as “natural tanks”, a kind of deposit typically found in arid regions of the continent (e.g. Brazilian Northeast, see Araújo-Júnior et al. 2013). Sediment deposition in tanks occurred under a debris-flow regime, in which a natural depression develops at the base of a rock outcrop due to physical-chemical weathering (Paulacouto 1980; Araújo-Júnior et al. 2015). Deposits of similar origin are named differently around the world (e.g. “gnammas”, see Domínguez-Villar et al. 2009).

We report the records of Lissamphibia preventing the influence of richer deposits, such as *Konzentrat-Lagerstätten* and *Konservat-Lagerstätten* (e.g. Aiuruoca Basin, Candeleros Formation). That was made based on the following premises: we computed as a single record any species or taxa represented by more than one specimen recorded in a given locality. For example, instead of computing 300 specimens for *Saltenia ibanezi* from Departamento De La Viña, Argentina (Báez 1981), and 840 undescribed specimens of *Calyptocephalella* sp. from Tagua-Tagua, Chile (Labarca et al. 2020) we report a single exemplar specimen for each taxon. In the Results, we provide separate accounts for each taxon recorded from each locality.

Remarks on stratigraphic and divergence-time estimates

In general, we rely on the age estimates and lithostratigraphic information from the original studies, except in cases where more recent and updated data are available. As only a few fossil-bearing sites in South America were radiometrically dated so far, some records were assigned only to a wide time range (e.g. Oligocene, Late Cretaceous). We also decided to standardize the age of the fossils following the International Chronostratigraphic Chart (Cohen et al. 2021) instead of the South American land mammal age (SALMA), in order to use a more widespread and familiar time scale. For divergence-time estimates, we use the data compiled in TimeTree (Kumar

et al. 2017), and other references not included there (e.g. Jetz and Pyron 2018; Hime et al. 2021).

Results

List of Fossil Lissamphibians from South America

Jurassic

Locality 1: Estancia Roca Blanca, Roca Blanca Formation, Santa Cruz, Argentina.

Age and depositional environment: Early Jurassic, Sinemurian-Toarcian (Herbst 1965); fluvial floodplains with the input of pyroclastic elements (Panza and Haller 2002).

Taxon and material: The holotype (PVL 2488) of *Vieraella herbsti* was described and illustrated by Reig (1961), whereas the counterpart (MLP 64-VII-15-1) was later recovered in the same outcrop, and the species was revised (Casamiquela 1965). Other works also commented on its anatomical interpretation (e.g. Hecht 1963; Estes and Reig 1973; Roček 2000). The holotype comprises the paired frontoparietals, quadratojugal, squamosal, nasals, vomer, maxilla with teeth, mandible, pterygoid, parasphenoid, sphenethmoid, hyoid apparatus, nine presacral vertebrae, ribs in the third and fourth vertebrae, clavicles, scapula, cleithrum, coracoid, humerus, fused radioulna, seven carpals, manus tetradactyl, femur, fused tibiofibula, free tibiale and fibulare. *Vieraella herbsti* was included in phylogenetic analyses and recovered as the most basal member of Anura (Báez and Basso 1996; Dong et al. 2013; Wang et al. 2018), and in a polytomy with *Prosalirus*, *Notobatrachus*, and crown-group Anura (Chen et al. 2016).

Locality 2: Zitarrosa, Las Chacritas Member, Cañadón Asfalto Formation, Chubut, Argentina.

Age and depositional environment: Early Jurassic, Toarcian (Pol et al. 2020); lacustrine to fluvial, with volcanic influence (Cabaleri and Benavente 2013).

Taxon and material: The holotype (MPEF 3006) of *Notobatrachus reigi* is composed of bone impressions of the skeleton (sculptured dermal skull bones, maxilla, nasal, frontoparietal, squamosal, columella, vomer, sphenethmoid, parasphenoid, nine presacral vertebrae, free ribs on vertebrae 2-5, clavicle, humerus, radioulna, carpus, femur, unfused tibiale and fibulare, and ilium). Báez and Nicoli (2008) described and illustrated the specimen.

Locality 3: Cerro Cóndor, Cañadón Asfalto Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 2.

Taxon and material: Báez and Gómez (2016) mentioned *Notobatrachus*-like frog remains from a new locality but did not provide further details about the material recovered.

Locality 4: Canela, Cañadón Asfalto Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 2.

Taxon and material: Turazzini et al. (2017) mentioned in a conference abstract the record of anuran remains (the kind of material was not detailed).

Locality 5: Queso Rallado, Cañadón Asfalto Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 2.

Taxon and material: Many *Notobatrachus*-like frog remains were briefly mentioned (the kind of material was not detailed; Báez and Gómez 2016; Turazzini et al. 2017).

Locality 6: Estancia la Matilde, La Matilde Formation, Bahía Laura Group, Santa Cruz, Argentina.

Age and depositional environment: Middle to Late Jurassic, Aalenian-Oxfordian, ~160-172 Ma (Stipanovic and Bonetti 1970; de Barrio et al. 1999); floodplains and water bodies, near an active volcanic system (Melchor et al. 2004).

Taxon and material: *Notobatrachus degiustoi* (holotype MACN 177720), comprising a complete skeleton, was initially described by Reig in Stipanovic and Reig (1955). Later, Reig detailed the anatomy of the species based on multiple specimens and suggested that *Notobatrachus degiustoi* was related to *Ascaphus* and *Leiopelma* in Stipanovic and Reig (1957). Other remains referred to as *Notobatrachus degiustoi* were also recovered in the same locality: CPBA-V 14001-14007; MACN 17721-17727; MACN 18658-18669; MACN 1867-18673; MACN 18675; MACN 18677; MLP 54-XI-18-1; 62-XII-1-1 to 4; MPEF-PV-1250-1266; PVL 2196, 2194; CTES-Pz 5739-5746. Later, the ontogenetic and intraspecific variation of *N. degiustoi* was described by Báez and Nicoli (2004a) based on about 100 specimens from distinct localities. Several works re-evaluated the anatomy of *N. degiustoi* (Casamiquela 1961; Estes and Reig 1973; Báez and Basso 1996; Báez and Nicoli 2004a). Báez and Basso (1996) recovered *Notobatrachus* as sister to all extant species of Anura. In the phylogeny of Chen et al. (2016), it was nested in a polytomy along with other stem-taxa and the crown-group Anura, but in other works it was also recovered as sister to *Prosalirus* (Dong et al. 2013; Wang et al. 2018).

Locality 7: Estancia El Malacara, La Matilde Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 6.

Taxon and material: *Notobatrachus*-like specimen (CPBA-V 14024) was recovered in this outcrop and was recognised as a juvenile (Báez and Nicoli 2004a).

Locality 8: 20 km north of Estancia La Trabajosa, La Matilde Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 6.

Taxon and material: *Notobatrachus*-like frog remains (MLP 55-VI-1-1 to 4; the kind of material was not detailed) were mentioned by Báez and Nicoli (2004a).

Locality 9: Laguna del Molino, La Matilde Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 6.

Taxon and material: *Notobatrachus*-like frog remains (MACN 19178; CTES-Pz 5747-5760; 7311-7318; MLP 89-XI-27-1 to 19; PVL 250, 261; the kind of material was not detailed) were mentioned by Báez and Nicoli (2004a).

Locality 10: Estancia El Puma, La Matilde Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 6.

Taxon and material: De Giusto et al. (1980) mentioned frog remains (the kind of material was not detailed). Later, Báez and Nicoli (2004a) stated those specimens were lost.

Cretaceous

Locality 11: Triunfo Mine, Nova Olinda Member, Crato Formation, Araripe Basin, Ceará, Brazil.

Age and depositional environment: Early Cretaceous, late Aptian, ~113 Ma (Heimhofer and Hochuli 2010); lacustrine and fluvio-deltaic (Assine et al. 2014).

Taxon and material: The unpublished specimen UFC-NO 004v was described and illustrated in the MSc thesis of Leite (2013) and referred to as an indeterminate ?Leptodactylidae. The material comprises an almost complete skeleton, preserved in ventral view, and with the vertebrae hidden by the rock matrix.

Locality 12: Pedra Branca Mine, Nova Olinda, Crato Formation, Araripe Basin, Ceará, Brazil.

Age and depositional environment: See the entry of locality 11.

Taxon and materials: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Kururubatrachus gondwanicus* (holotype UFRJ-DG 08) was described, illustrated, and phylogenetically placed as an extinct representative of Neobatrachia (Agnolin et al. 2020). *Kururubatrachus gondwanicus* is represented by a nearly complete skeleton with its left side exposed.
- 2) Taxon B— Carvalho et al. (2019) described and illustrated the holotype of *Cratopipa novaolindensis* (UFRJ-DG 05 A) based on an almost complete specimen. *Cr. novaolindensis* was phylogenetically nested with Pipimorpha, as sister to the group with *Saltenia*, *Shelania*, and *Kuruleufenia* (Carvalho et al. 2019). The holotype was later redescribed (Báez et al. 2021), and a new diagnosis for the species was proposed, correcting

misinterpretation in the original description. Báez et al. (2021) also revised character-states scores of *Cratopipa*, *Saltenia*, *Shelania*, and *Kuruleufenia*.

Locality 13: Undetermined source locality(ies), Crato Formation, Araripe Basin, Ceará, Brazil.

Age and depositional environment: See the entry of locality 11.

Taxon and materials: 13 anuran taxa have been reported, as follows:

- 1) Taxon A— Leal and Brito (2006) described the species *Arariphrynus placidoi* based on the holotype (MPSC-Am 893), a complete skeleton, and the paratypes (890, 891, 892, 894, and 138). *A. placidoi* was proposed as belonging to Leptodactylidae (Leal and Brito 2006), but Báez et al. (2009) reviewed these specimens and concluded that they belonged to more than one taxon and redescribed the anatomy of *A. placidoi*. Furthermore, the species was coded in phylogenetic analyses and recovered as belonging to Ceratophryidae (Báez et al. 2009), Natatanura (Laloy et al. 2013); Pelodyadidae (Evans et al. 2014), and Hyperoliidae (Báez and Gómez 2018). The specimen MPSC-Ap 894 was neither described nor illustrated. MPSC-Ap 894 was collected near the municipality of Crato (Báez et al. 2009).
- 2) Taxon B— Leal and Brito (2006) mentioned the specimen MPSC-Ap 890 (skull, fore, and hindlimbs) as a paratype of *A. placidoi*. But, Báez et al. (2009) erected a new species, *Eurycephalella alcinae*, and described and illustrated its holotype (MPSC-Ap 890). *E. alcinae* was coded in phylogenetic analyses and recovered as belonging to Ceratophryidae (Báez et al. 2009), and Calyptocephalellidae (Báez and Gómez 2018). Here, we take a conservative approach and consider *E. alcinae* as a putative Australobatrachia. MPSC-Ap 890 was collected near the municipality of Crato (Báez et al. 2009).
- 3) Taxon C— MPSC-Ap 891 was mentioned in Leal and Brito (2006) as a paratype of *A. placidoi*. Later, Báez et al., (2009) described it as a new species, *Cratia gracilis*. MPSC-Ap 891 (holotype) is an articulated postmetamorphic specimen, but possibly a juvenile. *Cratia gracilis* was recovered as sister of Neobatrachia (Báez et al. 2009), to Eleutherodactylidae or nested within Neobatrachia (Báez and Gómez 2018), and to Panpipidae Shelanidae (Carvalho et al. 2019). MPSC-Ap 891 was collected near the municipality of Crato (Báez et al. 2009).
- 4) Taxon D— Pipimorpha indet. MPSC-Am 892 was mentioned in Leal and Brito (2006), and Báez et al. (2009). The specimen was later described and illustrated by Báez et al. (2021). Pipimorpha indet. MPSC-Am 892

is poorly preserved and exposed in ventral view, presenting pterygoid, maxilla, mandible, humerus, metacarpals, phalanges, ilium, femur, tibiofibula, tibiale-fibulare, tarsals, and metatarsals.

- 5) Taxon E— Leal et al. (2007) suggested the specimen MPSC-Ap 1189 as belonged to Pipoidea. This assertion was doubted later, due to the absence of synapomorphies that support the affinities of MPSC-Ap 1189 with pipoids (Báez et al. 2009). The specimen was neither described nor illustrated. MPSC-Ap 1189 was collected near the municipality of Crato (Báez et al. 2009).
- 6) Taxon F— The Pipimorpha MPSC-Am 138 is poorly preserved as part and counterpart. The material was mentioned in Leal and Brito (2006) and Báez et al. (2009). Báez et al. (2021) described and illustrated this specimen. The bones presented in the fossil are frontoparietal, nasal, parasphenoid, tympano-squamosal, pterygoid, sphenethmoid, septum nasi, stapes, maxilla, mandible, cleithrum, coracoid, ilium, ischia, femur, metatarsal, pubis, tibiofibula, and tibiale-fibulare. MPSC-Am 138 was collected near the municipality of Crato (Báez et al. 2009).
- 7) Taxon G— MN 7073-V (skull, forelimbs, and metatarsals preserved as impressions and ischium, ilium, urostyle, femur, tibiofibula, tibiale-fibulare as fragments) was described and illustrated in the MSc thesis of Magalhães (2018). This specimen was coded in the matrix of Báez et al. (2009) and suggested as belonging to Ranidae. In our opinion, this assignment is unwarranted, due to the deficiency of explanation, and the most conservative position of this material is Neobatrachia indet. MN 7073-V was collected near the municipality of Crato (Báez et al. 2009).
- 8) Taxon H— Anura indet. MN 7072-V (fragmentary skull, and postcranial remains) was described and illustrated in the undergraduate thesis of Magalhães (2012). MN 7072-V was collected near the municipality of Crato (Báez et al. 2009).
- 9) Taxon I— GP/2E-9497 (an almost complete skeleton) was briefly mentioned in a conference abstract (Prado et al. 2019). Later, GP/2E-9497 (holotype) was described and illustrated as *Primaevorana cratensis* and was recovered as nested within Neobatrachia (Moura et al. 2021). The type locality is undetermined, but Moura et al. (2021) recognised that the material was collected near the municipality of Nova Olinda.
- 10) Taxon J—The unpublished Xenonura indet. (MPSC-Am 2098) includes parasphenoid, quadratojugal, squamosal, maxilla, mandible, vomers, frontoparietal, prootic, incomplete scapular, and pelvic girdles, femur, tibiofibula, tibiale-fibulare, tarsals, metatarsals, and phalanges exposed in ventral view. The material was described and illustrated in the PhD dissertation of Moreira (2016). He coded the specimen MPSC-Am 2098 in the matrix of Henrici et al. (2013) and phylogenetically placed it as sister to *Rhinophrynus dorsalis*. The type locality is undetermined, but Moreira (2016) stated it was collected between the municipalities of Santana do Cariri and Nova Olinda.
- 11) Taxon K— The undescribed Anura indet. was briefly mentioned in Kellner and Campos (1986). The specimen is composed of part and counterpart, with a fragmentary skull, maxillary arch with teeth, clavicles, pelvic girdle, and hindlimbs with phalanges. Anura indet. was figured in Maisey (1991) and mentioned in Báez (1991a). There is no information on which collection houses the specimen. The source locality is undetermined.
- 12) Taxon L— The SMNK unnumbered Anura indet. is an almost complete skeleton that was briefly mentioned and figured by Leal et al. (2007). They commented that some unidentified fragmentary materials were preserved in association with this Anura indet., in the abdominal region, and interpreted it as a putative fossilised stomach content. This undescribed specimen is housed at the State Museum of Natural History Karlsruhe in Germany. We tried to contact the curator, but we could not obtain further information on this specimen. The source locality is undetermined.
- 13) Taxon M— The undescribed Anura indet. MPSC Am 94 (the kind of material was not detailed) was mentioned in a conference abstract by Silva et al. (2019). The source locality is undetermined.

Locality 14: Villa El Chocon, Candeleros Formation, Neuquén Basin, Neuquén, Argentina.

Age and depositional environment: Late Cretaceous, Cenomanian, 102 ± 2 Ma, according to Di Giulio et al. (2012); braided and meandering rivers, and swamps (Legarreta and Uliana 1998).

Taxon and material: Pipimorpha indet. (MACN Pv N96) was described and illustrated (Báez et al. 2007). The specimen is preserved as part and counterpart (including frontoparietal, parasphenoid, pterygoid, prootic, presacral, and post-sacral vertebrae, ribs, coracoid, cleithrum, scapula, clavicle, tibiofibula, humerus, sacral vertebra, ilium, urostyle, and femur). The same rock matrix preserves a few disarticulated remains belonging to other individuals (e.g. MACN Pv N103 right otic capsule).

Locality 15: El Gigante, Candeleros Formation, Neuquén Basin, Neuquén, Argentina.

Age and depositional environment: See the entry of locality 14.

Taxon and material: *Avitabatrachus uliana* (holotype MUCPv 123) was described and illustrated (Báez et al.

2000). The holotype is preserved as an assemblage of disarticulated and partially articulated bones (frontoparietal, sphenethmoid, parasphenoid, maxilla, premaxilla, pterygoid, angulosphenial, hyoid, clavicle, coracoid, scapula, humerus, radioulna, metacarpal, presacral vertebrae, sacral vertebra, urostyle, ilium, femur, and tibiofibula). *A. uliana* was considered as belonging to Pipimorpha (Báez et al. 2000) and it was coded in phylogenetic analyses, being recovered as sister to the crown-group Pipidae (Báez et al. 2007, 2012a; Gómez 2016), sister to Panpipidae plus *Vulcanobatrachus* (Rolando et al., 2019), and sister to Pipimorpha (Carvalho et al. 2019).

Locality 16: Río Limay, Río Limay Subgroup, Neuquén Basin, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 14.

Taxon and material: Báez and Calvo (1990) mentioned the record of a fossil Pipidae indet. The material was neither described nor illustrated.

Locality 17: Bajo Barreal Formation, Chubut Group, Gulf San Jorge Basin, Chubut, Argentina.

Age and depositional environment: Late Cretaceous, Cenomanian-Turonian (Bridge et al. 2000; Casal et al. 2016); fluvial to lacustrine with volcanic influence (Bridge et al. 2000).

Taxon and material: Casal et al. (2016) mentioned in a faunal list the record of some vertebrae referred to as Anura indet.

Locality 18: Estrada Velha de Marília, Adamantina Formation, Bauru Group, São Paulo, Brazil.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian, ~72.1–68 Ma (Geroto and Bertini 2019); braided rivers and ephemeral small ponds (Carvalho et al. 2007).

Taxon and material: Two lissamphibian taxa have been reported, as follows:

- 1) Taxon A— The unpublished specimens (MZUSP-PV 25-8), comprising an almost complete skeleton and several other anuran remains, were described and illustrated in a PhD dissertation (Carvalho 2006). MZUSP-PV 25-8 was coded in a phylogenetic analysis and recovered as related to the hyloid *Pseudis* (Carvalho, 2006). The material was later compared to *Uberabatrachus* (Báez et al., 2012b), and also mentioned in Marjanović and Laurin (2014) as “Adamantina hyloid”, suggesting it as belonging to Athesphatanura, but without explanation.
- 2) Taxon B— The undescribed specimen Amphibia indet. was mentioned in a faunal list by Zaher et al. (2006). There is no information about the preserved remains and where the specimen is housed. The material was neither described nor illustrated.

Locality 19: Prata, Adamantina Formation, Bauru Group, Minas Gerais, Brazil.

Age and depositional environment: See the entry of locality 18.

Taxon and material: The unpublished specimen MBC-058-PV was mentioned in a conference abstract (Silva et al., 2018) and suggested as an occipital belonging to an indeterminate Anura. It was neither described nor illustrated.

Locality 20: Auriflama, Adamantina Formation, Bauru Group, São Paulo, Brazil.

Age and depositional environment: See the entry of locality 18.

Taxon and material: Unpublished material encompassing three humeri, were assigned to Anura in conference abstracts (Freitas et al. 2019; Barbosa et al. 2019).

Locality 21: Araçatuba, Araçatuba Formation, Bauru Group, São Paulo, Brazil.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian (Gobbo-Rodrigues et al. 1999); palustrine (Fernandes et al. 2003).

Taxon and material: An unpublished humerus was mentioned in a conference abstract (Freitas et al. 2017) and considered as belonging to an indeterminate Anura. This specimen was neither described nor illustrated.

Locality 22: Ranquil C6, Loncoche Formation, Neuquén Basin, Mendoza, Argentina.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian (Sepúlveda et al. 1989); tidal (González-Riga 1999).

Taxon and material: González-Riga (1999) briefly mentioned MACN-M 14 (a fragmentary humerus) and considered that it belongs to Leptodactylidae, but without explanation. The specimen was later identified as *Calyptocephalella* cf. *C. satan*, also without explanation (Agnolin 2012). The specimen was neither described nor illustrated.

Locality 23: Between Cafayate and Salta, 67 Km north along route 68, Las Curtiembres Formation, Salta, Argentina.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian (Narváez and Sabino 2008); fluvial to lacustrine (Marquillas et al. 2005).

Taxon and material: Reig (1959) described and illustrated *Saltenia ibanezi* based on the holotype (PVL 2010) and several specimens (PVL-2001 to 2025). Parodi Bustos et al. (1960) also mentioned fossils of *S. ibanezi* (P. 59-1 to 59-33). More than 300 specimens of this species, including tadpoles, juveniles, and adult specimens (P. 59-34, 59-36 to 38, 59-41, PVL-2026 to 2031, PVL-2199 to 2226, PVL-2228 to 2260, PVL-2270, PVL-2521, PVL-2525 to 2526, PVL-2528 to 2535, PVL-2537 to 2540, PVL-2689 to 2692, PVL-2775 to

2779, MLP 59-VIII-3-1 to 5, MLP 62-XII-5-1 to 44, MLP 62-XII-5-46 to 66, MLP 62-XII-5-68 to 105, MLP 62-XII-5-107 to 116, CPBA 9715 to 9754, MACN 18045 to 18046), were later grouped and revised (Báez 1981). Scanferla et al. (2011) also mentioned new records for it (MAS-P/2 unnumbered, three tadpoles, and 30 postmetamorphic specimens). *Saltenia ibanezi* was included in several phylogenetic analyses, and recovered within the crown-group Pipidae Xenopodonomorpha (Báez and Pügener 1998 2003; Báez and Harrison 2005; Báez et al. 2012a; Cannatella 2015), in a polytomy in the base of crown-group Pipidae (Gómez 2016), and in the Panpipidae Shelanidae (Carvalho et al. 2019; Rolando et al. 2019).

Locality 24: Puente Morales, Las Curtiembres Formation, Salta, Argentina.

Age and depositional environment: See the entry of locality 23.

Taxon and material: Barcelos and Verdade (2020b) mentioned in a conference abstract the record of two specimens referred to as *Saltenia ibanezi*.

Locality 25: Estancia Los Alamitos, Los Alamitos Formation, Río Negro, Argentina.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian (Bonaparte et al. 1984); coastal floodplain and fluvial (Bonaparte et al. 1984).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A—Báez (1987) suggested that MACN-RN 160 (left ilium, three distal humeri, three incomplete maxillae, and a fragmentary right squamosal) belonged to *Calyptocephalella* indet., de la Fuente et al. (2007) mentioned the specimen that later was revised by Agnolin (2012) and proposed as a referred specimen of *Calyptocephalella satan*, without explanation. Later, Suazo-Lara and Gómez (2022) identified it as *Calyptocephalellidae* indet.
- 2) Taxon B—Bonaparte (1986a, 1986b) mentioned in conference abstracts the record of two specimens (the kind of material was not detailed) assigned as Pipidae indet. The materials were neither described nor illustrated and were mentioned in Sanchiz (1998). There is neither information about the institution in which the specimens are housed nor their collection number.

Locality 26: Arroyo Verde, Los Alamitos Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 25.

Taxon and material: Báez (1987) mentioned a humerus and ilium of cf. *Xenopus* sp., that was later referred to as *Kuruleufenia* (Gómez, 2016).

Locality 27: Cerro Cuadrado, Los Alamitos Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 25.

Taxon and material: MACN-RN 159 (1) (humeri), MACN-RN 159 (2) (sphenethmoid), MACN-RN 159 (3) (sacrourostyle), and MACN-RN 159 (4) (pelvis) were referred to as cf. *Xenopus* sp. by Báez (1987), and were later revised and referred to as *Kuruleufenia xenopoides* (Suazo-Lara and Gómez, 2022). Additional elements (fragment of skull, presacral, and ilium) catalogued as bulk number MACN-RN 159 identified by Báez (1987) as cf. *Xenopus* sp. were not mentioned by Suazo-Lara and Gómez (2022).

Locality 28: Puma Cave, Chorrillo Formation, Santa Cruz, Argentina.

Age and depositional environment: Late Cretaceous, late Campanian-early Maastrichtian (Nullo et al. 2006); braided and meandering rivers (Tettamanti et al. 2018).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A—*Calyptocephalellidae* indet. MPM 21519 (fragmentary right humerus) and MPM-PV-22841e22846 (fragments of maxilla and postcranial bones) were mentioned by Novas et al. (2019) and commented on by Suazo-Lara and Gómez (2022).
- 2) Taxon B—Novas et al. (2019) mentioned the record of MPM 21518 (fragmentary tibiofibula) and assigned it to *Anura* indet.

Locality 29: Magallanodon, Chorrillo Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 28.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A—MPM-PV-22840 (right humerus) was described, figured, and referred to as *Pipoidea* indet. by Moyano-Paz et al. (2022). Later, this material was suggested as *Kuruleufenia* sp. by Suazo-Lara and Gómez (2022).
- 2) Taxon B—MPM-PV-22841 (incomplete left maxilla), MPM-PV-22842 (incomplete right maxilla), MPM-PV-22843 (incomplete right ilium), MPM-PV-22844 (proximal right radioulna), MPM-PV-22845 (left proximal end of tibiofibula), MPM-PV-22846 (proximal half of urostyle) were described, figured, and referred to as *Calyptocephalella* sp. (Moyano-Paz et al., 2022).

Locality 30: Bajo de Santa Rosa, Allen Formation, Río Negro, Argentina.

Age and depositional environment: Late Cretaceous, late Campanian-early Maastrichtian (Dingus et al. 2000);

ephemeral ponds, fluvial, and coastal marine (Armas and Sánchez 2015).

Taxon and material: Four anuran taxa have been reported, as follows:

- 1) Taxon A— Martinelli and Forasiepi (2004) described and illustrated records of Pipidae indet., e.g. MACN RN 1064 and 1065 (fragmentary sphenethmoids). Later, Gómez (2016) interpreted isolated fragmentary materials recovered in several localities nearby Trapalcó and Santa Rosa depressions as representing a single anuran species. He described the pipid *Kuruleufenia xenopoides* based on the holotype (MACN-PV RN 1064), MACN-PV RN 1065, and multiple isolated fragments mentioned in Martinelli and Forasiepi (2004) and Báez (1987).
- 2) Taxon B— Leptodactylidae indet. MACN-PV RN 1066 (right humerus) was described and illustrated by Martinelli and Forasiepi (2004). Later, Agnolin (2012) referred this material to *Calyptocephalella satan* without explanation. Most recently, Gómez (2016) recognised it as belonging to *Kuruleufenia xenopoides*.
- 3) Taxon C— Martinelli and Forasiepi (2004) described and illustrated several remains identified as Leptodactylidae indet., including MACN-PV RN 1063 (right maxilla) and MACN-PV RN 1069 (skull fragments), and as Anura indet., comprising MACN-PV RN 1067 (5 vertebrae), MACN-PV RN 1068 (angulosplenic), and MACN-PV RN 1070 (radioulna). Later, all mentioned specimens were referred to as *Calyptocephalella satan* by Agnolin (2012) without explanation.
- 4) Taxon D— Bonaparte (1991) mentioned, in a conference abstract, the presence of a fossil specimen belonging to ?Leptodactylidae without explanation. There is no information about the institution where the specimen is housed, or its collection number.

Locality 31: Cerro Tortuga, Allen Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 30.

Taxon and material: Five anuran taxa have been reported, as follows:

- 1) Taxon A— *Calyptocephalella satan* holotype is a right maxilla (MML 870). This species was described based on multiple isolated remains. The material was illustrated in Agnolin (2012), and was phylogenetically nested within Calyptocephalellidae, as sister to *Beelzebufo ampinga* (Agnolin, 2012). Later, some inconsistencies were recognised in the work of Agnolin (2012), e.g. *Calyptocephalella* was recovered as paraphyletic with *Calyptocephalella satan* sister to *Beelzebufo ampinga* (Báez and Gómez, 2018) and the diagnosis of *C. satan*

does not present characteristics exclusive to this species, meaning it cannot reliably be differentiated from other species of *Calyptocephalella* (Muzzopappa et al., 2021). Therefore, the status of this species has been repeatedly doubted (Báez and Gómez 2018; Muzzopappa et al. 2021; Suazo-Lara and Gómez 2022) and proposed as *species inquirenda* (Suazo-Lara and Gómez 2022). Other remains were also referred to as *Calyptocephalella satan* by Agnolin (2012), but without explanation, i.e. MML 847 (complete atlas), MML 848 (complete atlas), MML 849 (fragmentary left squamosal), MML 851 (incomplete fragment of skull roof), MML 850 (presacral vertebral centrum), MML 851 (incomplete fragment of skull roof), MML 854 (incomplete sacral centrum), MML 855 (mid-portion of right maxilla), MML 857 (incomplete left frontoparietal), MML 858 (incomplete posterior portion of right maxilla), MML 859 (incomplete right frontoparietal), MML 860 (incomplete urostyle), MML 862 (presacral vertebral centrum and incomplete sacrum), MML 863 (incomplete left maxilla), MML 864 (incomplete right squamosal), MML 865 (incomplete right maxilla preserving tooth bases), MML 866 (right radius-ulna without its distal end), MML 867 (two distal ends of right humeri), MML 868 (fragmentary urostyle), MML 869 (incomplete right frontoparietal), MML 872 (incomplete left premaxilla), MML 875 (complete atlas), and MML 886 (fragmentary sacrum). Following Suazo-Lara and Gómez (2022), we suggest that the status of specimens referred to as *Calyptocephalella satan species inquirenda* deserve to be reevaluated.

- 2) Taxon B—MML-PV 1042 (two humeri), MML-PV 1047 (fifth presacral vertebrae and two incomplete presacrals), MML-PV 1059 (incomplete sacro-urostyle), MML-PV 1060 (incomplete ilia), MML-PV 1057–1058 (right and left otic capsules), and MML-PV 1062–1063 (incomplete presacrals) were referred to as *Calyptocephalella satan* by Agnolin (2012) without explanation. Later, those isolated fragmentary specimens were considered part of the hypodigm of *Kuruleufenia xenopoides* (Gómez 2016).
- 3) Taxon C— MML-PV 1053 was referred to as *Calyptocephalella satan* by Agnolin (2012) without explanation. Later, this specimen was referred to as Calyptocephalellidae indet. (Suazo-Lara and Gómez 2022).
- 4) Taxon D— MML 856 (right humerus) and MML 871 (vertebra) were figured by Agnolin (2012) and referred to as Pipidae indet., without explanation.

Locality 32: Cerro Bonaparte, Allen Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 30.

Taxon and material: Báez (1987) mentioned the record of a *Calyptocephalella*-like specimen MML-PV 1061 (fragmentary ilia). Later, this specimen was referred to as *Ca. satan* by Agnolin (2012).

Locality 33: Cerro Alberto, Allen Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 30.

Taxon and material: Suazo-Lara and Gómez (2022) referred MML-PV 1066 (humerus) to *Kuruleufenia xenopoides*.

Locality 34: Valle de Las Chinas, Dorotea Formation, Magallanes Basin, Última Esperanza, Chile.

Age and depositional environment: Late Cretaceous, late Campanian-early Maastrichtian, 74.9–71.7 Ma (Gutiérrez et al. 2017); fluvial, shoreface, and deltaic (Schwartz and Graham 2015).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— CPAP 5881 (right humerus) was reported as cf. *Kuruleufenia* sp. by Suazo-Lara (2019), and later referred to as *Kuruleufenia* sp. by Suazo-Lara and Gómez (2022).
- 2) Taxon B— Suazo-Lara et al. (2017) reported the record of Calyptocephalellidae based on CPAP 5878–5879 (humeri). Later, Suazo-Lara and Gómez (2022) identified the humeri as Calyptocephalellidae indet. The humeri were not described, but were figured by Suazo-Lara and Gómez (2022).
- 3) Taxon C— Suazo-Lara et al. (2018) mentioned a new record of Anura indet. in a conference abstract. The material is composed of fragmentary bones, including six humeri, tibiofibula, and radioulna.

Locality 35: El Uruguayo, La Colonia Formation, Chubut, Argentina.

Age and depositional environment: Late Cretaceous, Campanian-Maastrichtian (Pascual et al. 2000); fluvial and marginal marine (Pascual et al. 2000).

Taxon and material: Muzzopappa and Varela (2014) briefly mentioned in a conference abstract the record of MPEF-PV 10890-8 and MPEF-PV 10891-10 (three premaxillae) and referred to them as Anura indet. Later, Suazo-Lara and Gómez (2022) also mentioned those records.

Locality 36: Ponto 1 do Price, Marília Formation, Bauru Group, Minas Gerais, Brazil.

Age and depositional environment: Late Cretaceous, Maastrichtian (Dias-Brito et al. 2001); braided rivers (Silva et al. 2017).

Taxon and material: *Baurubatrachus pricei* (holotype DNPM 1412 R A-B) is an almost complete skeleton described

and illustrated by Báez and Peri (1989). The species was proposed as nested within Ceratophryidae, and several analyses corroborated this scenario (e.g. Evans et al. 2014; Báez et al. 2009). The holotype was prepared further, which favoured a proper redescription of its anatomy, and was illustrated by Báez and Gómez (2018). The phylogenetic affinity of *Baurubatrachus pricei* was reassessed and it was recovered outside Ceratophryidae (Nicoli et al. 2016). Later, *Ba. pricei* was recovered within Calyptocephallidae (Báez and Gómez 2018). Due to the different topologies recovered by Báez and Gómez (2018), we take a conservative approach and recognise it as a putative Australobatrachia.

Locality 37: Km 153 of BR 050, Marília Formation, Bauru Group, Minas Gerais, Brazil.

Age and depositional environment: See the entry of locality 36.

Taxon and material: The unnumbered Anura indet. MBC was presented in a conference abstract and is composed of radioulna and phalanges (Silva et al. 2018). It was neither described nor illustrated.

Locality 38: Uberaba, Serra da Galga Member, Uberaba Formation, Bauru Group, Minas Gerais, Brazil.

Age and depositional environment: See the entry of locality 36.

Taxon and material: *Uberabatrachus carvalhoi* (holotype CPPLIP 1115) was described and illustrated in Báez et al. (2012b), and assigned to Nobleobatrachia. Later, it was recovered as belonging to Telmatobiidae (Evans et al. 2014; Nicoli et al. 2016), and as wild-card taxa, placed within Odontophrynidae, Ranoidea, Myobatrachoidea, in a polytomy (including Ceratophryidae, Batrachylidae, Telmatobiidae, and Odontophrynidae), and as sister to Pelodyadidae (Báez and Gómez 2018). The holotype of *Uberabatrachus carvalhoi* was recovered in association with a titanosaur's femur (Agustin G. Martinelli, pers. comm.), but this likely palaeoecological association was not explored yet.

Locality 39: Pajcha Pata, El Molino Formation, Cochabamba, Bolivia.

Age and depositional environment: Late Cretaceous to early Paleocene, Maastrichtian-Danian (Sempere et al. 1997); lacustrine with marine influence (Sempere et al. 1997).

Taxon and material: Three lissamphibian taxa have been reported, as follows:

- 1) Taxon A— MHNC-8583 (seven disarticulated and damaged vertebrae) referred to as *Gymnophiona* indet. (Gayet et al. 2001).
- 2) Taxon B— Thirty-seven vertebrae, including the holotype (MHNC-6636, a trunk vertebra) of *Noterpeton bolivianum* (Rage et al., 1993) and another 46 vertebrae also assigned to *No. bolivianum* (Gayet et al. 2001).

- 3) Taxon C—Gayet et al. (1991) mentioned and Gayet et al. (2001) described and illustrated three fragmentary presacral vertebrae (MHNC-8585), assigning them to *Anura* indet.

Locality 40: Vila Vila, El Molino Formation, Cochabamba, Bolivia.

Age and depositional environment: See the entry of locality 39.

Taxon and material: MHNC-8584 (16 vertebrae) were referred to as *Noterpeton bolivianum* (Rage et al., 1993).

Paleocene

Locality 41: Punta Peligro, Salamanca Formation, San Jorge Basin, Chubut, Argentina.

Age and depositional environment: Early Paleocene, Danian, 65.7–63.5 Ma (Clyde et al. 2014); shallow marine/estuarine (Comer 2011).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A—*Calyptocephalella sabrosa* MPEF 3003 (holotype) was described and illustrated (Muzzopappa et al. 2021). It is an almost complete skeleton preserved in an avian gastric pellet (Muzzopappa et al. 2021).
- 2) Taxon B—*Gigantobatrachus casamiquelai* MACN CH-1625a (holotype; incomplete right maxilla), was mentioned in Bonaparte et al. (1993) as a new species nested within the genus *Calyptocephalella*. Other remains were also assigned to *Gigantobatrachus casamiquelai*, i.e. incomplete maxillae and skull-roof bones, three incomplete angulosplenials, a single presacral vertebra, proximal urostyles, distal humeri, incomplete tibiofibula, and a left ilium. Agnolin (2012) described, illustrated, and coded *G. casamiquelai*, and it was recovered within *Calyptocephalellidae*. Later, this assignment was doubted by Muzzopappa et al. (2021).
- 3) Taxon C—Báez (2000) mentioned the record of *Caudiverbera* indet., but the material was neither described nor illustrated, and the repository was not mentioned. Nicoli et al. (2016) assigned this specimen (the kind of material was not detailed) to *Calyptocephalella* indet.

Locality 42: Las Flores, Peñas Coloradas Formation, Río Chico Group, Chubut, Argentina.

Age and depositional environment: Early Paleocene, late Danian, 62.5–61.6 Ma (Clyde et al. 2014); floodplain (Raigemborn et al. 2009).

Taxon and material: An unnumbered specimen (a fragmentary maxilla) was briefly described by Báez (1991a). Later, it

was referred to *Gigantobatrachus casamiquelai* by Agnolin (2012) without explanation.

Locality 43: Tiupampa, Santa Lucía Formation, Potosí Basin, Cochabamba, Bolivia.

Age and depositional environment: Middle Paleocene, Selandian–Thanetian, ~60–58.2 Ma (Sempere et al., 1997); alluvial to lacustrine (Sempere et al. 1997).

Taxon and material: Two lissamphibian taxa have been reported, as follows:

- 1) Taxon A—Báez (1991a) described and illustrated *Estesius boliviensis* (holotype MHNC 4501), based on an incomplete skull with fragmentary mandible, part of the pectoral girdle, part of forelimb, and atlas centrum. The specimen was assigned to “Leptodactylidae” (Báez 1991a). Báez (1995) proposed *Estesiella boliviensis* to be a *nomen novum* due to the principle of priority of ICZN, and recognised that the phylogenetic affinity of *Estesiella* should be revised. Other remains were also assigned to *Estesiella boliviensis*, MHNC 4502-5 (four fragments of posterior portion of skull), MHNC 4509/10 (two maxillary fragments), MHCN 4506/7 (two sphenethmoids), and MHCN 4508 (left scapula) (Báez 1991a). Gómez et al. (2008) doubted the affinities of *Estesiella boliviensis* with Leptodactylidae, and in conference abstracts and his PhD dissertation recovered *Estesiella boliviensis* as a nobleobatrachian Hyloidea (Gómez and Báez 2010; Gómez 2011). The anatomy of the specimen was reassessed in Gómez (2011) and reported in Gómez et al. (2010); the latter suggested that the expanded prehallux and well-ossified “ethmoidal” of the species were adaptations for fossoriality.
- 2) Taxon B—MHNC-2635 (single and incomplete vertebra) assigned to an indeterminate Gymnophiona (Rage 1991).

Locality 44: Estancia Blanco Rancho, Santa Lucía Formation, Potosí Basin, Cochabamba, Bolivia.

Age and depositional environment: See the entry of locality 43.

Taxon and material: An unnumbered specimen that comprises an isolated vertebra was assigned to *Noterpeton bolivianum* (Gayet et al., 2001).

Locality 45: Laguna Umayo, Muñani Formation, Puno, Peru.

Age and depositional environment: Late Paleocene to early Eocene (Sigé et al. 2004); alluvial plain to lacustrine (Sigé et al. 2004).

Taxon and material: Sigé (1968) and Muizon et al. (1983) mentioned the record of a Leptodactylidae indet. Estes and Báez (1985) doubted the relationship of this specimen (the kind of material was not detailed) with Leptodactylidae.

Eocene

Locality 46: São José de Itaboraí, Itaboraí Basin, Rio de Janeiro, Brazil.

Age and depositional environment: Early Eocene, Ypresian, ~53–50 Ma (Woodburne et al., 2014); lacustrine to alluvial (Pereira et al. 2017).

Taxon and material: Five lissamphibian taxa have been reported, as follows:

- 1) Taxon A— Single damaged pre-cloacal vertebra (DGM 551) erected as the holotype of the caecilian *Apodops pricei* (Estes and Wake, 1972).
- 2) Taxon B— Estes (1970), Estes and Reig (1973), and Estes and Báez (1985) mentioned one ilium that could belong to *Bufo* indet., without explanation. The material was neither described nor illustrated.
- 3) Taxon C— Hylidae indet. (ilium; Estes 1970; Estes and Reig 1973) was mentioned, but neither described nor illustrated.
- 4) Taxon D— An ilium was assigned to Leptodactylidae indet. (Estes 1970; Estes and Reig 1973), but was neither described nor illustrated.
- 5) Taxon E— Estes (1975a) described “*Xenopus*” *romeri* (holotype DGM 568), comprising a braincase and sphenethmoid region of a skull. Other materials were also assigned to the species, i.e. DGM 569–570, DGM 579 (incomplete skulls), DGM 575a–e DGM VI–V and DGM VK 576 (fused atlas), and DGM V2 573 (sacrum and urostyle), DGM 571 (scapula-clavicle), DGM 572 (humerus), and DGM 577–578 (ilia) (Estes 1975b). The holotype was coded in several phylogenetic analyses, and the hypothesis that “*Xenopus*” *romeri* belongs to the genus *Xenopus* has repeatedly been questioned (e.g. Báez and Púgener 1998; Gómez 2016). The material is currently *species inquirenda* and should be revised.

Locality 47: Laguna del Hunco, Laguna del Hunco Formation, Chubut, Argentina.

Age and depositional environment: Early Eocene, Ypresian, 52.22 ± 0.22 Ma (Wilf 2012); lacustrine (Wilf et al. 2003).

Taxon and material: *Shelania pascuali* was described by Casamiquela (1960) based on a juvenile incomplete specimen (holotype PVL 2186). The morphology of *Shelania pascuali* was reassessed, and the specimen was phylogenetically nested within Pipidae (Báez and Trueb 1997). Other complete specimens were referred to *Shelania pascuali* (PVL 2187–88; PVL 3989; MLP 62-XII-21-1; MLP 62-XII-22-1; MLP 62-X11-20-1; CIC 3-3-75/1; MJHG 2-3-72; CPBA 9855-56; CPBA 12222; CPBA 12224; CPBA 12226; CPBA 12231-32; PVL 3991-98; PVL 3983; PVL 3994; PVL 4002; PVL 4007; PVL 4009-10; PVL 4081-87; CBPA 12211-12;

CBPA 12219; CBPA 12223; and MPEF-PV 1150-51). The species was included in several phylogenetic analyses and recovered as sister to *Kuruleufenia* (Rolando et al., 2019), and as belonging to Xenopodinomorpha (Gómez 2016).

Locality 48: Peralta Nahueltripay, Laguna del Hunco Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 47.

Taxon and material: Báez and Trueb (1997) redescribed the morphology of *Shelania pascuali* based on multiple complete specimens (PVL 3989; MLP 62-XII-21-1; MLP 62-XII-22-1; MLP 62-X11-20-1; CIC 3-3-75/1; MJHG 2-3-72; CPBA 9855-56; CPBA 12222; CPBA 12224; CPBA 12226; CPBA 12231-32; PVL 3991-98; PVL 3983; PVL 3994; PVL 4002; PVL 4007; PVL 4009-10; PVL 4081-87; CBPA 12211-12; CBPA 12219; CBPA 12223; and MPEF-PV 1150-51).

Locality 49: Sierra Dorotea, Río Turbio Formation, Magallanes, Chile.

Age and depositional environment: Early to middle Eocene (Panti 2016); estuarine and shallow marine (Panti 2016).

Taxon and material: SGO.PV.6546 (a fragmentary humerus) was assigned to Calyptocephalellidae indet., described and illustrated by Otero et al. (2014). The humerus was estimated to be from an individual having a snout-vent length of about 59 cm, making it the largest frog specimen ever known (Otero et al. 2014). It was mentioned in Jimenez-Huidobro and Sallaberry (2015).

Locality 50: Pampa de Jones, Huitrera Formation, Neuquén, Argentina.

Age and depositional environment: Early to middle Eocene, Ypresian-Lutetian, ~54–47 Ma (Wilf et al. 2005; Wilf et al. 2010); lacustrine (Melendi et al. 2003).

Taxon and material: Báez (1988, 1991b, 1996, 2000) mentioned in conference abstracts and book chapters the record of specimens referred to as Pipidae. Later, the species *Llankibatrachus truebae* was named based on the holotype BAR 2469–10 (an almost complete skeleton), described and illustrated by Báez and Púgener (2003). *Llankibatrachus truebae* is known by the holotype and multiple complete specimens (mostly postmetamorphs, but also some tadpoles) from this locality (CP-Bar 2467–10, 2471–10, 2474–10, 2475–10, 2478–10, 2479–10, 2480–10, 2611–10 a-b, 2720–10, 3076–10, 3077–10, 3078–10, 3079–10, 3080–10. Tadpoles: 1309–10, 2474–10, 2476–10, 2477–10, 2599–10, 2606–10, 4111–10, 4112–10, and 4113–10) (Báez 1996, 2000; Báez and Púgener 2003). *Llankibatrachus truebae* was recovered as related to *Shelania laurenti* and ‘*Xenopus*’ *romeri* (Báez and Púgener 2003; Gómez 2016).

Locality 51: Laguna del Hunco, Confluencia, Huitrera Formation, Neuquén, Argentina.

Age and depositional environment: See the entry of locality 50.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Calyptocephalella* indet. (CP-Bar 2466-1-A-B, tadpole) was mentioned in Báez et al. (1990), and Báez (2000).
- 2) Taxon B— Skeletons CP-Bar 303–1, 1515-1, 1609–1, 2361–1, 2363-1, 2364–1, 3083-1a/b, and tadpoles (1518–1, 1612–1, 1613–1) were mentioned in Báez et al. (1990), and assigned as Pipidae indet. Later, those specimens were referred to *Llankibatrachus truebae* by Báez and Púgener (2003).

Locality 52: Río Pichileufu, Huitrera Formation, Río Negro, Argentina.

Age and depositional environment: See the entry of locality 50.

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— *Patagopipa corsolinii* MLG 2630 (holotype) was described and illustrated in Rolando et al. (2019). The material is a juvenile specimen composed of an almost complete skeleton, with a disarticulated skull, an incomplete vertebral column, and nearly complete right fore- and hindlimbs. *Patagopipa corsolinii* was coded in the matrix of Gómez (2016) and recovered in Shelaniinae as sister of *Saltenia ibanezi* (Rolando et al., 2019).
- 2) Taxon B— *Calyptocephalella pichileufensis* (holotype BAR 85a-b) is an articulated skeleton that was described and illustrated (Gómez et al. 2011). The specimen was mentioned by Kramarz et al. (2011).
- 3) Taxon C— Leptodactylidae indet. was mentioned in a conference abstract (Báez 1988). The kind of material was not detailed.

Locality 53: CTA-47, lower member, Pozo Formation, Ucayali, Peru.

Age and depositional environment: Middle Eocene (Antoine et al. 2016); fluvial with marine influence (Antoine et al. 2016).

Taxon and material: Antoine et al. (2016) mentioned in a faunal list postcranial elements referred to Anura indet. The material was not specified in more detail.

Locality 54: CTA-51, lower member, Pozo Formation, Ucayali, Peru.

Age and depositional environment: Middle Eocene (Antoine et al. 2016); fluvial (Antoine et al. 2016).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Antoine et al. (2016) mentioned in a faunal list postcranial elements referred to as Pipidae indet. The material was not specified in more detail.
- 2) Taxon B— Fragmentary maxilla and postcranial elements were mentioned in a faunal list and referred to as Anura indet. (Antoine et al. 2016). The materials were not specified in more detail.

Locality 55: CTA-27, lower member, Pozo Formation, Ucayali, Peru.

Age and depositional environment: See the entry of locality 54.

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— Pipidae indet. (postcranial bones) were mentioned in a faunal list by Antoine et al. (2016). The material was not specified in more detail.
- 2) Taxon B— ‘Leptodactyloid’ indet. (postcranial bones) were mentioned by Antoine et al. (2016) in a faunal list. The material was not specified in more detail.
- 3) Taxon C— Anura indet. (postcranial bones) were mentioned in a faunal list by Antoine et al. (2016). The material was not specified in more detail.

Locality 56: CTA-66, lower member, Pozo Formation, Ucayali, Peru.

Age and depositional environment: See the entry of locality 54.

Taxon and material: Pipidae indet. (postcranial bones) were mentioned in a faunal list by Antoine et al. (2016). The material was not specified in more detail.

Locality 57: CTA-29, lower member, Pozo Formation, Ucayali, Peru.

Age and depositional environment: See the entry of locality 54.

Taxon and material: Pipidae indet. (postcranial bones) were mentioned in a faunal list by Antoine et al. (2016). The material was not specified in more detail.

Locality 58: Near Curitiba and Araucária municipalities, Guabirotuba Formation, Curitiba Basin, Paraná, Brazil

Age and depositional environment: Middle Eocene to early Oligocene (Riccomini et al., 2004; Sedor et al. 2014); fluvial system and associated lakes (Sedor et al. 2017).

Taxon and material: Sedor et al. (2014) briefly mentioned the record of an indeterminate Anura in a faunal list of a conference abstract. The material is a fragmentary humerus that is unnumbered and housed at MCN-SCB-UFPR. This Anura indet. was neither described nor illustrated.

Locality 59: Cañadón Hondo, Sarmiento Formation, Chubut, Argentina.

Age and depositional environment: Middle Eocene to early Miocene (Ré et al. 2010); aeolian and fluvial plains, including shallow ponds (Bellosi 2010).

Taxon and material: The holotype (AMNH 3165), encompassing a left nasal and maxilla assigned to *Eophractus casamayorensis*, was described by Schaeffer (1949). AMNH 3164 (fragmentary maxilla and a presacral vertebra) was also referred to the species by Schaeffer (1949). The materials were later revised as *Calyptocephalella casamayorensis* (Lynch 1971; Nicoli et al. 2016).

Locality 60: Puesto Baibíán, Sarmiento Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 59.

Taxon and material: MPEF-PV 1498 was described, illustrated, and assigned to *Calyptocephalella canqueli* (Muzzopappa and Báez, 2009). Other materials were also referred to the species, i.e. AMNH 3427 (partial skeleton), MPEF-PV 1881 (fragmentary skull), MPEF-PV 1882 (sphenethmoid), MPEF-PV 1883 (ilium and presacral vertebra), MPEF-PV 1884 (left humerus), MPEF-PV 1885 (sacrum, atlas, urostyle, maxilla), MPEF-PV 1886 (incomplete, disarticulated skull, and sacral vertebra), MPEF-PV 1887 (disarticulated premaxilla, a portion of maxilla, frontoparietal, quadratojugal, sphenethmoid, otic capsules, mandible, left humerus, proximal portion of right humerus, scapula, and coracoid), MPEF-PV 1888 (left clavicle), MPEF-PV 1889 (left maxilla), and MPEF-PV-1890 (tibiofibula) (Muzzopappa and Báez, 2009).

Locality 61: Gran Barranca, Colhue-Huapi Member, Sarmiento Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 59.

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— The materials AMNH 3236-39 (fragments of maxilla, sphenethmoid, and ilium) and AMNH 3241 (fragments of maxilla, fragmentary skull-roof, and two presacral vertebrae) were referred to as *Calyptocephalella canqueli* (Schaeffer 1949).
- 2) Taxon B— *Calyptocephalella rugata* (holotype MACN 11656-1, MACN 11656-49; skull and postcranial fragmentary remains from several individuals) was described by Ameghino (1901). The species name was later corrected as *Calyptocephalella rugosa* (Báez 1977; Agnolin, 2012).
- 3) Taxon C— *Saniwa australis* (holotype MACN A-5805; two fragmentary vertebral centra) was described by Ameghino (1899). Gasparini et al. (1986) suggested *nomen dubium* for the species. The material was later referred to as *Calyptocephalellidae* aff. (Agnolin, 2012).

Locality 62: Cerro Sacanana, Colhue-Huapi Member, Sarmiento Formation, Chubut, Argentina.

Age and depositional environment: See the entry of locality 59.

Taxon and material: Estes and Báez (1985) mentioned in a faunal list a specimen referred to as ?Leptodactylidae (the kind of material was not detailed).

Locality 63: Sierra El Fresco, Vaca Mahuida Formation, La Pampa, Argentina.

Age and depositional environment: Paleogene to middle Miocene, although for the deposits at the Sierra El Fresco locality, an Eocene age is well-established (Montalvo and Bond 1998); lacustrine, small and ephemeral ponds, with some marine influence (Uliana and Camacho 1975; Melchor et al. 1992).

Taxon and material: Báez and Púgener (1998) described and illustrated *Shelania laurenti* (holotype GHUNLPam 4022), comprising a fused atlas and second presacral vertebra. Other remains were recognised as paratypes of *Shelania laurenti* (GHUNLPam 4115, braincase and otic capsule; GHUNLPam 4047, sphenethmoid; GHUNLPam 4025, frontoparietal; GHUNLPam 4036, left scapula; and GHUNLPam 4002b, right maxilla). Báez and Púgener (1998) referred to other isolated bones as belonging to *Shelania laurenti*, i.e. GHUNLPam 4000 (vertebra), 4001-4005 (frontoparietals), 4006 (frontoparietal impression), 4007 and 4008 (frontoparietals), 4009 (sphenethmoid), 4010 (frontoparietal and ventral impression), 4011a (fused sacrum and urostyle), 4011b (squamosal), 4012a (cleithrum), 4012b (vertebra), 4012c (femur), 4013 (fused sacrum and urostyle), 4016 (vertebra), 4017-4021 (frontoparietals), 4022 (fused Vertebrae I + II), 4023 (Vertebra V?), 4024 (fused Vertebrae I + II and III), 4026-4028 (frontoparietals), 4029 (vertebra), 4030 (Vertebra VI or VII), 4031 (last presacral vertebra), 4032 (Vertebra III), 4033 (Vertebra V or VI), 4034 (vertebrae, 4035 and 4037 (scapulae), 4038 (otic capsule), 4039, 4040, and 4042 (otic capsules), 4043 (humeri), 4044 (thyrohyal), 4046 (sacrum), 4048a and 4048b (ilia), 4048c (ischia), 4054, 4056, and 4057 (frontoparietals), 4058 (sphenethmoid), 4059 (vertebra), 4060 (Vertebra III ?), 4061 (vertebra), 4062 (Vertebra III ?), 4063 and 4064 (ilium), 4065 and 4066 (single humeri), 4067-4069 (angulosplenials), 4070 (frontoparietal), 4072 (otic capsule), 4073a (fused Vertebra I + II), 4073b and 4074 (frontoparietals), 4075 (thyrohyal), 4077 (articulated Vertebrae I-IV), 4078 (frontoparietal), 4080 (vertebrae), 4081 (frontoparietal), 4085 (sphenethmoid), 4089 (Vertebrae I+ II + III), 4091 (thyrohyal), 4096a (frontoparietal), 4096b (tibiofibulae), 4101a (otic capsule), 4101b and 4104 (frontoparietals), 4105 (vertebrae), 4113 (urostyle), and 4114 (otic capsule). This species was coded in several phylogenies, being recovered as sister to '*Xenopus*' *romerii* (Rolando et al., 2019), in a polytomy with *Shelania pascuali* and '*Xenopus*' *romerii* (Báez and Púgener 1998), and in a polytomy with

'*Xenopus*' *romerii* and *Llankibatrachus truebae* (Báez and Pügener, 2003).

Locality 64: TAR-74, upper member (Pozo Shales), Pozo Formation, San Martín, Peru.

Age and depositional environment: Late Eocene, Priabonian, ~36–34.3 Ma (Antoine et al. 2021); fluvial floodplain, oxbow lake, and coastal plains (Antoine et al. 2021).

Taxon and material: A fragmentary humerus was referred to as Anura indet. in a faunal list by Antoine et al. (2021).

Locality 65: TAR-20, upper member (Pozo Shales), Pozo Formation, San Martín, Peru.

Age and depositional environment: See the entry of locality 64.

Taxon and material: A fragmentary humerus and radioulna were referred to as Anura indet. in a faunal list by Antoine et al. (2021).

Locality 66: TAR-21, upper member (Pozo Shales), Pozo Formation, San Martín, Peru.

Age and depositional environment: See the entry of locality 64.

Taxon and material: A fragmentary radioulna was mentioned in a faunal list and referred to as Anura indet. by Antoine et al. (2021).

Locality 67: Aiuruoca, Entre-Córregos Formation, Aiuruoca Basin, Minas Gerais, Brazil.

Age and depositional environment: Eocene to Oligocene (Bernardes-de-Oliveira et al. 2014); lacustrine (Santos 1999).

Taxon and material: Around 200 Pipidae indet. specimens were briefly described and illustrated in Bedani and Haddad (2002 2012). The materials represent complete adult and tadpole fossil specimens.

Oligocene

Locality 68: Chaparral, Tuné Formation, Gualanday Group, Tolima, Colombia.

Age and depositional environment: Early Oligocene (Stirton 1953; Hoffstetter 1971); alluvial (Stirton 1953).

Taxon and material: Porta (1969) mentioned specimens of Anura indet. in a faunal list (the kind of material was not detailed).

Locality 69: TAR-01, upper member (Pozo Shales), Pozo Formation, San Martín, Peru.

Age and depositional environment: Early Oligocene, Rupelian, ~32.5 Ma (Antoine et al. 2021); fluvial floodplain, oxbow lake, and coastal plains (Antoine et al. 2021).

Taxon and material: Radioulna and ilium were mentioned in a faunal list and referred to as Anura indet. by Antoine et al. (2021).

Locality 70: Calabozo Pata, Salla Formation, Salla-Luribay Basin, Bolivia.

Age and depositional environment: Oligocene, Rupelian-Chattian 29.4–25.5 Ma (Kay et al. 1998); fluvial (MacFadden et al. 1985).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— MNHN Sal 273-6 (two presacral vertebrae, one sacral vertebra, a fragmentary humerus, fragmentary pelvis, and several tibiofibulae) was assigned to *Bufo* sp. (Hoffstetter 1968; Báez and Nicoli 2004b).
- 2) Taxon B— Báez and Nicoli (2004b) identified UF 92824 (left ilium) as a fossil representative of *Bufo aff. B. arenarum* (currently *Rhinella arenarum*).

Locality 71: Sici Lomo Cayo, Salla Formation, Salla-Luribay Basin, Bolivia.

Age and depositional environment: See the entry of locality 70.

Taxon and material: Báez and Nicoli (2004b) assigned UF 204997 (fragmentary left ilium) to *Bufo* sp.

Locality 72: Tapial Pampa, Salla Formation, Salla-Luribay Basin, Bolivia.

Age and depositional environment: See the entry of locality 70.

Taxon and material: The specimens UF 205000 and 205709 (fragmentary posterior portions of pelvic girdles) were assigned to *Bufo* sp. (Báez and Nicoli, 2004b).

Locality 73: Scarritt Pocket, Sarmiento Formation, Sierra Canquel, Chubut, Argentina.

Age and depositional environment: Middle Oligocene, Rupelian–Chattian, ~29–27 Ma (Marshall et al. 1986; Flynn and Swisher 1995); lacustrine (Mazzoni 1994).

Taxon and material: Nine anuran taxa have been reported, as follows:

- 1) Taxon A— The holotype (AMNH 3429) of *Calyptocephalella canqueli* (formerly *Caudiverbera canqueli*), comprising a skull, pelvic girdle, four presacral vertebrae, and fragmentary fore and hind limbs, was described by Schaeffer (1949). Other materials were also referred to *Calyptocephalella canqueli*: AMNH 3400 (mandible and limb bones); AMNH 3427 (right forelimb, pelvic girdle, and hind limbs) (Schaeffer 1949; Muzzopappa and Báez 2009; Muzzopappa and Nicoli 2010); FCEN

- PV 14084 (skull and postcranial remains of a tadpole), and AMNH 3401 (complete tadpole) (Muzzopappa and Nicoli 2010).
- 2) Taxon B— AMNH 3407 (complete postcranial skeleton in part and counterpart, fragmentary skull) was described as *Eupsophus* sp. (Schaeffer 1949), but after a reanalysis, Nicoli (2017) considered it a representative of *Chachaiphrynus lynchi*. Nicoli (2017) has also referred to *Chachaiphrynus lynchi* other remains (i.e. AMNH 3422 fragmentary skull, left forelimb, and vertebral column, and CPBA-V/FCEN-PV 14085-87) formerly referred to as *Eupsophus* sp. (Báez and Fernicola 1999). Those latter materials from Báez and Fernicola (1999) were not described.
 - 3) Taxon C— Schaeffer (1949) mentioned the record of *Eupsophus* sp. based on two skeletons: AMNH 3415, a small-sized individual, with pelvic girdle and hind limbs preserved, and AMNH 3420, a skull and hind limbs.
 - 4) Taxon D— The holotype AMNH 3428 (skull and fragmentary postcranial remains) was described as *Neoprocoela edentatus* by Schaeffer (1949), and suggested to be related to *Telmatobius*. Tihen (1962) proposed that the species was a fossil representative of the *Epidalea calamita* (former *Bufo calamita*) species group. The material was also suggested as belonging to *Telmatobufo* and *Telmatobius* (Lynch 1971). Báez (1977) proposed a *nomem novum*, i.e. *Neoprocoela edentata*. Later, Nicoli (2017) revised the material as being representative of *Chachaiphrynus lynchi*.
 - 5) Taxon E— Báez and Fernicola (1999) mentioned the record of CPBA-V-14089a (humeri, vertebral column, and ilium), CPBA-V 14088/FCEN-PV, and CPBA-V 14090/FCEN-PV, and considered these materials as representatives of *Neoprocoela edentata*, suggesting the species belong to *Telmatobiinae*. The last two specimens were only mentioned in a faunal list, and were not described or illustrated. Nicoli (2017) later reassigned all those specimens to *Chachaiphrynus lynchi*.
 - 6) Taxon F— The holotype (MPEF-PV 10572), a part and counterpart containing skull and postcranial remains assigned to *Chachaiphrynus lynchi*, was described by Nicoli (2017). *Chachaiphrynus lynchi* was identified as a putative odontophrynid, but the material has not yet been included in a phylogenetic analysis.
 - 7) Taxon G— AMNH 3425 (part and counterpart of a fragmentary skull) and AMNH 3426 (postcranial skeleton) were referred to as *Anura* indet. (Nicoli 2012), but were later identified as *Chachaiphrynus lynchi* (Nicoli, 2017).
 - 8) Taxon H— Nicoli (2017) assigned the specimens MPEF-PV 10573 (part and counterpart, skull and postcranial remains), MPEF-PV 10574-77, MPEF-PV 10893-98

(fragmentary skull) (neither described nor figured) as representatives of *Chachaiphrynus lynchi*.

- 9) Taxon I— AMNH 3424 (hindlimbs) and AMNH 3430 (two partially superimposed skeletons) were identified as *Anura* indet. and mentioned in Nicoli (2012).

Locality 74: Fazenda Extrativa Santa Fé, Tremembé Formation, Taubaté Basin, São Paulo, Brazil.

Age and depositional environment: Oligocene (Chagas et al. 2009); playa-lake (Riccomini et al. 1996).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— An unpublished Neobatrachia indet. (UFRJ 01-A), encompassing a skull partially preserved and postcranial remains, was mentioned in Barcelos' (2016) undergraduate thesis.
- 2) Taxon B— An unpublished Pipoidea indet. was mentioned in a conference abstract (Campo et al. 2016). The material comprises a skull and sacral vertebra fused to the urostyle, but it was neither described nor illustrated.

Locality 75: CTA-32, Chambira Formation, Ucayali, Peru.

Age and depositional environment: Late Oligocene (Antoine et al. 2016); oxbow lake (Antoine et al. 2016).

Taxon and material: Maxilla fragments and postcranial elements were referred to as *Anura* indet. by Antoine et al. (2016). The materials were not specified in more detail.

Locality 76: CTA-61, Chambira Formation, Ucayali, Peru.

Age and depositional environment: Late Oligocene (Antoine et al. 2016); fluvial (Antoine et al. 2016).

Taxon and material: Antoine et al. (2016) mentioned in a faunal list postcranial elements referred to *Anura* indet. The material was not specified in more detail.

Locality 77: CTA-74, Chambira Formation, Ucayali, Peru.

Age and depositional environment: See the entry of locality 76.

Taxon and material: Antoine et al. (2016) mentioned postcranial elements in a faunal list and referred them to *Anura* indet. The material was not specified in more detail.

Miocene

Locality 78: Cerro Rucañanco, Rucañanco Member, Río Pedregoso Formation, Cura-Mallín Group, Araucanía, Chile.

Age and depositional environment: Early to middle Miocene, Aquitanian-Serravallian, ~22–11.6 Ma (Pedroza et al. 2017); fluvial, deltaic and lacustrine (Wall et al. 1991; Pedroza et al. 2017).

Taxon and material: Cf. Bufonidae indet. SGO.PV. 22205 (fragmentary left humerus and radioulna) was described by Guevara et al. (2018).

Locality 79: Río Santa Cruz, Santa Cruz Formation, Santa Cruz, Argentina.

Age and depositional environment: Early Miocene, Burdigalian, ~18.2–15.6 Ma (Cuitiño et al. 2016); estuarine and fluvial floodplains (Raigemborn et al. 2015).

Taxon and material: *Calyptocephalella* cf. *C. canqueli* (MPM-PV 20025), comprising a left frontoparietal and fragmentary maxilla, was described and illustrated by Muzzopappa (2019).

Locality 80: Estancia La Costa, Santa Cruz Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 79.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— A specimen assigned to Leptodactylidae indet. (CORD-PZ 1230), encompassing a left premaxilla, left maxilla, left frontoparietal, and presacral vertebrae, was mentioned in Tauber (1999). Agnolin (2012) proposed that the material actually belongs to *Calyptocephalella*.
- 2) Taxon B— *Calyptocephalella* sp. (formerly *Caudi-verbera*) CORD-PZ 1232 (right maxilla) was mentioned in Tauber (1999). Femicola and Albino (2012) revised this material and included other two records: MPM-PV 3712 (fragmentary frontoparietal and maxilla) and MPM-PV 3507 (fragmentary frontoparietal), assigning them to *Calyptocephalella* sp.

Locality 81: Río Pinturas, Pinturas Formation, Santa Cruz, Argentina.

Age and depositional environment: Early Miocene, Burdigalian (Kramarz and Bellosi 2005; Brandoni et al. 2019); aelolian pyroclastic (ash fall) or epiclastic (palaeodune sands) (Bown and Larriestra 1990).

Taxon and material: Agnolin (2012) mentioned the record of *Calyptocephalella* indet., based on the specimen “MACN PV ?” unnumbered (the kind of material was not detailed).

Locality 82: Laguna Blanca, Río Frías Formation, Santa Cruz, Argentina.

Age and depositional environment: Early to middle Miocene, Burdigalian-Langhian, ~16.5–14.8 Ma (Flynn and Swisher 1995; de la Cruz and Cortés 2011); fluvial (Bellosi et al. 2014).

Taxon and material: The holotype of *Gigantobatrachus parodii* (MLP 59-VII-30-1) was described and illustrated by

Casamiquela (1958). The material is composed of: left maxilla and premaxilla, frontoparietal, fragmentary mandible, fragmentary presacral vertebra, fragmentary right humerus, right maxilla and premaxilla, and nasal (Casamiquela 1958). Lynch (1971) suggested *Gigantobatrachus parodii* was a synonym of *Calyptocephalella gayi*. The species was treated as *Calyptocephalella parodii* in Sanchiz (1998). *G. parodii* was recovered within Calyptocephalellidae in Agnolin’s (2012) phylogeny, as sister to *G. casamiquelai*. The genus is currently valid (Agnolin 2012).

Locality 83: Río Guenguel, Río Frías Formation, Santa Cruz, Argentina.

Age and depositional environment: See the entry of locality 82.

Taxon and material: MLP 59-VII-30-2 fragmentary left maxilla, frontoparietal, fragmentary presacral vertebra, fragmentary left humerus, and fragmentary right maxilla were referred to *Gigantobatrachus parodii* by Casamiquela (1958).

Locality 84: C-A-53, Chucal Formation, Las Vicuñas National Reserve, Putre Parinacota, Chile.

Age and depositional environment: Early to late Miocene, Burdigalian-Tortonian, ~18.8–11.2 Ma (Flynn et al. 2002); floodplain and lacustrine (Charrier et al. 2002).

Taxon and material: Croft et al. (2007) mentioned the record of Anura indet. in a faunal list (the kind of material was not detailed).

Locality 85: Lif Mahuida, Collón Curá Formation, Neuquén Basin, Río Negro, Argentina.

Age and depositional environment: Early to late Miocene, Burdigalian-Tortonian, ~16.1–10.7 Ma (Cazau et al. 1989; Mazzoni and Benvenuto 1990; see also table 2 of Brandoni et al. 2017 for a review of geochronological data for this unit); fluvial to lacustrine, with pyroclastic influence (Figari et al. 2016).

Taxon and material: *Wawelia gerholdi* (holotype MLP 62-XII-7-1) was described and illustrated by Casamiquela (1963). Báez and Peri (1991) revised its osteological description and suggested that the fossil is actually related to Ceratophryidae. Agnolin (2012) recovered *Wawelia* within Ceratophryidae. Later, Nicoli et al. (2016) also revised the material and considered *Wawelia gerholdi* as a non-Ceratophryidae, and based on comparative studies suggested that the material represents a juvenile of *Calyptocephalella*.

Locality 86: Cruces Infinitos, Collón Curá Formation, Paso del Sapo Basin, Chubut, Argentina.

Age and depositional environment: Middle Miocene, Langhian-Serravalian, 14.86–12 Ma (Bucher et al. 2019); lacustrine to deltaic (Bucher 2018; Bucher et al. 2018).

Taxon and material: Bucher et al. (2021) referred to Anura indet. several remains (vertebrae, fragmentary maxilla, and cranial bones). The materials were neither described nor illustrated.

Locality 87: Los Yeguarizos, Collón Curá Formation, Paso del Sapo Basin, Chubut, Argentina.

Age and depositional environment: See the entry of locality 86.

Taxon and material: Bucher et al. (2021) referred to Anura indet. several undescribed remains (fragmentary maxilla, other cranial bones, and vertebrae).

Locality 88: La Gloria, Collón Curá Formation, Paso del Sapo Basin, Chubut, Argentina.

Age and depositional environment: See the entry of locality 86.

Taxon and material: Bucher et al. (2021) referred to Anura indet. several undescribed remains (fragmentary maxilla, other cranial bones, and vertebrae).

Locality 89: La Hoyada, Collón Curá Formation, Paso del Sapo Basin, Chubut, Argentina.

Age and depositional environment: See the entry of locality 86.

Taxon and material: Bucher et al. (2021) referred several remains (vertebrae, fragmentary maxilla, and cranial bones) to Anura indet. The materials were neither described nor illustrated.

Locality 90: Río Chico 2, Collón Curá Formation, Paso del Sapo Basin, Chubut, Argentina.

Age and depositional environment: See the entry of locality 86.

Taxon and material: Agnolin et al. (2021) described, figured, and identified LIEB-PV 8006-7 (incomplete right maxillae) and LIEB-PV 8008 (proximal end of urostyle) as Calyptocephalellidae indet.

Locality 91: La Venta, La Victoria Formation, Honda Group, Magdalena Valley, Colombia.

Age and depositional environment: Middle Miocene, Serravallian, ~13.5–11.6 Ma (Flynn et al., 1997); meandering fluvial (Guerrero 1997).

Taxon and material: Three lissamphibian taxa have been reported, as follows:

- 1) Taxon A—Gymnophiona indet. (three large and damaged anterior postatlantal vertebrae, and an incomplete atlas, without accession numbers) was partially figured and briefly described (Hecht and LaDuke 1997).
- 2) Taxon B—UC 41159, comprising a fragmentary skull, eight presacral vertebrae, scapulae, humeri, radioulnae,

two fragments of the acetabulum, femur, tibiofibulae, and right tibiale fibulare, was described and illustrated by Estes and Wassersug (1963), and identified as *Bufo marinus* (currently *Rhinella marina*).

- 3) Taxon C—Leptodactylidae indet. was mentioned in a faunal list by Savage (1951) and Hirschfeld and Marshall (1976), but the material was not described or illustrated, and this identification was not justified and this material should be revised. The most conservative identification of this material is indeterminate Anura.

Locality 92: Barranca de los Loros, Barranca de los Loros Formation, Santa Cruz, Argentina.

Age and depositional environment: Middle Miocene (Rodríguez et al. 2007); fluvial floodplain (Uliana 1979; Rodríguez et al. 2007).

Taxon and material: The materials MLP 61-IV-6-2, (skull fragment, sphenethmoid, six mandible fragments, scapulae, two right clavicles, fragmentary presacral vertebra, urostyle, pelvic girdle, three left femura, and tibiofibula) were referred to *Gigantobatrachus parodii* (Casamiquela, 1963).

Locality 93: Corralito, Urumaco Formation, Falcón Basin, Falcón State, Venezuela.

Age and depositional environment: Middle to late Miocene (Linares 2004); complex system of coastal lagoons (Díaz de Gamero 1996).

Taxon and material: Delfino and Sánchez-Vilagra (2018) described and figured the specimen AMU-CURS-726 (fused sacral vertebra and urostyle) as *Pipa* sp.

Locality 94: Talismã, Solimões Formation, Acre Basin, Brazil.

Age and depositional environment: Late Miocene (Cozzuol 2006); dynamic fluvial to lacustrine-swampy system without marine influx (Gross et al. 2011).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A—Pipidae indet. UFAC 6457/1766 (ilium and humeri) was mentioned in a conference abstract (Muniz et al. 2016).
- 2) Taxon B—UFAC 2060-3 (tibiofibulae and femurs) fragments were identified as Anura indet. in a conference abstract (Muniz et al. 2016).

Locality 95: Quehué, Cerro Azul Formation, Colorado Basin, La Pampa, Argentina.

Age and depositional environment: Late Miocene (Verzi et al. 2008); predominantly aeolian, but also scarce fluvial and lacustrine (Visconti et al. 2010).

Taxon and material: GHUNL Pam 8633 (fragmentary maxilla) was assigned to *Ceratophrys* (Scanferla and Agnolin,

2015), and later was described as a new fossil representative of *Lepidobatrachus* (Nicoli, 2017). A phylogenetic analysis by Gómez and Turazzini (2021) recovered GHUNL Pam 8633 within *Ceratophrys*, but those authors argued that placement was unreliable and instead suggested the specimen was better regarded as *Ceratophryidae* indet.

Locality 96: Ullum Valley, Loma de las Tapias Formation, San Juan, Argentina.

Age and depositional environment: Late Miocene, Tortonian-Messinian, ~9–5.33 Ma (Contreras and Baraldo 2010); alluvial plains and braided fluvial (Contreras and Baraldo 2010).

Taxon and material: *Ceratophryidae* indet. PVSJ 284 (fragmentary maxilla, premaxilla, and mandible) was mentioned in Contreras and Acosta (1998), and described and illustrated in Nicoli (2016). PVSJ 284 was suggested as belonging to the genus *Lepidobatrachus* (Nicoli, 2016), but Gómez and Turazzini (2021) argued it was better regarded as *Ceratophryidae* indet.

Locality 97: Arroyo Chasicó, Arroyo Chasicó Formation, Colorado Basin, Buenos Aires, Argentina.

Age and depositional environment: Late Miocene, Tortonian, 9.43–9.07 Ma (Zárate et al. 2007); fluvial (Zárate et al. 2007).

Taxon and material: *Ceratophrys* sp. MD-CH-06-165 (fragmentary interorbital portion and left maxilla). Urrutia and Rosset (2006) mentioned the specimen and it was later described and illustrated (Nicoli et al. 2017). The material was coded in Gómez and Turazzini's (2021) phylogeny and recovered in a polytomy within *Ceratophrys*.

Locality 98: Santa Rosa, Palo Pintado Formation, Payogastilla Group, Salta, Argentina.

Age and depositional environment: Late Miocene, Tortonian-Messinian (Zimicz et al. 2018); anastomosing fluvial (Zimicz et al. 2018).

Taxon and material: *Ceratophrys* sp. IBIGEO-P 99 (fragmentary skull) was mentioned in Gómez and Turazzini (2021).

Locality 99: Puerta de Corral Quemado, Andalhualá Formation, Catamarca, Argentina.

Age and depositional environment: Late Miocene, Messinian, ~7.14 Ma (Latorre et al. 1997; Esteban et al. 2014); floodplains (Bonini 2014).

Taxon and material: Marshall and Patterson (1981) listed the record of *Ceratophrys* sp. FMNH P 14402 (fragmentary skull). The material is currently lost (Nicoli 2019).

Pliocene

Locality 100: Río Seco de los Loros, Tunuyán Formation, Mendoza, Argentina.

Age and depositional environment: Early Pliocene (see Gomez and Turazzini 2021); Aeolian-alluvial (see Chiesa et al. 2019).

Taxon and material: The undescribed specimen *Lepidobatrachus* sp. IANIGLA.PV 112 (fragmentary skull and postcranial remains) was mentioned in a conference abstract (Turazzini 2015). It was referred to as *Lepidobatrachus* “new form”, and was recovered within the total group of *Lepidobatrachus* in Gómez and Turazzini's (2021) phylogeny.

Locality 101: Cascada Grande, Irene “Formation”, Quequén Salado Basin, Buenos Aires, Argentina.

Age and depositional environment: Early Pliocene (Isa et al. 2014); fluvial floodplains (Beilinson et al. 2017).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Rhinella* cf. *R. pisanoi* was described and illustrated by Casamiquela (1967). The specimen PVL 2197 (left frontoparietal, maxilla, sacrum, and a fragment of femur) was analysed and recovered within the intraspecific variation of *Rhinella arenarum* (Pérez-Ben et al., 2014).
- 2) Taxon B— Mercadal de Barrio and Barrio (2002) mentioned the specimen MLP 94.II.1.171. The material was later phylogenetically placed within *Ceratophrys aurita* species group and referred to as *Ce. cf. Ce. ameghinorum* (Gómez and Turazzini, 2021).

Locality 102: Farola Monte Hermoso, Monte Hermoso Formation, Buenos Aires, Argentina.

Age and depositional environment: Early Pliocene, Zanclean, ~5.8–4.5 Ma (Deschamps et al., 2012; Tomassini et al. 2013); fluvial (Zavala 1993; Zavala and Navarro 1993; Tomassini et al. 2013).

Taxon and material: Ten anuran taxa have been reported, as follows:

- 1) Taxon A— MACN 197317-19 (skulls) were identified as *Ceratophrys prisca* (Rovereto, 1914). Later, Fernicola (2001) revisited the material, describing, illustrating, and erecting a skull (MACN 14318) as the holotype of *Ceratophrys ameghinorum*. Other materials (MMP 892.M; MACN 197317, 197319; 14323-26, all of them skulls) were also referred to this species by Fernicola (2001). Those materials were coded in Gómez and Turazzini's (2021) phylogeny (except MMP 892.M) and recovered in a polytomy with the *Ce. aurita* species group.
- 2) Taxon B— MLP 48.XII.16.195 (fragmentary right maxilla) was mentioned as *Ceratophrys* sp. in Mercadal de Barrio and Barrio (2002), and as *Ceratophrys* cf. *Ce. ameghinorum* by Gómez and Turazzini (2021). In the

supplementary material, Gómez and Turazzini (2021) erroneously listed the specimen as MLP 48.VII.16.195, instead of MLP 48.XII.16.195. MACN 14322/25 (fragmentary skull) was mentioned by Fericola (2001) as *Ceratophrys ameghinorum*, and later the species was referred to as *Ceratophrys* sp. (Mercadal de Barrio and Barrio, 2002). Those materials were reassessed in Nicoli (2019) and phylogenetically placed as *Ceratophrys ameghinorum* (Gómez and Turazzini, 2021).

- 3) Taxon C— Ameghino (1899) briefly described *Ceratophrys prisca* (skull), but did not indicate the collection identification or its repository. The holotype of *Ceratophrys prisca* is currently lost and *species inquirenda* (Fericola, 2001). The material mentioned by Rovereto (1914) may be the same specimen described by Ameghino (1899) (Rovereto, 1914; Nicoli, 2019), but Ameghino (1899) did not illustrate it, and due to the insufficient description of *Ceratophrys prisca*, it was not possible to solve this problem (Reig 1958b).
- 4) Taxon D— Bufonidae indet. (the kind of material was not detailed) was briefly mentioned by Tomassini et al. (2013). The material was neither described nor illustrated.
- 5) Taxon E— Two specimens (the kind of material was not detailed) of *Rhinella* cf. *R. pisanoi* (currently *Rhinella arenarum*) were mentioned by Tomassini and Montalvo (2013). Later, this identification was doubted by Barcelos and Verdade (2020a).
- 6) Taxon F— *Rhinella* cf. *R. schneideri* (the kind of material was not detailed) was mentioned by Tomassini et al. (2013).
- 7) Taxon G— Rovereto (1914) suggested that the specimens MACN 14317 and MACN 14319 (fragmentary skulls) were referred to as *Ceratophrys prisca*. The materials were later designated as paratypes of *Ceratophrys ameghinorum* (Fericola, 2001), and recovered as representatives of that species (Gómez and Turazzini 2021).
- 8) Taxon H— *Ceratophrys ameghinorum* MMH 84.1.15 (skull, vertebral column and dorsal shield) was mentioned by Fericola (2001) and Gómez and Turazzini (2021). *Ceratophrys ameghinorum* MACN 19731 (skull, left mandible, left humerus, scapulae, coracoids, clavicles, first and second, presacral vertebrae and part of the dorsal shield) and MACN 14324 (fragmentary skull, vertebral column, and dorsal shield) were proposed as the paratypes of *Ceratophrys ameghinorum* (Fericola, 2001). In a phylogenetic analysis, two of those specimens (MACN 14324 and MACN 19731) were placed within *C. ameghinorum* (Gómez and Turazzini, 2021).
- 9) Taxon I— Tomassini et al. (2011) mentioned MMH 85.12.2a (fragmentary skull) as a new fossil representative of *Lepidobatrachus laevis*. Later the material was

reassessed and proposed to be a new extinct species, *Lepidobatrachus australis* Nicoli, 2015 (holotype MMH 85.12.2a). The material was nested within the total group of *Lepidobatrachus* (Gómez and Turazzini, 2021).

- 10) Taxon J— *Leptodactylus* sp. MLP 87-II-25-5 (ilium) and MLP 87-II-25-6 (sacrum) described and illustrated by Gómez et al. (2013).

Locality 103: Paso del Río Arriba Cliffs, Brochero Formation, Córdoba, Argentina.

Age and depositional environment: Pliocene (Cruz 2013); meandering fluvial (Cruz et al. 2018).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Cruz et al. (2018) mentioned the record of MCNC-PV 307 (right nasal, two left maxillae, two left frontoparietals, maxillae, right frontoparietal, right maxilla, left pterygoid, left cleitrum, right scapula, left humerus, four presacral vertebrae, two sacral vertebrae, urostyle, and ischium) assigning it to *Rhinella* cf. *R. arenarum*. The material was neither described nor illustrated. Later, this identification was doubted by Barcelos and Verdade (2020a).
- 2) Taxon B— *Rhinella* cf. *R. spinulosa* MCNC-PV 308 (sacral vertebra) was mentioned, but was neither described nor illustrated (Cruz et al. 2018). Later, this identification was doubted by Barcelos and Verdade (2020a).

Locality 104: Laguna Inca Coya, San Francisco de Chiu Chiu, Chiu Chiu Formation, Antofagasta, Chile.

Age and depositional environment: Pliocene to Late Pleistocene (May et al. 2010); fluvial to lacustrine (May et al. 2010).

Taxon and material: Suazo-Lara et al. (2018) mentioned in a conference abstract the record of Telmatobiidae indet. (first presacral vertebra, a sacral vertebra, clavicle, coracoids, scapula, humerus, radioulna, left ilium, and phalanges).

Locality 105: Chapadmalal, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: Middle Pliocene, Zanclean-Piacenzian, ~4.5–3.2 Ma (Zárate 2005); Fluvial floodplains (Zárate and Fasano 1989).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Reig (1958b) briefly mentioned the record of isolated skull fragments referred to as *Ceratophrys ornata*.
- 2) Taxon B— Mercadal de Barrio and Barrio (2002) mentioned the record of *Ceratophrys* sp. MACN 18074 (left

maxilla and right squamosal). Later, the specimen was described and illustrated by Nicoli (2019), and identified as *Ce. cf. Ce. ameghinorum* by Gómez and Turazzini (2021).

Locality 106: Barranca de Los Lobos, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: MMP 664.S (skull) was assigned to *Ceratophrys ameghinorum* (Femicola 2001), and later to *Ceratophrys* sp. (Mercadal de Barrio and Barrio, 2002).

Locality 107: Playa de los Lobos, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: MMP 664.M (skull) and MMP 1063.M (skull and mandible) were assigned to *Ceratophrys ameghinorum* (Femicola, 2001), and later to *Ceratophrys* sp. (Mercadal de Barrio and Barrio, 2002). The materials were neither described nor illustrated.

Locality 108: Arroyo Lobería, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: Mercadal de Barrio and Barrio (2002) mentioned the record of *Ceratophrys* sp. MACN 17585 (left maxilla). Later, the specimen was described and illustrated (Nicoli, 2019), and identified as *Ce. cf. Ce. ameghinorum* (Gómez and Turazzini, 2021).

Locality 109: Punta Lobería, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Mercadal de Barrio and Barrio (2002) mentioned the specimen MACN 17936 (two skull fragments). This material was described and illustrated by Nicoli (2019) and referred to as *Ceratophrys* sp. Later, MACN 17936 was identified as *Ce. cf. Ce. ameghinorum* (Gómez and Turazzini, 2021). MACN Pv 17911 (fragmentary skull) was coded in the data matrix of Gómez and Turazzini (2021) and referred to as *Ceratophrys cf. Ce. ameghinorum*. The material was not described but only illustrated (Gómez and Turazzini 2021).
- 2) Taxon B— *Rhinella loba* MMP 1003 (holotype, fragmentary skull) was described and illustrated (Pérez-Ben et al. 2019a).

Locality 110: Barranca Parodi, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Ceratophrys* sp. MLP 88.V.20.1 (fragmentary skull) was mentioned in Mercadal de Barrio and Barrio (2002) as *Ceratophrys* sp. Those materials were described and figured in Nicoli (2019), and were referred to as *Ceratophrys* sp. by Nicoli (2019), and as *Ceratophrys* aff. *Ce. ameghinorum* ‘new form B’ by Gómez and Turazzini (2021).
- 2) Taxon B— MACN 17785 (fragmentary left humerus), MLP 89.XII.35.25 (fragmentary skull and mandible, fragmentary humerus, partial pelvis, and femur) were referred to as *Ceratophrys* sp. (Gómez and Turazzini, 2021).

Locality 111: Bajada de Los Lobos, Playa Los Lobos Alloformation, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— MMP 733 (fragmentary skull) was coded in the data matrix of Gómez and Turazzini (2021) and referred to as *Ceratophrys cf. Ce. ameghinorum*. The material was neither described nor illustrated.
- 2) Taxon B— *Lepidobatrachus cf. L. australis* MMP 4680 (fragmentary skull) was figured and phylogenetically placed within *Lepidobatrachus* (Gómez and Turazzini, 2021). The material is presumably from Playa Los Lobos Alloformation.

Locality 112: Las Brusquitas, Playa Los Lobos Alloformation, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: *Ceratophrys* sp. MPH.P0124 (fragmentary skull) was briefly described and figured in Cenizo et al. (2016). Gómez and Turazzini (2021) mentioned the reference as Cenizo et al. (2015) instead of Cenizo et al. (2016). Later, MPH.P0124 was included in the phylogeny of Gómez and Turazzini (2021) and referred to as *Ceratophrys cf. Ce. ameghinorum*.

Locality 113: La Estafeta, Playa Los Lobos Alloformation, Chapadmalal Formation, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 105.

Taxon and material: Gómez and Turazzini (2021) figured and coded the specimen MLP 97-V-1-19 (fragmentary skull) in their phylogeny and referred to it as *Ceratophrys*

aff. *Ce. ameghinorum* 'new form A'. The material was not described.

Locality 114: Norte Casa Chiguaje, Vergel Member, San Gregorio Formation, Falcón Basin, Falcón, Venezuela.

Age and depositional environment: Late Pliocene (Carrillo-Briceño et al., 2021); fluvial (Hambalek et al. 1994).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— AMU-CURS-722 (sacral vertebra fused to a fragmented urostyle) as cf. *Pipa* sp. by Carrillo-Briceño et al. (2021).
- 2) Taxon B— AMU-CURS-723, 1149, 1162, and 1165–1166, 1150-53, and 807 (cranial and postcranial remains) were referred to as *Anura* indet. by Carrillo-Briceño et al. (2021).

Locality 115: Punta Vorohué, Vorohué Formation, Buenos Aires, Argentina.

Age and depositional environment: Late Pliocene to Early Pleistocene (Barbière et al. 2021); aeolian (loessic) (Kraglievich 1952).

Taxon and material: Mercadal de Barrio and Barrio (2002) mentioned MLP 34.V.10.8 (fragmentary maxilla), assigning it to *Ceratophrys* sp. without explanation. The material was later described and figured (Nicoli 2019), corroborating the taxonomic identification of Mercadal de Barrio and Barrio (2002). *Ceratophrys* sp. MLP 34.V.10.8 was referred to as *Ce.* cf. *Ce. ameghinorum* by Gómez and Turazzini (2021).

Locality 116: San Roque, Humahuaca, Uquía Formation, Jujuy, Argentina.

Age and depositional environment: Late Pliocene to Pleistocene, Piacenzian-Calabrian, ~3.54-1.5 Ma (Marshall et al. 1982; Pingel et al. 2013); braided fluvial (Reguero et al. 2007).

Taxon and material: Cf. *Rhinella* sp. PVL 6450-3 (12 frontoparietals, seven parasphenoids, two pterygoids, and 12 fragments of otoccipitals), PVL 56-57 (67 vertebrae and seven atlases) were described and illustrated (Ortiz et al. 2012).

Pleistocene

Locality 117: Punta San Andres, Punta San Andres Alloformation, Buenos Aires, Argentina.

Age and depositional environment: Early Pleistocene (Gómez and Turazzini 2021).

Taxon and material: *Anura* indet. MACN 19659 (premaxilla, fragmented maxilla and partial postcranium) was mentioned by Quintana (1994). The material was later referred to as *Ce. ornata* by Gómez and Turazzini (2021).

Locality 118: Olivos, Ensenada Formation, Buenos Aires, Argentina.

Age and depositional environment: Early to Middle Pleistocene (Verzi et al. 2004); aeolian (Tonni et al. 1999a).

Taxon and material: *Ceratophrys ensenadensis* PVL 699 (holotype, skull) and PVL 767 (postcranial) was described by Rusconi (1932), but this assignment was later doubted (Nicoli 2019), and suggested as *species inquirenda* (Nicoli 2019). Later, it was phylogenetically allocated and interpreted as a fossil representative of *Ce. ornata* by Gómez and Turazzini (2021).

Locality 119: GADA 601, Buenos Aires Formation, Mar del Plata, Buenos Aires, Argentina.

Age and depositional environment: Middle Pleistocene (Turazzini et al. 2016); fluvial (Turazzini et al. 2016).

Taxon and material: MMP 5355 (right ilium) was described and illustrated by Turazzini et al. (2016), and was referred to as *Odontophrynus* aff. *O. americanus* or *O. cordobae*.

Locality 120: Mene de Inciarte Tar Pits, Sierra de Perijá, Mara, Venezuela.

Age and depositional environment: Pleistocene (Urbani and Galarraga 1991); asphalt lake (Rincón et al. 2008).

Taxon and material: Rincón et al. (2006) mentioned the presence of three specimens of *Anura* (the kind of material was not detailed). The specimens were neither described nor illustrated.

Locality 121: Cerro Pintado, Cueva de los Huesos, Sierra de Perijá, Venezuela.

Age and depositional environment: Pleistocene (Schubert 1975); cave (Rodríguez and Galán 2008).

Taxon and material: Rincón (2000) mentioned in a conference abstract the record of specimens assigned to Leptodactylidae, and *Anura* (both skulls). The specimens were neither described nor illustrated.

Locality 122: Curití, Santander, Colombia.

Age and depositional environment: Pleistocene (Porta 1969); fissure deposit (Porta 1969).

Taxon and material: Bufonidae indet. (the kind of material was not detailed) was mentioned by Porta (1969) in a faunal list.

Locality 123: General Pueyrredón, Miramar Formation, Mar del Plata, Buenos Aires, Argentina.

Age and depositional environment: Pleistocene (Cione and Tonni 2005); fluvial and subaerial (Kraglievich 1952).

Taxon and material: *Ceratophrys* sp. MLP 88.VII.20.1 and MLP 88.VII.20.2 (fragmentary skulls) was mentioned by Mercadal de Barrio and Barrio (2002). These remains were also identified as *Ceratophrys* sp. by Nicoli (2019). Later, this material was coded in the phylogeny of Gómez and Turazzini (2021) and referred to as *Ceratophrys* cf. *Ce. ameghinorum*.

Locality 124: Mar Chiquita, Playa Dorada (Playa Santa Elena), Miramar Formation, Mar del Plata, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 123.

Taxon and material: Agnolin (2005) described and illustrated the species *Ceratophrys rusconii* MACN 19744 (holotype, fragmentary skull). The material was reassessed and its species status was doubted (Nicoli 2019). This specimen was coded in Gómez and Turazzini (2021) phylogeny and recovered as a fossil representative of *Ce. ornata*.

Locality 125: Tarija, Tolomosa Formation, Tarija, Bolivia.

Age and depositional environment: Late Pleistocene, 0.76 ± 0.03 Ma (MacFadden et al. 2013); fluvial to lacustrine (Suárez-Montero 1996).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— Vergnaud-Grazzini (1968) described and illustrated the specimen *Bufo marinus* MNHN unnumbered (skull). The material was reassessed, and its anatomical description was updated in Barcelos and Verdade (2020a). The material was coded in the matrix of Pramuk (2006) and recovered nested in a polytomy within the *Rhinella marina* species group (Barcelos and Verdade 2020a).
- 2) Taxon B— Vergnaud-Grazzini (1968) described and illustrated the specimen *Ceratophrys* sp. MNHN unnumbered, a fragmentary skull.
- 3) Taxon C— Hoffstetter (1963) mentioned the presence of procoelous vertebrae of *Anura* indet. The material was neither described nor illustrated and it is currently lost.

Locality 126: Centinela del Mar, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene, ~120 ka (Isla et al. 2010); shallow lacustrine (Báez et al. 2008).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— Pipidae indet. MLP 04-V-2-220 (three sacro-urostyle complexes and two incomplete ilia) was described and illustrated by Báez et al. (2008). The Alloformation for this specimen was not specified.
- 2) Taxon B— Ceratophryidae indet. MLP 04-V-2-704 (right ilium), MLP 04-V-2-705 (right squamosal), MLP 04-V-2-701 (skull, lower jaw, hyoid, and several postcranial bones), and MLP 04-V-2-702 (fragmentary skull) were mentioned by Gómez and Turazzini (2021). Those materials were neither described nor illustrated. MLP 04-V-2-704 comes from the Punta San Andres Alloformation, whereas MLP 04-V-2-705 and MLP 04-V-2-702 are from

Centinela del Mar Alloformation (Gómez and Turazzini 2021).

- 3) Taxon C— *Ceratophrys* sp. MLP 04-V-2-703 (fragmentary left mandible), from Centinela del Mar Alloformation, was mentioned by Gómez and Turazzini (2021).

Locality 127: Locality n° 2, San Sebastian Formation, Quebrada de Cachimayu, Cuzco Valley, Peru.

Age and depositional environment: Late Pleistocene, 43 ka (Frailey and Campbell 1980); lacustrine and fluvial (Mendivil and Manrique 1994).

Taxon and material: KUVF 49566 (right humerus) *Bufo spinulosus* (*Rhinella spinulosa*) was described and illustrated by Frailey and Campbell (1980).

Locality 128: Campo Spósito (San Pedro in Gómez and Turazzini 2021), Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene, ~41.5–37.6 Ka (Gasparini et al. 2016); fluvial and aeolian (loess) (Brambilla et al. 2019).

Taxon and material: MPS 127 (fragmentary skull) was figured and referred to as *Ceratophrys* aff. *Ce. ameghinorum* ‘new form B’ by Gómez and Turazzini (2021).

Locality 129: Gruta do Ioiô, Chapada Diamantina, Bahia, Brazil.

Age and depositional environment: Late Pleistocene, ~22–19.98 ka (Castro et al. 2014); cave (Castro et al. 2014).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— Muniz et al. (2020) mentioned in a conference abstract the record of a femur, three humeri, and a tibio-fibula referred to as *Anura* indet.
- 2) Taxon B— Muniz et al. (2020) mentioned in a conference abstract the record of a fragmentary skull referred to as *Rhinella* sp.
- 3) Taxon C— Muniz et al. (2020) mentioned in a conference abstract the record of an ilium referred to as *Rhinella jimi*.

Locality 130: Talara, Tar Seeps, Piura, Peru.

Age and depositional environment: Late Pleistocene, ~14.418–13.616 ka (Churcher 1966); asphalt lake (Alván et al. 2009).

Taxon and material: Seymour (2015) mentioned the presence of 13 specimens of Bufonidae and one of Ranidae (the kind of material was not detailed). The specimens were neither described nor illustrated.

Locality 131: ORS20 tar pit, El Breal de Orocuál, Monagas, Venezuela.

Age and depositional environment: Late Pleistocene (Solórzano et al. 2015); asphalt lake (Solórzano et al. 2015).

Taxon and material: Solórzano et al. (2015) mentioned the record of an indeterminate Lissamphibia (the kind of material was not detailed). The specimens were neither described nor illustrated.

Locality 132: Mariano Acosta, Reconquista River Basin, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene (Agnolin and Jofré 2011); fluvial to lacustrine (Agnolin and Jofré 2011).

Taxon and material: Four anuran taxa have been reported, as follows:

- 1) Taxon A—*Leptodactylus* sp. was mentioned in a conference abstract (Turazzini et al. 2015). This postcranial remain was not specified in more detail.
- 2) Taxon B—Pipidae indet. was mentioned in a conference abstract (Turazzini et al. 2015). This postcranial remain was not specified in more detail.
- 3) Taxon C—Odontophrynidae indet. was mentioned in a conference abstract (Turazzini et al. 2015). This postcranial remain was not specified in more detail.
- 4) Taxon D—*Rhinella* sp. was mentioned in a conference abstract (Turazzini et al. 2015). This postcranial remain was not specified in more detail.

Locality 133: Yacimiento Constitución, Unit F, Santa Clara Formation, Mar del Plata, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene (Bidegain et al. 2005); lacustrine (Fasano et al. 1994).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A—*Ceratophrys ornata* MMP 4844 (skull fragments) were mentioned in Gómez and Turazzini (2021). Those materials were not described or illustrated.
- 2) Taxon B—Postcranial remains assigned to *Pseudis* sp. were mentioned in a conference abstract (Turazzini et al. 2014). This assignment was justified by a set of diagnostic features.
- 3) Taxon C—Around 1,000 postcranial materials of Anura were also collected and mentioned as putative representatives of Ceratophryidae, Odontophrynidae, Bufonidae, Hylidae, and Leptodactylidae (Turazzini et al. 2014).

Locality 134: Ñuapua, Ñuapua Formation, Chuquisaca, Bolivia.

Age and depositional environment: Late Pleistocene to early Holocene (Hoffstetter 1968; Marshall et al. 1984); lacustrine (Marshall et al. 1984).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A—Vergnaud-Grazzini (1968) described and illustrated material (skull, humerus, scapula, atlas, sacral vertebra, and ilium) of *Bufo paracnemis* (*Rhinella diptycha* in the current taxonomy).
- 2) Taxon B—Vergnaud-Grazzini (1968) described and illustrated the specimen (six presacral vertebrae, scapula, clavicle and coracoid, urostyle, and sacral vertebra) of *Leptodactylus* cf. *L. ocellatus* (currently *Leptodactylus bolivianus*).
- 3) Taxon C—Vergnaud-Grazzini (1968) described and illustrated a specimen (fragmentary skull) of *Ceratophrys ornata*. The material was later identified as *Ceratophrys* sp. (Nicoli, 2019).

Locality 135: Gruta do Urso, Aurora do Tocantins, Tocantins, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Castro et al. 2013); cave (Castro et al. 2013).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A—Barcelos et al. (2019) mentioned in a conference abstract the record of 200 specimens assigned to indeterminate Anura. The specimens were neither described nor illustrated.
- 2) Taxon B—Barcelos et al. (2019) referred to five fragmentary ilia as indeterminate Odontophrynidae. This assignment was justified by a set of diagnostic features.

Locality 136: Daireaux, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene to early Holocene (Cione and Tonni 2005); fluvio-lacustrine (Isla et al. 2010).

Taxon and material: All specimens were collected from ‘Unit B’ of Báez et al. (2012a). Three anuran taxa have been reported, as follows:

- 1) Taxon A—Pipidae indet. MMP M-5121 (ilium) was described and illustrated by Báez et al. (2012a).
- 2) Taxon B—*Rhinella arenarum* MMP 5119 (fragmentary skull, four presacral vertebrae, urostyle, cleithrum, radioulna, ilium, tibiofibula, and phalanges) was described and illustrated by Pérez-Ben et al. (2019b).
- 3) Taxon C—*Ceratophrys ornata* MMP 4846 (fragmentary maxilla) was described and illustrated by Pérez-Ben et al. (2019b).

Locality 137: Riacho Verde Paleontological Site, Ouro Branco, Rio Grande do Norte, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Araújo-Júnior et al. 2016); tank deposit (Araújo-Júnior et al. 2016).

Taxon and material: *Rhinella jimi* UERN PV-50 (tibiale and fibulare) was described and illustrated by Araújo-Júnior et al. (2016).

Locality 138: João Cativo, Itapipoca, Ceará, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Araújo-Júnior and Moura 2014); tank deposit (Ximenes 2008).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Rhinella schneideri* MN 3288-V (ilium) was described and illustrated (Araújo-Junior and Moura 2014). Later, this identification was doubted by Barcelos and Verdade (2020a).
- 2) Taxon B— Material assigned to *Rhinella jimi*, including MN 3274-V, and MN 3287-V (both ilia), MN 3278-V, and MN 3285-V (both tibiofibulae), MN 3283-V, and MN 3286-V (both femura), were described and illustrated by Araújo-Junior and Moura (2014). Later, this identification was doubted by Barcelos and Verdade (2020a).

Locality 139: Versalles Cave, Apiaí, São Paulo, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Barcelos et al. 2020); cave (Barcelos et al. 2020).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Barcelos et al. (2020) described and illustrated *Ceratophrys sagani* ZUFABC 037-f (holotype, skull).
- 2) Taxon B— *Ceratophrys aurita* ZUFABC 038-f (fragmentary skull) was described and illustrated in Barcelos and Verdade (2022).

Locality 140: G. Chávez, Laguna de Los Tres Reyes, La Postrera Formation, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene to early Holocene (Tonni and Fidalgo 1978); aeolian (Johnson et al. 2012).

Taxon and material: *Ceratophrys* sp. MLP 86.VIII.1.5/6 (skull) and *Ceratophrys ornata* MLP 86.VIII.1.4 (skull) were described and illustrated by Peri (1993). The materials were coded in Gómez and Turazzini's (2021) phylogeny and recovered as representatives of the extant species *Ceratophrys ornata*.

Locality 141: Arroyo Perico Flaco, Dolores Formation, Uruguay.

Age and depositional environment: Late Pleistocene to early Holocene, ~30.1–10.48 ka (Ubilla and Martínez 2016); aeolian (Ubilla and Martínez 2016).

Taxon and material: *Leptodactylus* sp. was mentioned in a conference abstract (Mones 1975) and in a book chapter (Ubilla et al. 2011). The kind of material was not specified.

Locality 142: Conchillas, Dolores Formation, Uruguay.

Age and depositional environment: See the entry of locality 141.

Taxon and material: *Ceratophrys* sp. MNHN 1560 (maxilla) was described and illustrated by Rinderknecht (1998). Later, it was also mentioned in a book chapter (Ubilla et al. 2011), and referred to as *Ceratophrys* cf. *Ce. ornata* by Gómez and Turazzini (2021).

Locality 143: Lago de Tagua Tagua, Tagua Tagua Formation, Cochamo, Los Lagos, Chile.

Age and depositional environment: Late Pleistocene to early Holocene, ~13,590–11,170 ka (Valero-Garcés et al. 2005); lacustrine (Labarca et al. 2020).

Taxon and material: Six anuran taxa have been reported, as follows:

- 3) Taxon A— Labarca et al. (2020) mentioned the record of 559 bone fragments referred to Anura indet. The materials were not specified in more detail.
- 4) Taxon B— Labarca et al. (2020) described and referred SGO.PV.20638 (scapula) to *Rhinella* sp.
- 5) Taxon C— 840 isolated bones, including fossils of tadpoles, juveniles, and adults were assigned to the extant species *Calyptocephalella gayi* (Labarca et al., 2020)
- 6) Taxon D— The unpublished specimen SGO.PV.26203 (skull) was referred to as *Calyptocephalella* sp., and considered as a new fossil species in a conference abstract (Suazo-Lara et al. 2020).
- 7) Taxon E— Suazo-Lara (2019) mentioned in his MSc thesis the record of 3.500 isolated bone fragments assigned to indeterminate anurans. The materials were not specified in more detail.
- 8) Taxon F— Suazo-Lara (2019) mentioned in his MSc thesis the record of postcranial remains of *Calyptocephalella*.

Locality 144: Quereo, Quebrada Quereo Formation, Coquimbo, Chile.

Age and depositional environment: Late Pleistocene to early Holocene, 11.1 ± 150 ka (Núñez et al. 1987); sandy beaches in the meanders (Núñez et al. 1994).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— Núñez et al. (1987) mentioned the record of *Rhinella spinulosa* sp. (formerly *Bufo spinulosus*; the kind of material was not detailed). Those materials were neither described nor illustrated and are currently lost (Jimenez-Huidobro and Sallaberry 2015).
- 2) Taxon B— Jimenez-Huidobro and Sallaberry (2015) and Núñez et al. (1987) mentioned the record of Bufonidae indet (the kind of material was not detailed). Those materials were neither described nor illustrated.

Locality 145: Barrancas del río Salto-Arrecifes, Lujan Formation, Salto-Arrecifes Basin, Buenos Aires, Argentina.

Age and depositional environment: Late Pleistocene to early Holocene (Bogan et al. 2010); fluvial (Bogan et al. 2010).

Taxon and material: MMS 1349 (fragmentary squamosal) was described and illustrated, being identified as *Ceratophryidae* indet. (Bogan et al. 2010). It was also mentioned in Gómez and Turazzini (2021).

Locality 146: Toca dos Ossos Cave, Ouarolândia, Bahia, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Lessa et al. 1998); cave (Lessa et al. 1998).

Taxon and material: 256 bone fragments were referred to *Anura* indet. (Scherer et al. 2012) in a conference abstract. The materials were not specified in more detail.

Locality 147: Ponta de Flecha Abyss, Iporanga, São Paulo, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Chahud 2001); cave (Chahud 2001).

Taxon and material: The ilia MZUSP 5/6-P and MZUSP 9-P were mentioned in a conference abstract and referred to *Anura* indet. (Chahud 2005).

Locality 148: Gêmeo Abyss, Iporanga, São Paulo, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Chahud 2001); cave (Chahud 2001).

Taxon and material: Five anuran taxa have been reported, as follows:

- 1) Taxon A—MZUSP 1-P (8 ilia) and MZUSP 2-P (31 ilia) were referred to *Brachycephalidae* indet. in an undergraduate thesis (Pinto, 2010).
- 2) Taxon B—MZUSP 4-P (ilium) was assigned to *Centrolene* sp. in an undergraduate thesis (Pinto 2010).
- 3) Taxon C—MZUSP 8-P (ilium) was assigned to *Bufo* sp. in an undergraduate thesis (Pinto, 2010).
- 4) Taxon D—MZUSP 7-P (ilium) was assigned to *Hypsiboas faber* (*Boana faber*) in an undergraduate thesis (Pinto, 2010).
- 5) Taxon E—MZUSP 3-P (ilium) was identified as *Leptodactylus* sp. in an undergraduate thesis (Pinto, 2010).

Locality 149: Lagoa Santa caves, Minas Gerais, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Hubbe et al. 2009); cave (Hubbe et al. 2009).

Taxon and material: Five anuran taxa have been reported, as follows:

- 1) Taxon A—*Ceratophrys cornuta* NHMUK 18896 (skull) and 18896 a, b, c (skull, fragmentary maxilla, and

fragmentary skull, respectively) were described and illustrated by Günther (1859), and also later mentioned by Lydekker (1890). The materials were subsequently suggested as *Ceratophrys aurita* (e.g. Lynch 1971), and Barcelos et al. (2020) justified that hypothesis based on the presence of diagnostic characters for this species. Most recently, these specimens were phylogenetically placed within *Ce. aurita* (Gómez and Turazzini 2021).

- 2) Taxon B—*Leptodactylus pentadactylus* NHMUK 18895a, b, c, d, e, f, g (left humerus, radioulnae, femora, tibiofibulae) were described by Günther (1859) and mentioned by Lydekker (1890) and Lynch (1971).
- 3) Taxon C—*Leptodactylus ocellatus* NHMUK 18895 h, i, j, j' (humeri, radioulnae) were described by Günther (1859) and mentioned by Lydekker (1890) and Lynch (1971).
- 4) Taxon D—*Leptodactylus* sp. NHMUK 18895 k, l, m, n, o, p, q, r (parasphenoid, radioulna, humeri, femur, tibiofibulare, ilium, and presacral vertebra) were described by Günther (1859) and mentioned by Lydekker (1890) and Lynch (1971).
- 5) Taxon E—*Anura* indet. (tibiofibula, and presacral vertebra) was mentioned in an undergraduate thesis (Purcino 2015). This material was recovered near the municipality of Prudente de Morais.

Locality 150: Lapa da Escrivantina, Minas Gerais, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Hubbe et al. 2009); cave (Hubbe et al. 2009).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A—The ancient DNA of a subfossil (the kind of material was not detailed) was sequenced and assigned to *Rhinella* sp. (Seersholm et al., 2021).
- 2) Taxon B—The ancient DNA of a subfossil (the kind of material was not detailed) was sequenced and assigned to (*Hypsiboas*) *Boana* sp. (Seersholm et al., 2021).
- 3) Taxon C—The ancient DNA of a subfossil (the kind of material was not detailed) was sequenced and assigned to *Leptodactylus* sp. (Seersholm et al., 2021).

Locality 151: Vale do Rio das Velhas caves, Lagoa Santa, Minas Gerais, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Hubbe et al. 2009); cave (Hubbe et al. 2009).

Taxon and material: *Pipa* sp. (skull) was mentioned in Liais (1872). This material is currently lost (Sanchiz 1998; Delfino and Sanchéz-Villagra 2018).

Locality 152: Gruta Bauzinho de Ossos, Lagoa Santa, Minas Gerais, Brazil.

Age and depositional environment: Late Pleistocene to early Holocene (Hubbe et al. 2009); cave (Hubbe et al. 2009).

Taxon and material: Perónico and Araújo (2002) mentioned the record of *Anura* indet., based on the specimen MCN-PUCMG unnumbered, which includes a tibiofibula and presacral vertebra.

Locality 153: Ex Laguna de Tagua Tagua, Formación Taguatagua, O'Higgins, Chile.

Age and depositional environment: Late Pleistocene to early Holocene (Jimenez-Huidobro and Sallaberry 2015); lacustrine (Jimenez-Huidobro and Sallaberry 2015).

Taxon and material: *Calyptocephalella* sp. SGO.PV.411.j (frontoparietal), SGO.PV.429.a (maxilla), SGO.PV.429.b (mandible), SGO.PV.431.w and SGO.PV.438.c (both scapulae), SGO.PV.428.a and SGO.PV.432.a (both coracoids), SGO.PV.427.i (ilium), SGO.PV.419.k and SGO.PV.440.d (both ischia), SGO.PV.410.a and SGO.PV.420.f (both humeri), SGO.PV.411.e and SGO.PV.437.f (both radioulnae), were described and illustrated by Jimenez-Huidobro and Sallaberry (2015).

Holocene

Locality 154: Miramar, La Postrera Formation, Buenos Aires, Argentina.

Age and depositional environment: Early Holocene, ~10.8–0.44 ka (Tonni 1990); aeolian (Tonni et al. 1999b).

Taxon and material: *Ceratophrys* sp. MLP 52.IX.27.11 (incomplete skull) was referred to as *Ce. ornata* by Frenguelli (1921), *Ce. ameghinorum* by Fernicola (2001), and was listed in Mercadal de Barrio and Barrio (2002). Later, Nicoli (2019) suggested the specimen be referred to as *Ceratophrys* sp. justifying the taxonomic identification based on the presence of diagnostic features.

Locality 155: Camping Americano, Monte Hermoso Formation, Buenos Aires, Argentina.

Age and depositional environment: Early Holocene, ~9 ka (Pardiñas 2001); interdune shallow ponds (Pardiñas 2001).

Taxon and material: Two anuran taxa have been reported, as follows:

- 1) Taxon A— *Ceratophrys ornata* MMH 85.3.8 and MMH 85.2.11 (both frontoparietals), MMH 88.2.5 and MMH 90.2.1 (both humeri) were mentioned by Pardiñas (2001). The subfossils were neither described nor illustrated and are currently lost (Nicoli 2019). These materials were later referred to as *Ce. cf. Ce. ornata* by Gómez and Turazzini (2021).

- 2) Taxon B— *Ceratophrys* sp. MLP 136 (skull) and MLP 247 (skull) were mentioned in Fernicola (2001) as extant specimens of *Ceratophrys ornata*, later the specimens were referred to as Pleistocene fossil representatives of *Ceratophrys* sp. (Mercadal de Barrio and Barrio 2002). Most recently, Gómez and Turazzini (2021) regarded the specimens as subfossils representative of *Ceratophrys ornata*.

Locality 156: Barrancas del Río Lujan, Pampeano Formation, Buenos Aires, Argentina.

Age and depositional environment: Early Holocene (Lezcano et al. 1993; Fucks and Deschamps 2008); fluvio-lacustrine (Lezcano et al. 1993).

Taxon and material: Three anuran taxa have been reported, as follows:

- 1) Taxon A— Lezcano et al. (1993) mentioned in a conference abstract the record of *Leptodactylus* cf. *L. ocellatus*. The subfossils (the kind of material was not detailed) were neither described nor illustrated.
- 2) Taxon B— Lezcano et al. (1993) mentioned subfossils (the kind of material was not detailed) referred to as *Bufo* cf. *B. arenarum*.
- 3) Taxon C— Lezcano et al. (1993) mentioned subfossils (the kind of material was not detailed) referred to as cf. *Ceratophrys* sp.

Locality 157: Gruta do Urso Fóssil, Parque Nacional de Ubajara, Ceará, Brazil.

Age and depositional environment: Middle Holocene, ~8.2–8.0 ka (Oliveira et al. 2014); cave (Oliveira et al. 2014).

Taxon and material: Lima et al. (2016) mentioned in a conference abstract the record of subfossils MDJ A-028-032 (phalanges), MDJ A -043/46 (presacral vertebrae), and MDJ A -034/37 (radioulna), all of them identified as *Anura* indet.

Locality 158: La Moderna, Buenos Aires, Argentina.

Age and depositional environment: Middle Holocene, ~7.510–4.680 ka (Messineo et al. 2021); paludal (Messineo et al. 2021).

Taxon and material: MLP 95.V.12.20 (fragmentary maxilla) was referred to as *Ceratophrys* cf. *Ce. ornata* by Gómez and Turazzini (2021).

Locality 159: General La Madrid, Fortin Necochea, Buenos Aires, Argentina.

Age and depositional environment: Middle Holocene, ~6 ka (Prado and Alberdi 1999); aeolian (Flegenheimer and Zárate 1993).

Taxon and material: *Ceratophrys* sp. MLP 96.V.18.12 (fragmentary skull) was mentioned by Mercadal de Barrio and Barrio (2002).

Locality 160: Arroyo Tapalqué, Olavarría, Buenos Aires, Argentina.

Age and depositional environment: Middle Holocene (Fingini et al. 1998); alluvial floodplain (Fidalgo et al. 1986).

Taxon and material: *Ceratophrys* sp. MLP 86.III.25.150/1 (maxilla and squamosal) were mentioned by Mercadal de Barrio and Barrio (2002).

Locality 161: Sambaqui Congonhas I, Santa Catarina, Brazil.

Age and depositional environment: Late Holocene, ~3.27–3.07 ka (Fish et al. 2000); sambaqui (shellmounds) (Beck 1972).

Taxon and material: Mendes and Rodrigues (2019) mentioned in a conference abstract fragmentary postcranial remains assigned to *Anura* indet. The materials were not specified in more detail.

Locality 162: Sambaqui Caiera, Santa Catarina, Brazil.

Age and depositional environment: Late Holocene, ~3.23–0.79 ka (Hurt 1974); sambaqui (shellmounds) (Fish et al. 2000).

Taxon and material: Fragmentary postcranial remains assigned to *Anura* indet. were mentioned in a conference abstract (Mendes and Rodrigues 2019). The materials were not specified in more detail.

Locality 163: San Antonio, Buenos Aires, Argentina.

Age and depositional environment: Late Holocene (Stoessel et al. 2008); aeolian (Stoessel et al. 2008).

Taxon and material: FCS.SA1.M3.590.1-2 (fragmentary maxilla and premaxilla), FCS.SA1.S1.486.1 (fragmentary sphenethmoid), FCS.SA1.S1.506.1, FCS.SA1.S1.525.1, and FCS.SA1.S1.534.1 (fragmentary frontoparietals) were referred to as *Ceratophrys* sp. by Stoessel et al. (2008). FCS.SA1.S1.506.1, FCS.SA1.S1.525.1, and FCS.SA1.M3.590.1 were described and illustrated by Nicoli (2019) and referred to as *Ceratophrys* sp. (Nicoli 2019). Later, FCS.SA1.M3.590.1-2 were referred to as *Ceratophrys* cf. *Ce. ornata* by Gómez and Turazzini (2021). FCS.SA1.S1.506.1, FCS.SA1.S1.525.1, and FCS.SA1.S1.534.1 were referred to as *Ce. ornata* by Gómez and Turazzini (2021). FCS.SA1.S1.486.1 was referred to as *Ceratophrys* sp. by Gómez and Turazzini (2021).

Locality 164: Paso Alsina 1, Buenos Aires, Argentina.

Age and depositional environment: See the entry of locality 163.

Taxon and material: FCS.PA1.E1.P4.1 (fragmentary maxilla) was referred to as *Ceratophrys* sp. (Stoessel et al. 2008; Nicoli 2019), and was described and illustrated by (Nicoli 2019). Later, the material was recovered in a phylogenetic analysis as a fossil representative of *Ceratophrys ornata* (Gómez and Turazzini, 2021).

Discussion

Introductory remarks

The fossil record of South America lissamphibians is represented by 273 fossil occurrences, distributed in 164 fossiliferous localities (as defined in the Materials and Methods). Those records comprise mainly *Anura* (approximately 97.6%), followed by *Gymnophiona* (approximately 1.4%), and *Urodela* (1%). Regarding their temporal distribution, 24% of the records are from Mesozoic and 76% from Cenozoic, whereas focusing on the fossil-bearing localities, 40 represent Mesozoic sediments and 123 Cenozoic ones. The ancientmost remains of Lissamphibia for South America are from the Early–Middle Jurassic. Considering the Cenozoic records, the Paleogene corresponds to approximately 27.5%, the Neogene comprises approximately 28%, whereas the Quaternary corresponds to 44.4% of the records. From a systematic perspective, the record of *Anura* is heavily biased towards *Neobatrachia* (approximately 62.8%), with lower percentages for *Pipimorpha* and stem-*Anura* (approximately 18.2%), and *Anura* indet. (~18.9%). The most speciose taxa in the fossil record are *Ceratophryidae* (~18.5%), *Pipimorpha* (~14.8%), *Calyptocephalellidae* (~13.3%), *Bufonidae* (~12.6%), and *Leptodactylidae* (~6.3%).

We infer that the anuran fossils (Fig. 3) are mainly from aquatic (*Pipimorpha*, *Ceratophryidae* i.e. *Lepidobatrachus*, and *Calyptocephalellidae*, see Cannatella 2015; Amphibia-Web 2021) or hyperossified taxa (*Ceratophryidae*, *Calyptocephalellidae*, *Bufonidae*, and *Pipimorpha*, see Trueb 1973; Trueb 1993; Paluh et al. 2020). Fossil occurrences, as well as fossiliferous localities, are mainly concentrated in Argentina and Brazil (~52% and ~23.8% of the total fossil occurrences, respectively). Our review suggests that frog remains are found mainly in depositional environments related to fluvial settings (e.g. fluvial floodplains). Lacustrine-related environments (e.g. lakes and ponds) are the second most common for *Anura* records, and the most common in which caecilian and salamander remains were found.

Concerning a quantitative perspective of the records, we note that the curve of the cumulative lissamphibian fossil descriptions in South America presents an exponential shape, and is far from reaching an asymptote (Fig. S2 in Supplementary Data 1). The last general review was conducted by Báez (2000), and since then, our estimates indicate that 85.4% of the records concentrate on materials that are new to science or previously reported materials that have been revised. Approximately 75.5% of the reports are in formal scientific publications, whereas 24.5% occur in grey literature (e.g. undergraduate, MSc, and PhD theses and dissertations, and conference abstracts). Considering the published material, approximately 17% represent fossils included in phylogenetic

analyses, whereas 83% are not (Fig. S3; Supplementary Data 2).

Anura

Anura are the most diverse clade of lissamphibians, comprising 56 families and around 8000 species described worldwide (Frost 2021). Nowadays, frogs are broadly distributed in South America, encompassing 24 families and approximately 2623 species (Vasconcelos et al. 2019; IUCN 2021). Anura exhibit higher diversity in the Tropics of South America (e.g. Amazon and Atlantic Forest) and lower diversity in the eastern-dry diagonal, in the temperate region, and in the tropical high-altitude region west of the Andes (Wake and Koo 2018; Vasconcelos 2019). The fossil record of frogs in South America ranges from the Early–Middle Jurassic to the late Holocene (Báez and Basso 1996; this study).

Currently, fossils assigned to 10 families of frogs are known from South America (i.e. Brachycephalidae, Bufonidae, Calyptocephalellidae, Centrolenidae, Ceratophryidae, Hylidae, Leptodactylidae, Odontophrynidae, Pipidae, and Telmatobiidae), encompassing 31 genera, and 36 extinct species. There are also putative records of Alsodidae and Ranidae, but these are based on materials whose taxonomic affinities still need to be clarified. Beyond the extinct taxa, the remaining records are split in the following approximation: Anura indet. or above (approximately 19%), identified at least at the family level or above (~16.5%), identified at the genus level (~21.8%), and identified as fossil representatives of extant species (12%). Despite this remarkable palaeodiversity, the anuran fossil record on this continent is mainly characterised by fragmentary and disarticulated postcranial remains.

It is known that the postcranium is highly conservative among frogs (Trueb 1973; Gómez and Turazzini 2016; Matthews et al. 2019), and the osteology of most anuran taxa is poorly known, with almost none of the Neotropical clades presenting synapomorphies based on osteological characters (Nicoli 2017). Considering that, we conceive that the phylogenetic assignment of fossil specimens from South America may have some flaws. For example, the identification of some materials as representative of extant or extinct species might not be supported by enough morphological evidence. Further, concerning fossils below Anura level, some identifications might be biased due to the restricted comparative scope used that reflects regional taxonomic diversity (Bell et al. 2010). However, correcting all these identifications is beyond the scope of our study.

Considering the localities where anuran fossils were recovered in South America (mainly fluvial and lacustrine palaeoenvironments), the fossil record of the group is probably biased favouring representatives of taxa that live in or close to large bodies of water, either as larvae or adults. Whereas

several species of Anura are mainly terrestrial, they use restricted bodies of water as reproductive sites and exhibit a remarkable diversity of reproductive modes (Duellman and Trueb 1986; Wells 2010; Nunes-de-Almeida et al. 2021).

Gymnophiona

Nowadays gymnophionans are widely distributed in South America. Considering the 214 species currently known worldwide, 96 are found on this continent, encompassing five of the 10 recognised families: Caeciliidae; Dermophiidae; Rhinatrematidae; Siphonopidae; and Typhlonectidae (Amphibia-Web 2021). Despite this diversity, the caecilian fossil record on this continent is impoverished, characterised by sporadic occurrences restricted to disarticulated vertebrae (this study, but also see Santos et al. 2020, and references therein). Indeed, the first records of fossils assigned to gymnophionans come from South America. *Prohypocephalus tunariense* was described by Marcus (1945) as a new species of caecilian based on a fossil from the Carboniferous of South America, but this assignment was later doubted and the specimen was reidentified as a cephalopod shell (see Estes and Wake 1972; Estes 1981). Some years later, a new species was described based on a single and broken trunk vertebra found in Eocene rocks of the Itaboraí Basin, Brazil (Estes and Wake 1972). *Apodops pricei* is considered the first *bona fide* caecilian known by fossilised remains (Estes 1981; Santos et al. 2020), but despite bearing the typical caecilian-like vertebral morphology, does not exhibit enough diagnostic features to allow a more accurate identification. Based on its general proportions, the authors recognised similarities between this fossil vertebra and dermophiids, including the West African *Geotrypetes* (Estes and Wake 1972).

The two geologically oldest records of fossil caecilians in South America come from the Late Cretaceous (Gayet et al. 2001) and Paleogene (Rage 1991) from Bolivia. Unfortunately, these specimens are restricted to disarticulated vertebrae that are too damaged to be taxonomically informative. The geologically youngest and most recently reported fossil record on the continent, also comprising only isolated vertebrae, comes from the Miocene of Colombia (Hecht and LaDuke 1997). These vertebrae stand out for their unusually large size, and based on the atlas figured by Hecht and LaDuke (1997), they are about four times larger than the average modern taxa. To date, all of these fossil vertebrae (including Mesozoic specimens) were assigned to the Gymnophiona-crown. Stem lineages, known mainly by the presence of limbs and the primitive morphology of vertebrae (e.g. Jenkins and Walsh 1993), have not been found yet in South America, but it is known that these forms inhabited at least other Gondwanan landmass (Africa) during the Mesozoic (Evans et al. 1996; Evans and Sigogneau-Russell 2001).

Therefore, Mesozoic amphibian-bearing localities in South America with depositional and palaeoenvironmental conditions

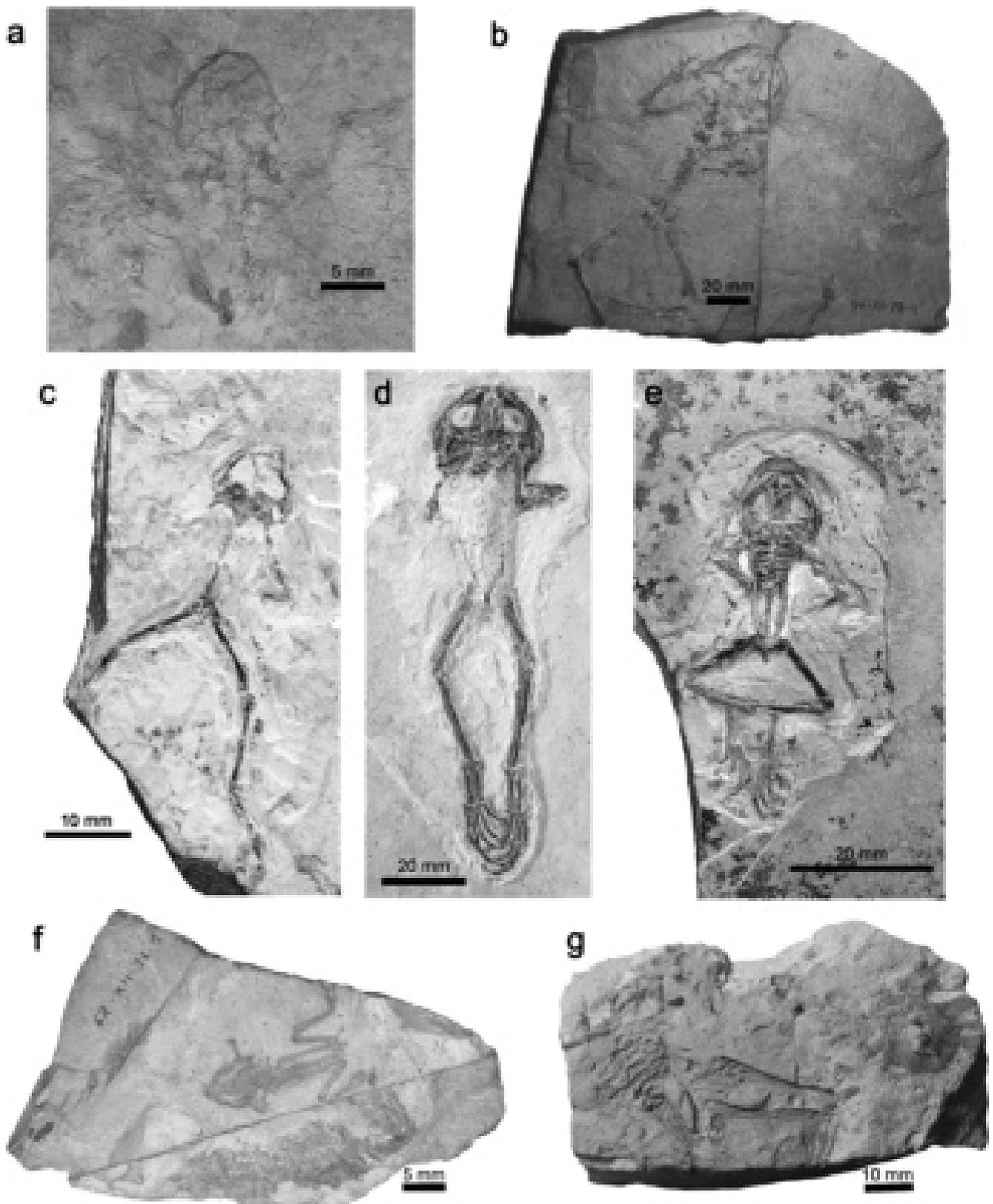


Fig. 3 Representative lissamphibian fossil specimens (all anurans) from South America. **a** *Vieraella herbstii* (Lower Jurassic of Roca Blanca Formation, locality 1); **b** *Notobatrachus degiustoi* (Middle to Upper Jurassic of La Matilde Formation, locality 6); **c** *Cratia gracilis* (Lower Cretaceous of Araripe Basin, locality 13); **d** *Eurycephalella alcinae*

(Lower Cretaceous of Araripe Basin, locality 13); **e** *Arariphrynus placidoi* (Lower Cretaceous of Araripe Basin, locality 13); **f** *Shelania pascuali* (lower Eocene of Laguna del Hunco Formation, locality 47); **g** *Wawelia gerholdi* (Miocene of Neuquén Basin, locality 85).

similar to the Kayenta Formation (which contains the stem caecilian *Eocaecilia*) in the USA, such as Estancia Roca Blanca, might potentially bear a still unknown diversity of stem-caecilians. Considering the deposits where caecilian fossils are found in South America (fluvial and lacustrine palaeoenvironments), their record is probably biased, favouring taxa that live near water, either as larvae (e.g. rhinatrematids) or adults (e.g. typhlonectids). However, because caecilian vertebral diversity is still poorly understood (e.g. Wilkinson et al. 2011), the taxonomic affinities of these specimens remain unclear (Santos et al. 2020), and therefore it has not been possible to test this hypothesis so far. In addition, based mainly on the large record of anurans in several Cenozoic deposits with similar depositional settings, crown-group caecilian remains could also be present in such localities.

Urodela

Modern lineages of salamanders have a distribution focused in the northern hemisphere, and their presence in Gondwanan landmasses is relatively recent, occurring only at the end of

the Cenozoic (Milner 1983). Fossil urodeles are relatively well known for Laurasian deposits, whereas their occurrence on the southern continents is uncommon (e.g. Nevo and Estes 1969; Rage et al. 1993; Evans et al. 1996; Gayet et al. 2001). In South America, extant representatives of the family Plethodontidae are restricted to the northern portions of the Amazonian Tropical Rainforest (Parra-Olea et al. 2004), but the fossil record of plethodontids is still unknown. The only salamander fossils in South America known so far were assigned to *Noterpeton bolivianum*, a species originally found in the Upper Cretaceous (Maastrichtian) Pajcha Pata deposits, in Bolivia (Rage et al. 1993; Gayet et al. 2001). This taxon has a vertebral morphology markedly different from the other salamanders, due to its procoelous vertebrae, whereas the remaining Urodela typically bear amphicoelous or opisthocelous vertebrae (Rage et al. 1993). In addition to the type material, Gayet et al. (2001) reported and briefly described other 63 vertebrae, including material found in Upper Cretaceous outcrops of Pajcha Pata and Villa Villa (46 and 16 vertebrae, respectively). A fragmentary vertebra from Estancia Blanco Rancho (late Paleocene) was also assigned

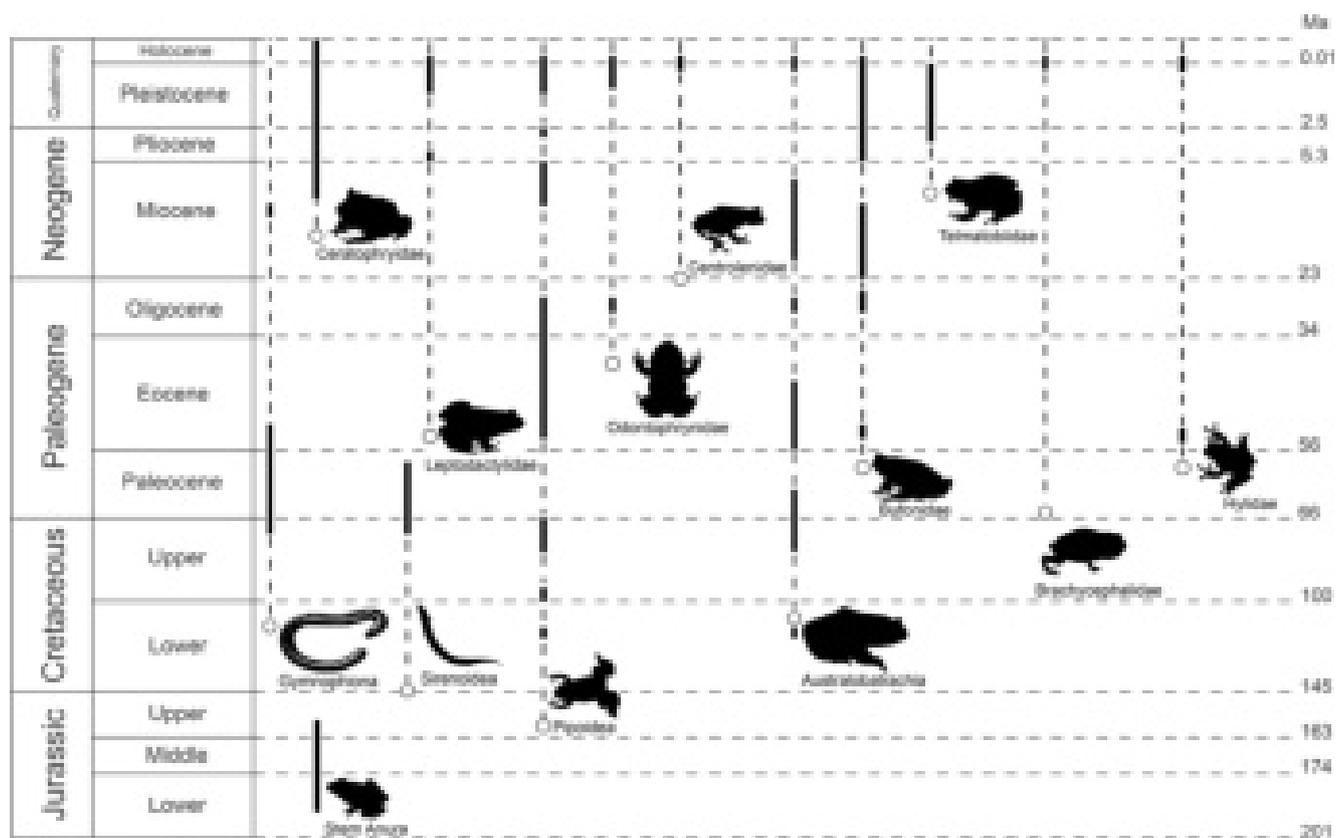


Fig. 4 Stratigraphic chart depicting the temporal records of Lissamphibia in South America. Vertical dashed lines indicate inferred gaps in the fossil record. Molecular-based age estimates are indicated by white circles and follow Hime et al. (2021) and Kumar et al. (2017). The silhouettes, not in scale, were downloaded and modified from phylopic.org, wikipedia.org/Calyptocephalella, wikipedia.org/wiki/Brachycephalus_auroguttatus, wikipedia.org/wiki/Telmatobius_ventriflavum, and spinops.blogspot.com.

all of them are under Creative Commons Attribution 3.0 Unported. *Calyptocephalella* by José Grau de Puerto Montt, *Ceratophrys* by Margot Michaud, *Hyalinobatrachium* and *Leptodactylus* by Jose Carlos Arenas-Monroy, *Hyla* by Will Booker, *Notobatrachus* by Nabu Tomura, *Odontophrynidae* by Pedro de Siracusa, *Siphonops* by Yan Wong, *Siren* by New York Zoological Society, *Xenopus* by Ingo Braasch

to *Noterpeton* based on general similarities (Gayet et al. 2001). Martill et al. (2013) briefly commented on a putative new record of a new noterpetid salamander from the Lower Cretaceous Crato Formation (Brazil), but further study indicated that the specimen is actually a squamate (see Gardner and Rage 2016).

Initially, in order to accommodate this distinct morph, the new family Noterpetidae Rage et al. 1993 (formerly Noterpetontidae, see Marjanović and Laurin 2014) was erected. However, in the description of *Kababisha humarenensis* and *Kababisha sudanensis* (Evans et al., 1996), two taxa from the Cenomanian of Sudan that present similarities with *Noterpeton* and also with modern sirenids, it was suggested that Noterpetidae is actually a junior synonym of Sirenidae. Evans et al. (1996) proposed an alternative explanation for the appearance of procoely in the vertebrae of such taxa, correlating this morphology to a progressive calcification in the posterior cotyles. Therefore, according to them, this feature would not be sufficiently different from amphicoely to sustain a new and separated family as originally considered by Rage et al. (1993). However, these *Noterpeton* affinities with sirenids were later questioned, being considered based on independently evolved features rather than true homologies (Gardner 2003). The lack of a robust phylogenetic test prevents the relationships of such salamanders with procoelous vertebrae from being better understood. Therefore, until these studies are carried out, this question remains open.

The South American *Noterpeton* was found in deposits associated with the El Molino Formation, interpreted as having been deposited in lacustrine settings (Marramà and Carnevale 2017), whereas their African relatives from Sudan were found in rocks deposited under fluvial conditions, representing an environment of braided rivers associated with floodplains and lakes (Evans et al. 1996; Rauhut 1999). Therefore, other localities with equivalent age and deposited under similar conditions can possibly also contain these procoelous salamanders. The presence of Plethodontidae in South America is relatively recent but occurred prior to the closure of the Panamanian Portal (Parra-Olea et al. 2004), and so far, fossils assigned to this group have not been found in South America. However, the different geographic and climatic conditions during the Neogene (e.g. Duque-Caro 1990) may have contributed to expanding their range, and therefore their fossil representatives may eventually be found in localities outside the distribution area of extant species.

Allocaudata

Albanerpetontids form an extinct clade of lissamphibians that show a predominantly Laurasian distribution (Gardner and Böhme 2008), and to date, there are only two records

for Gondwana, from the Middle Jurassic (Haddoumi et al. 2016) and Lower Cretaceous (Gardner et al. 2003) of Morocco. Albanerpetontids appeared in the fossil record during the Middle Jurassic (see Gardner and Böhme 2008, and references therein), whereas the most recent remains are from the Early Pleistocene (Villa et al. 2018). So far, no records of this group are known for South American deposits, however, its presence on the continent cannot be completely dismissed.

The Evolutionary History of Lissamphibia in South America

The record of fossil lissamphibians in South America ranges from the Early Jurassic to the Late Pleistocene–late Holocene. However, fossil occurrences are unequally distributed within this time-span, for some intervals where the record is abundant and well documented (e.g. Campanian–Maastrichtian), whereas in others both fossiliferous localities and fossil specimens are relatively uncommon (e.g. Paleocene). There is also a disparity in the temporal distribution among the different clades of lissamphibians. Some groups present a record scattered in parts of the Mesozoic and Cenozoic (e.g. pipoids and australobatrachians), whereas other taxa have occurrences concentrated within a more restricted interval (e.g. ceratophryids).

We provide below a discussion on the evolutionary history of some groups of South American lissamphibians. To avoid potential biases, we decided not to consider several earlier records referred to Leptodactylidae (as this clade was used for a long time to accomplish a wide diversity of frogs that today are known to be poorly related to each other; see Suazo-Lara and Gómez 2022) and some specific records assigned to Ranidae and Alsodidae (as such records are based on specimens whose taxonomic affinities still need to be clarified). In such cases, we used a conservative approach, and so these taxa were reassigned to a more inclusive clade (e.g. Neobatrachia). All these taxonomic changes are summarised in Supplementary Data 2. In Figure 4, we also indicate the divergence-time estimates for several lissamphibian crown groups based on the most recent phylogenomic studies available (e.g. Kumar et al. 2017; Hime et al. 2021).

Stem frogs

The oldest occurrences of stem frog taxa (i.e. *Triadobatrachus* and *Czatkobatrachus*) come from Lower Triassic deposits (Evans and Borsuk-Bialynicka 1998; Sanchiz 1998), but according to some molecular estimates, the origin of this group dates back to the middle Permian (e.g. Hime et al. 2021). In South America, such Triassic forms are still unknown, but stem lineages are represented by *Notobatrachus* and

Vieraella, with a record limited to the Early–Late Jurassic (see Báez and Basso 1996 and also Figure 4).

Pipoidea

Pipoidea have an extensive fossil record in South America, ranging from the Early Cretaceous to the Holocene, but with three pronounced hiatuses: during the Paleocene; most of the Miocene; and the Pliocene and part of the Pleistocene (see Figure 4). Despite the oldest records known so far dating back to the Early Cretaceous, molecular estimates indicate that pipoids originated in the Early or Late Jurassic (Hime et al. 2021; Kumar et al. 2017, respectively), leaving a huge gap of approximately 65 Ma in which no fossil is known. Interestingly, despite the numerous records of pipoids for the Late Cretaceous, especially in Campanian–Maastrichtian deposits (e.g. Candeleros Formation, Los Alamitos Formation), there are still no Paleocene records for the group in South America. Paleocene fossil-bearing localities containing lissamphibians in South America are uncommon (only seven, according to our review), but include units with depositional environments consistent with the pipoid habitats (i.e. aquatic environment). Thus, it is not yet clear whether this scarcity is related to some taphonomic bias or if it reflects a true scenario, in which pipoids were particularly affected by the K/Pg extinction.

Australobatrachia

Australobatrachians form a clade recently revealed through phylogenies based on molecular data (Frost et al. 2006), grouping species from South America, Australia, Tasmania, and New Guinea. In South America, they are currently represented by calyptocephalellids. The Australobatrachia fossil record in South America (limited to calyptocephalellid-like specimens) is distributed from the Early Cretaceous to the Holocene, but it is characterised by multiple occurrences separated by numerous gaps. The main gaps are located in parts of the Late Cretaceous, Paleocene, Eocene, Oligocene, Miocene, and Pleistocene, as well as a complete absence in the Pliocene (see Figure 4). Curiously, according to recent molecular estimates, the divergence between calyptocephalellids and myobatrachoids (corresponding to the Australobatrachia crown) occurred during the Late Cretaceous (Hime et al. 2021), an age slightly younger than the record of *Eurycephalella alcinae* (Báez et al., 2009). This species was recovered as the sister group of *Calyptocephalella gayi* under some analytical conditions in the phylogenies of Báez and Gómez (2018), but its affinities with calyptocephalellids still need to be better understood. Indeed, *E. alcinae* could alternatively be a stem australobatrachian or occupy an even more distinct position in the anuran phylogenetic tree. These uncertainties suggest that further studies on the osteological anatomy and phylogeny of extinct

species related to Calyptocephalellidae are needed to shed light on such issues.

Ceratophryidae

Ceratophryidae exhibit a well-documented fossil record, spanning from the late Miocene to the Holocene, without significant gaps (Nicoli 2019; Barcelos et al. 2020; see Figure 4). Some Mesozoic fossils (e.g. *Baurubatrachus*) were initially assigned to Ceratophryidae, which would extend its temporal range back to the Cretaceous (Báez et al. 2009). However, the affinities of such fossils were later reinterpreted (Báez and Gómez 2018), and now this family is considered to be exclusively Cenozoic. Based on molecular data, the origin of this group was in the early to middle Miocene (Kumar et al. 2017; Hime et al. 2021), slightly older than the oldest fossils known so far (Nicoli et al. 2017).

Odontophrynidae

This family exhibits a scarce fossil record, characterised by sparse occurrences through time. The putative oldest records come from middle Oligocene deposits, represented by several specimens assigned to *Chachaiphrynus lynchi* (Nicoli, 2017). However, molecular estimates place the origin of crown Odontophrynidae in the late Eocene (Kumar et al. 2017), leaving a maximum gap of around 9 Ma between these oldest fossils and the divergence-time estimates. Another huge gap of approximately 28 Ma occurs between these Oligocene fossil occurrences and younger Pleistocene–Holocene records (see Figure 4).

Leptodactylidae

When numerous fossil frogs were assigned to Leptodactylidae in the past, the time range of the leptodactylid fossil record was considered extensive. However, after improvements in the understanding of anuran taxonomy, several of these records were reinterpreted, and currently, the time range of fossil leptodactylids is more restricted. The earliest known *bona fide* record of a leptodactylid from South America dates back to the early Pliocene (see Figure 4), whereas divergence time estimates suggest that the family appeared in the early Eocene (Hime et al. 2021). Thus, there is a wide gap of approximately 50 Ma between these estimates and the fossil occurrence. Another gap, this one more limited, occurs between this Pliocene occurrence and other Pleistocene–Holocene records.

Centrolenidae

The fossil record of centrolenids in South America is particularly sparse, being limited to only one record from an Upper Pleistocene–Holocene locality (see Figure 4). Molecular-

based divergence time estimates put the origin of the Centrolenidae-crown between the late Oligocene and the early Miocene (Hime et al. 2021). Therefore, there is a gap of approximately 23 Ma between such estimates and the known fossil record.

Bufonidae

The fossil record of bufonids in South America comprises several specimens and is limited to the Cenozoic (see Figure 4). Bufonid fossils have been found in deposits from all Cenozoic epochs except the Paleocene. Estimates for the origin of the group, based on molecular data, suggest that bufonids diverged from other frogs in the late Paleocene (Hime et al. 2021), whereas the oldest occurrence of a bufonid fossil in South America is from the early Eocene, leaving a small gap between them. There are two other gaps. The first one is more pronounced and encompasses most of the Eocene and part of the Oligocene, whereas the second one is restricted to the late Miocene.

Telmatobiidae

Some fossil specimens were initially assigned to Telmatobiidae (e.g. *Neoprocoela* and *Uberabatrachus*, see Schaeffer 1949; Evans et al. 2014; and Nicoli et al. 2016), but in subsequent studies, such telmatobiid affinities were doubted (Nicoli 2017; Báez and Gómez 2018). Considering only the undisputed records, this family is poorly represented in the South American fossil record, with only a single record from a Pliocene to Upper Pleistocene deposit (see Figure 4). Estimates based on molecular data consider that telmatobiids diverged from other anurans 8.8 million years ago, during the late Miocene (Kumar et al. 2017). Therefore, there is a small gap of 3.5 Ma between these estimates and the available fossil record.

Brachycephalidae

The only South American fossil assigned to Brachycephalidae comes from an Upper Pleistocene–Holocene locality (see Figure 4). However, divergence time estimates, based on molecular data, consider that brachycephalids have a long evolutionary history, with the clade diverging from other frog groups approximately 65 million years ago, slightly after the K–Pg extinction event (Kumar et al. 2017). Therefore, there is a huge gap between the known fossil and the estimated origins of the brachycephalid-crown.

Hylidae

The fossil record of hylids in South America is sparse and encompasses only an uncertain occurrence from the early

Eocene, in addition to isolated remains from some Quaternary localities (see Figure 4). A Cretaceous fossil from Brazil was described in a PhD dissertation and, in a preliminary phylogenetic analysis, was recovered as the sister taxon of the extant hylid *Pseudis* (Carvalho, 2006), but its taxonomic affinities still need to be further clarified. Estimates of time divergence based on phylogenomic data indicate that the crown Hylidae appeared in the late Paleocene (Hime et al. 2021), leaving a small gap between this estimate and the oldest fossil known to date. However, there is still a huge gap (~50 Ma) between the Eocene and Quaternary records.

Gymnophiona

The caecilian fossil record, including stem lineages, ranges from the Middle Jurassic to Holocene (Santos et al. 2020, and references therein). In South America, the oldest record comes from the Late Cretaceous of Bolivia (Gayet et al. 2001), followed by occurrences in the Paleocene of Bolivia (Rage 1991), Eocene of Brazil (Estes and Wake 1972), and Miocene of Colombia (Hecht and LaDuke 1997). According to molecular estimates, the origin of the gymnophionan crown occurred in the Early Cretaceous (Hime et al. 2021), and thus there is a gap of ~30 Ma between these estimates and the oldest occurrences from South America (see Figure 4). Regarding Oligocene deposits, no fossil has been assigned to Gymnophiona so far and, thus, there is another gap of approximately 40 Ma between the Eocene *Apodops pricei* and the isolated and uncommonly large vertebrae from the Miocene of Colombia (Hecht and LaDuke 1997). Moreover, caecilian remains are still unknown in South America from Pliocene and Pleistocene deposits.

Urodela

The record of fossil salamanders in South America is restricted to the putative sirenid *Noterpeton bolivianum*, known only in deposits from the Late Cretaceous (Rage et al. 1993) and Paleocene (Gayet et al. 2001). According to recent molecular estimates, the divergence between the lineage represented by *Siren intermedia* and salamandroids (corresponding to the origin of stem sirenids, treated here as Sirenoidea) occurred between the Late Jurassic and Early Cretaceous (Hime et al. 2021). Therefore, there is a gap in the record during the Cretaceous (see Figure 4), partially filled by the occurrence of salamanders with procoelous vertebrae found in African deposits dated from the Cenomanian and Coniacian–Santonian (Evans et al. 1996; Gardner and Rage 2016).

Palaeodistribution of South America Fossil Lissamphibians

Our review of the lissamphibian fossil record suggests that the palaeodistribution of extinct species does not match

rigorously the current distribution of extant species. The discrepancy among the differential historical distribution is remarkable, in a way that none of the palaeodistribution models, which only consider the current distribution, could infer such a disjunct distribution exhibited for lissamphibians records in South America (e.g. Pipidae, Calyptocephalellidae, and Urodela; Savage 1973). Metcalf (1923), who studied the extant host-parasite distribution (i.e. Anura species and Opalinidae, a group of Heterokonta), already recognised these remarkable disjunct patterns, suggesting that Australia and New Zealand should have been connected in the past to Antarctica and South America. He also proposed a past connection between Papua, Solomon Islands, and Australia.

Even though Metcalf (1923) followed the dispersalist paradigm of Matthew (1915), his observations were notable. This dispersalist paradigm of Matthew (1915) was later recognised as incompatible for Lissamphibia (Savage 1973). South America has experienced large radiations of clades that are absent or uncommon in Eurasia (Duellman 1999), so the lissamphibian fauna from South America comprises mainly endemic clades. The geographical distribution differences in those clades suggest the potential for a strong role for history acting through common cause biogeographical events in determining the species richness patterns in Lissamphibia (Smith et al. 2005). Lynch (1971) and Savage (1973) discussed the geographic-distributional pattern of extant and extinct species of Anura in the world, but they did not include many fossil specimens known at that time. Knowledge on the fossil record of frogs increased substantially after their contributions, and the systematic framework of Anura improved considerably. However, fossil occurrences of Lissamphibia are generally disregarded in biogeographic inferences (Savage 1973). We present our review as a first step for the consideration of the South American fossil lissamphibians in the inferences of biogeographic common cause events. This will improve the accuracy of hypotheses concerning the evolutionary history of South American lissamphibians. Our work mainly discusses the congruences or contrasts between the distribution of extant and extinct species of Lissamphibia and presents hypotheses on this topic.

Anura

The extant species of Anura that currently occupy the South American landmass are mainly from Neobatrachia clades (except for the genus *Pipa*; AmphibiaWeb 2021), especially Hyloides and Microhylidae (Jetz and Pyron 2018), with nearly 80% of its diversity corresponding to endemic clades (Haddad et al. 2013). The most speciose anuran clades in South America are the Hyloides Craugastoridae (878 spp.), Hylidae (520 spp.), Bufonidae (274 spp.), and Leptodactylidae (200 spp.; Vasconcelos et al. 2019). The extant species diversity is concentrated in the Central and Northern

Andes mountains, and their adjacent western Amazon basin, and in the complex region encompassing the Atlantic Brazilian coast and the central Brazilian shield (Vasconcelos et al. 2019). Both regions have a sparse fossil record of Anura species and, therefore, it is difficult to hypothesise on the evolutionary history of the speciose and endemic clades in those regions.

Pipoidea: The clade is currently broadly distributed on Gondwanan landmasses, with *Pipa* occupying South America and *Xenopus*, *Hymenochirus*, and *Pseudohymenochirus* occupying Africa (Fig. S4 in Supplementary Data 1). The palaeodistribution of the clade is even more expanded, reaching Laurasian landmasses, including specimens in the Arabian Plate, Europe, North America, and Asia (Sanchiz 1998). The phylogenetic relationship of African and Arabian fossil specimens was used by Metcalf (1923) for suggesting a later connection in the Isthmus of Suez, that would allow a dispersal event across the western margin of the Mediterranean Sea or through the Afro-Arabian to the Eurasian land bridge (Yuan et al. 2018). The close phylogenetic relationship among fossil Pipoidea from South America and Africa raised the question of whether the origin of the *Xenopus* lineage antedated the separation of Africa and South America (dated around 100 Ma; Veevers 2004; Granot and Dymont 2015). The early origin of the clade before the separation of those landmasses is a well-corroborated hypothesis (Evans et al. 2004; Bewick et al. 2012; Gómez 2016), but some works endorsed the hypothesis of overwater dispersal rather than vicariance (Metcalf 1923; Cannatella 2015). Still, other works advocate that both hypotheses occurred (Estes 1975a; Buffétau and Rage 1993).

Biogeographical studies (Pyron 2014; Frazão et al. 2015) and phylogenies (Bisbee et al. 1977; Gómez 2016; Carvalho et al. 2019) strengthen the first hypothesis, that the divergence between *Pipa* and *Xenopus* occurred around 135 Ma, before the opening of the Atlantic Ocean. Also, the record of Cretaceous species deeply related to Xenopodinomorpha (e.g. *Kuruleufenia* and *Oumtkoutia*) in South America, plus the relationship of African fossils (*Pachycentrata* and *Singidella*) within the clade [Hymenochirini–*Pipa*] do not demand the evocation of a transatlantic dispersal (Gómez 2016). Xenopodinomorpha represent the most speciose clade of Pipidae in South America, with species being recorded until the Pleistocene. All species related to Xenopodinomorpha that occupied this landmass are extinct. The only remaining pipoid species belong to Pipinae (i.e. *Pipa*). Xenopodinomorpha have records mainly in southern South America, whereas the current distribution of *Pipa* is concentrated in northern South America (Savage 1973; Fouquet et al. 2022), with the first fossil specimens of *Pipa* being recorded in the late Miocene of the Urumaco Formation, Venezuela (Delfino and Sánchez-Vilagra 2018), and late Miocene of the Solimões Formation, Brazil (Muniz et al. 2016).

Australobatrachia: Australobatrachia are a recently erected clade (Frost et al. 2006), with a clearly Gondwanan distribution, which comprises the Myobatrachoidea of Australia and New Guinea and the South American Calyptocephalellidae. Calyptocephalellids are currently restricted to the southwest coast of South America (Frost 2021; IUCN 2021). But the palaeodistribution of fossils is broader, reaching larger areas of South America (Fig. S5 in Supplementary Data 1), and even other Gondwanan landmasses, such as Antarctica and maybe Africa and Madagascar. The current diversity of extant calyptocephalellid species is relictual in comparison with its rich fossil record. The absence of a phylogenetic hypothesis that includes both extant and extinct species prevents a thorough understanding of the family's evolutionary history. Phylogenetic positioning of fossils assigned to calyptocephalellids was attempted with a restricted scope, and interesting results were achieved (Agnolin 2012), such as the first-time recognition of *Beelzebufo ampinga* as a Calyptocephalellidae and *Gigantobatrachus* as a distinct genus. However, those results were later severely criticised by Báez and Gómez (2018), Muzzopappa et al. (2021), and Suazo-Lara and Gómez (2022). In some of the phylogenies presented by Báez and Gómez (2018), *Beelzebufo ampinga*, *Baurubatrachus pricei*, and *Eurycephalella alcinae* were recovered as closely related to calyptocephalellids under some analytical conditions, but the authors stated that these results should be viewed with caution. If these assignments are correct, they indicate that in the past calyptocephalellid-like australobatrachians were more broadly distributed in Madagascar and in northern regions of South America.

Additionally, the close phylogenetic relationship of Calyptocephalellidae and Myobatrachoidea (Jetz and Pyron 2018) and biogeographic hypotheses (Pyron 2014; Frazão et al. 2015) suggest that South America, Antarctica, and Australia were connected until at least the early Paleocene (Woodburne and Case 1996; Vizcaíno et al. 1998), suggesting that the former family could have occupied the Antarctic landmass. This inference was later endorsed by the record of *Calyptocephalella* sp., from the Eocene of Seymour Island, in Antarctica (Mörs et al. 2020), representing the first lissamphibian record for that continent. Fossil occurrences of Calyptocephalellidae in South America (Fig. S5 in Supplementary Data 1) do not match the extant species distribution, except for a single occurrence (Ex Laguna de Tagua Tagua, see Locality 153). The records are concentrated in southern South America (i.e. Patagonia, a region of Argentina and Chile). Beyond that, there are two putative occurrences in central and northern South America: *Baurubatrachus* in Bauru Basin, Minas Gerais, Brazil, and *Eurycephalella alcinae* in Araripe Basin, Ceará, Brazil.

Ceratophryidae: The extant representatives of the family are distributed in South American Amazon (*Ceratophrys cornuta* species group), Atlantic Forest (*Ce. aurita* species group),

Caatinga (*Ce. aurita* species group), and Pampas (*Ce. aurita* species group), but the majority of species are concentrated in the Gran Chaco region (*Ce. aurita* species group, plus *Lepidobatrachus* and *Chacophrys*; Vieira et al. 2018). An analysis of the distribution of species within Ceratophryidae during the Last Glacial Maximum and Last Interglacial demonstrated that species did not respond equally to climate fluctuations (Vieira et al. 2018). Some species within Ceratophryidae were much more sensitive to the oscillatory effects of temperature and others to precipitation, both of which could have caused the retraction or expansion in species' palaeodistributions (Vieira et al. 2018).

The fossil record of Ceratophryidae is rich, with around 50 specimens known so far (Nicoli 2019; Barcelos et al. 2020; Gómez and Turazzini 2021). Barcelos et al. (2020) demonstrated a disjunct distributional pattern in some fossil records for Ceratophryidae, in comparison with extant species distributions. The middle Miocene (15–13 Ma) marine incursions into the Chaco and Paraná basins, forming the Paranaense Sea (Hernández et al. 2005), were suggested as the main influence on *Lepidobatrachus* diversification (Brusquetti et al. 2018). The Paranaense Sea could have acted as a vicariant agent on the broadly distributed ancestral Chacoan populations, possibly generating divergences among populations in the north, east, and southwards out of the current Chaco (Brusquetti et al. 2018). Gómez and Turazzini (2021) presented new records of *Lepidobatrachus* and *Ceratophrys*, and we confirm that the distribution of fossil records of the genera are still congruent with the Barcelos et al. (2020)'s observation (Fig. S6 in Supplementary Data 1). Nevertheless, a comprehensive biogeographical study including both extinct and extant species is needed to properly understand the abiotic factors accountable for this disjunct pattern.

Bufoidea: Extant bufonids are nearly cosmopolitan, except for Australia, Madagascar, Antarctica, and Oceanic regions (Pramuk et al. 2008; Frost 2021). The fossil record of Bufoidea is also near cosmopolitan (Sanchiz 1998; Paleobiology Database 2021). Many works suggested the taxonomic affinity of fossil specimens without any description, comparison, or discussion (Barcelos and Verdade 2020a). Furthermore, the morphology of Bufoidea is notoriously conservative (Pramuk 2006). As such, taxonomic identifications of fragmentary fossil remains are problematic (Pramuk et al. 2008; Barcelos and Verdade 2020a). However, relying on those putative records, we can cautiously discuss the distribution of extant and extinct species of Bufoidea.

Concerning the fossil record of the taxon in South America, several specimens identified as Bufoidea indet. and *Rhinella* sp. fall within the extant species' distributions. Records of *R. jimi* and *R. arenarum* also fall within the extant species distribution (Fig. S7 in Supplementary Data 1). However, the

records of *R. marina* do not match the extant species' distribution, in which the fossil specimens are recorded in Tarija, southern Bolivia, and Magdalena Valley, western Colombia (Fig. S7 in Supplementary Data 1). Fossil specimens of *R. spinulosa* and *R. diptycha* (also formerly referred to as *Bufo paracnemis*, *B. schneideri*, and *R. schneideri*) present a disjunct distributional pattern (Fig. S8 in Supplementary Data 1). Fossil remains of *R. diptycha* were recorded in Buenos Aires Province, Argentina, and *R. spinulosa* were recorded in Córdoba Province, Argentina.

Leptodactylidae: This family is broadly distributed in South America, whereas the palaeodistribution of the clade is concentrated in the southeastern portion of the continent. The fossil record of Leptodactylidae needs a thorough revision, mainly because historically many works suggested the taxonomic affinity of fossil materials without any description, comparison, or discussion. Those works may use the former classification of Leptodactylidae that included several groups distantly related (Lynch 1971; Suazo-Lara and Gómez 2022). We tried to avoid the inclusion of those problematic records in our palaeodistributional map. Still, we present a distribution map of extant and extinct species of *Leptodactylus* (Fig. S9 in Supplementary Data 1). According to our review, all records of species of Leptodactylidae and Leptodactylidae indet. fall within the current distribution of extant species.

Odontophrynidae: The distribution of extant species of Odontophrynidae ranges from southern and eastern South America (Frost 2021; AmphibiaWeb 2021). This family is endemic to South America (Frost 2021) and its fossil record is sparse. Two records match the current distribution of species in Buenos Aires Province, but occurrences of putative odontophrynids like *Chachaiphrynus* and *Neoprocoela* in southern South America, and of *Odontophrynus* sp. in northern Brazil are outside the distributional range of extant species of Odontophrynidae (Fig. S10 in Supplementary Data 1).

Hylidae: The family is broadly distributed, reaching other landmasses beyond South America (i.e. North America, the West Indies, the Australo-Papuan regions, Eurasia, Africa, and the Japanese Archipelago; Frost 2021; AmphibiaWeb 2021). Despite the world fossil record of Hylidae being one of the richest (Sanchiz 1998; Paleobiology Database 2021), their fossil remains in South America are poorly known, comprising only putative records (e.g. Hylidae indet. from Itaboraí Basin), except for the subfossils of *Boana* sp. (former *Hypsiboas*) from the Lapa da Escrivantina, Lagoa Santa, Minas Gerais, Brazil. All the fossil occurrences of Hylidae from South America fall within the distribution of extant species (Fig. S11 in Supplementary Data 1).

Gymnophiona

Despite older occurrences of fossils assigned to caecilians (e.g. Jenkins and Walsh 1993; Evans and Sigogneau-Russell 2001) in places outside the distribution range of modern species, all fossil specimens from South America were found in localities within or very close to the occurrence areas of extant taxa (Fig. S12 in Supplementary Data 1). Caecilians are not currently present in Patagonia, but it is at least possible that, due to the warmer conditions during the Neogene (e.g. Duque-Caro 1990), representatives of the group might have occupied regions farther south on the continent, although their fossils have not yet been found.

Urodela

Extant sirenids are restricted to North America, but the distribution of this group in the past was much wider (but only if the procoelous forms are indeed closely related to this family) and includes areas in Africa (Evans et al. 1996) and South America (Rage et al. 1993). In general, urodeles form a typically Laurasian taxon, but the subgroup of putative sirenids formed by *Kababisha* and *Noterpeton*, characterised by their procoelous vertebrae, possibly represents a lineage that dispersed towards Gondwanan landmasses during the Mesozoic (Evans et al. 1996) (Fig. S13 in Supplementary Data 1).

Biological and Taphonomic Bias of Lissamphibian Records

Lissamphibians are, with few exceptions, animals of diminutive size and with fragile skeletons, and thus extremely susceptible to transportation, reworking, and destruction of their remains (Dodson 1973). In addition, usually they do not tolerate saltwater or arid environments, preferring to live in hot and humid habitats (Hopkins and Brodie 2015). Physiological and reproductive restrictions of Lissamphibia are well documented and suggest strong sensitivity to environmental conditions (Feder and Burggren 1992). Lissamphibians breathe through their highly permeable skin and need a moist environment for oviposition, which means water is a constraint and a crucial resource for them (Feder and Burggren 1992).

Assuming that their fossil relatives had similar preferences, the above-listed factors affect the occurrence of lissamphibian remains in fossiliferous deposits. But, a substantial body of knowledge on Lissamphibia taphonomy is missing (Lyman and Lyman 1994). Lissamphibian fossils are still absent or poorly represented in numerous fossiliferous deposits, although in many of these localities the conditions for the presence of these animals are suitable (e.g. Aiuruoca Basin, Taubaté Basin, Acre Basin, Itaboraí Basin, Pozo Formation, and Santa Lucía Formation). The occurrence of other

vertebrates associated with the aquatic environment (e.g. fishes, turtles, crocodiles) contrasts with the apparent absence of lissamphibians, suggesting a hidden diversity in such deposits. Additionally, so far, the co-occurrence of fossils assigned to the three lissamphibian groups in the same deposit in South America is limited to a single locality: Pajcha Pata, Bolivia. Several units exhibit similar depositional and palaeoenvironmental conditions to it, and thus, if the palaeodistribution roughly meets the taphonomical requirements, at least in such places remains of salamanders and caecilians are more likely to be present. All these factors may indicate a potential of such localities for new lissamphibian findings, making them good targets for future collection efforts.

Regions that accommodate higher numbers of species (e.g. Amazon and Atlantic Forest Biomes; Fig. S1) might contain older clades due to more time for speciation or higher diversification rates (Wiens and Donoghue 2004; Pyron and Burbrink 2009; Wiens 2012). Studies on species diversification in those regions are scarce and present conflicting explanatory hypotheses for the origin of this great diversity (Thomé et al. 2010). Further, fossil occurrences of lissamphibian clades that occupy those territories are scant or non-existent. This hampers an adequate exploration of the evolutionary history of those clades, based on both neontological and palaeontological data.

This scenario could be explained by two factors: low fossil collection efforts in the Amazon and Atlantic Forest regions, and the higher decomposition and decay rates of these humid environments; the latter hinder fossilisation and shorten the time a friable lissamphibian fossil could be available in the field (Dodson 1973). Despite these problems, some deposits in these regions, such as La Venta and Maquía-Cachiyacu, contain a high number of vertebrate fossils, including lissamphibians. Therefore, new findings in other units should be expected, and the exploration and description of lissamphibian fossils in those regions should be encouraged.

Anura

The study of biological and taphonomic bias in anuran records is more extensive than on the other lissamphibians, but it is still deficient. Actupalaeontological studies (Richter 1928) have tried to establish a starting point for the comprehension of those biases. The causal factors (e.g. weathering, microbial mats) that influence the thanatocoenosis and taphocoenosis process of Anura fossils have been considered in some works (e.g. Dodson 1973; Wüttke 1983; Pinto-Llona and Andrews 1999; Iniesto et al. 2017). Dodson (1973) presented the maximum time needed to achieve a complete disarticulation of an anuran corpse floating in pond water (i.e. the corpse would be partially disarticulated past 45 days), without the influence of other factors (e.g. the action of scavengers). Furthermore, a series of experiments with anuran corpses entombed in clay and sand sediments demonstrated the average time needed for

complete disarticulation of an anuran corpse in the wild. Magalhães (2014) recognised that it took 11 days to note bone disarticulation in specimens entombed in the sand, and autopodium and zeugopodium elements first underwent disarticulation. The experiments comparing the effect of the depositional location on the corpses were carried out in Moura and Barreto (2006). Specimens deposited in a lacustrine environment usually present post-mortem distension of the limb muscles, whereas specimens deposited in an open-air condition present post-mortem contraction of the limb muscles (Moura and Barreto 2006).

Iniesto et al. (2017) explored the decay rate of soft tissue preservation over three years, contrasting the taphocoenoses of frog corpses covered and not covered by microbial mats. The microbial mats form a filamentous sarcophagus that highly increases corpse preservation (Iniesto et al. 2017). The mineralization of soft tissues was reached after approximately a year and a half (Iniesto et al. 2017). Beyond that, the corpse's volume and size were significantly less altered in specimens enveloped by microbial mats (Iniesto et al. 2017). Factors related to the thanatocoenosis, such as water transport, weathering, predation, and its effects on amphibian bones, were examined by Pinto-Llona and Andrews (1999), which is a reference source for taphonomic alterations on amphibian remains. They analysed alterations and breakage in anuran bones present in scats and pellets of known predators and produced a set of categories that would be applied to the fossil record. The remains recovered from *Tyto alba* (a species of owl) pellets were the ones with less breakage and digestion, in comparison with other frog predators (Pinto-Llona and Andrews 1999). From *Tyto alba* pellets, the ilium is recognised as the bone with the highest resistance to taphonomic alterations, being a reliable basis for systematic identification (Sanchiz and Rey 2005; Matthews et al. 2019).

Our review suggests that depositional environments related to fluvial settings (e.g. fluvial floodplains) are the most common for Anura records, whereas the second most common are the ones related to lacustrine environments. That is congruent with the physiological and ecological features of Anura species, which usually use those kinds of environments as mating and oviposition sites. We do not estimate the biased effect that *Konservat-Lagerstätten* could have on those records, but our approach minimised the effect of *Konzentrat-Lagerstätten* (e.g. 300 specimens recovered in the same outcrop source of the holotype of *Saltenia ibanezi*). Although lacustrine settings are the second most common for anuran fossils, we note that this depositional environment present most features that allow the more recurrent preservation of complete skeletons and tadpoles of anurans. The third most common depositional environment is related to karst landscapes (e.g. caves, abyss). Lissamphibians fossils recovered in those caves could have lived and died inside the cave, or their corpses were brought into there in predators' scats or pellets, or by other agents such as sedimentary motion, and water transport (Pinto-Llona and

Andrews 1999). Therefore, we prefer not to consider suggested palaeoenvironment information for those records.

Amber deposits have been a valuable source of fossils, documenting the diversity within tropical rainforest environments, often based on exceptionally well-preserved specimens which usually contain fossilised soft tissues (e.g. Poinar 1992; Grimaldi et al. 1994). Examples of lissamphibian remains described based on specimens preserved in amber include frogs (Poinar and Cannatella 1987; Xing et al. 2018), salamanders (Poinar and Wake 2015), and albanerpetontids (Daza et al. 2020), from the Cretaceous of Myanmar and Eocene of the Dominican Republic. In South America, amber deposits are still poorly known (e.g. Antoine et al. 2006; Pereira et al. 2007). There are still no records of lissamphibian fossils found in amber inclusions in South America, but recent studies of invertebrates found in amber from the middle Miocene of Amazonia (e.g. Petrulevičius et al. 2011) reinforce the potential of the region for future findings.

Concerning ichnofossils, Johnson and Hembree (2015) explored the properties of a living anuran species burrow to understand the characteristics that fossilised ones could present. There are ichnofossils of anuran trackways in the USA and South Korea. The USA materials are from the Lower Cretaceous Patuxent Formation (Weems and Bachman 1997), Upper Cretaceous Blackhawk Formation (Robinson 1991), and *Ranipes laci* (Sperry 1980; Lockley and Milner 2014) from the Eocene Flagstaff Formation. The records from South Korea include *Ranipes saokensis* (Park et al., 2018) from the Late Cretaceous and *Ranipes* sp. indet. (Kim et al. 2019) from the Early Cretaceous of Gyeongsang Basin. Xing et al. (2019a) presented a frog spawn preserved in amber. Another important record is the one that includes palaeoecological information, such as the predation record found in China of an individual of the anuran *Genibatrachus* whose stomach content includes remains of the urodele *Nuominerpeton* (Xing et al., 2019b). Taphonomic data helps to understand associations between fossils, and represent an exploration of other approaches beyond the systematic (Schoch 2014).

For South America lissamphibians there are three examples of palaeoecologic interactions. The first is a record of predation on anurans, which is known by the agglutinated bones of *Calyptocephalella sabrosa* in fossilised avian pellets (Muzzopappa et al. 2021). The second and also the oldest association of South America lissamphibians was reported by Leal et al. (2007), comprising an indeterminate Anura from the Crato Formation (12th taxon of the locality 13) that presents fossilised remains of another specimen in its abdomen region. This association has not yet been explored. The third association comprises the record of *Uberabatrachus carvalhoi* (Báez et al. 2012b). The remains of this taxon were recovered associated with a sauropod femur (Agustin G. Martinelli, pers. comm.), but unfortunately, this information was not explored yet. We suggest that the

holotype specimen of *Uberabatrachus* might have been feeding on invertebrate scavengers of the sauropod remains, but there is no recorded evidence for this statement. It is important to recognise that lissamphibians are deeply inserted in biological interaction webs, and this characteristic could also be potentially observed in extinct species (Schoch 2014).

In South America, there is still no record of ichnofossils referred to Lissamphibia. These traces are naturally rare, but the existence of adequate sedimentological settings to preserve the diminutive size of frogs' trackways makes those findings at least likely. Other approaches could increase the probability of finding those fossils, e.g. try to notice them, as those records can co-occur with other larger and more noticeable tracks and traces (Park et al. 2018), and actuopalaeontological experiments to map the trackway and pace of several lissamphibian specimens morphotype. Still, part of the knowledge on the biological and taphonomic bias in lissamphibian records remains in the sphere of conjectures, mainly due to the deficient knowledge in this field of study and the restricted supporting evidence for hypothesised taphonomic processes. Conjectures on the taphonomic history of each fossil can be interpreted through direct observation of the fossil specimens. However, actuopalaeontological experiments on lissamphibians are essential to interpret properly the fossil record (Iniesto et al. 2017). This could significantly increase the reliability of palaeoenvironmental and palaeobiological interpretations of those records.

Gymnophiona

Due to the limited fossil record, the taphonomical biases of caecilian remains are poorly understood. Comments on this subject are usually restricted to brief and specific remarks, instead of considering general patterns. For example, Wake et al. (1999) described an isolated vertebra from the Quaternary of Mexico and assigned it to the extant species *Dermophis mexicanus*. To explain the fact that only one vertebra was found (considering that this species has a vertebral count ranging from 100 to 112, according to Wake 1980), the authors suggested that the remains were quarried from the upper layers and reworked in a lower one.

Among the most important factors related to the fossilisation process, the kind of depositional environment and the degree of transport events are particularly relevant (Behrensmeier et al. 2000). The transport of the carcass before the burial, a factor that negatively impacts the fossilisation chances, is usually reduced or even absent for fossorial taxa. Details on the behaviour of most caecilian taxa are virtually unknown, but several species are considered well adapted to a fossorial existence, whereas the representatives of Typhlonectidae are capable of occupying aquatic or semi-aquatic environments (Taylor 1968; Tanner 1971). However, as most fossorial caecilians usually do not live where deposition of sediments occurs, the fossilisation of their remains is uncommon.

Additionally, considering the most common depositional environments where lissamphibian fossils are found, such as lakes and braided or meandering rivers (Behrensmeyer et al. 2000), the caecilian fossil record could be biased, favouring taxa that live next to or inside aquatic environments, either as larvae or adults. Unfortunately, fossils assigned to such aquatic-related forms are still unknown, and as caecilian fossils are usually restricted to isolated vertebrae, with low taxonomic value considering the current knowledge on their post-cranial anatomy, the validity of such conjectures remain uncertain.

Urodela

Fossils of *Noterpeton bolivianum*, as well as *Kababisha humarensis* and *Kababisha sudanensis*, their closely related African relatives, were found in localities deposited under lacustrine conditions (see details of the localities 39, 40, and 44; and Gardner and Rage 2016, for details of palaeo-environmental conditions in which *Kababisha* fossils were found). This is consistent with the behaviour of sirenids, their putative modern relatives. Nowadays, the only native salamanders from South America are the plethodontids, distributed in two different portions of the Amazonian Rainforest (Parra-Olea et al. 2004). Their fossils are still unknown from South American deposits, and this lack could be related to a particularity of tropical forest environments, usually characterised by high biological activity in decomposition and carbon cycling of the remains in acid soils, factors known to decrease the chances of fossilisation (e.g. Tappen 1994).

Calibration Constraints for Divergence-Time Estimates

Divergence-time estimates are particularly important for phylogenies based on molecular data and are highly dependent on a well-established stratigraphy and a good fossil record (Parham et al. 2012). Furthermore, the fossil record could diminish the uncertainties intrinsic to the model of divergence-time estimates (Louca and Pennell 2020). Therefore, the estimates proposed here are based on the most recent or widely accepted taxonomic and stratigraphic data. In the cases where the age of the rocks has been determined by indirect dating methods (e.g. biostratigraphy), the estimates are given considering the entire interval of the stratigraphic unit where the fossil was found. Recently, Santos et al. (2020) proposed three calibration constraints for major clades of caecilians (Gymnophionomorpha, Gymnophiona, and Teresomata), but none of these constraints were based on South American specimens, whereas in a previous study the Eocene record of *Apodops pricei* was used to calibrate Gymnophiona (Benton et al. 2015). Regarding salamanders, the occurrences of *Noterpeton bolivianum* in Upper Cretaceous

(Maastrichtian) and lower Paleocene deposits of Bolivia (Rage et al. 1993; Gayet et al. 2001) are younger than the records of fossil forms with procoelous vertebrae from Africa (Evans et al. 1996) and sirenids in North America (Gilmore 1928; Gardner 2003).

Although the high diversity of South American fossil anurans allows the use of at least some of these records to erect new calibration constraints, in some cases the uncertainty about the taxonomic affinities of such specimens has led to a misinterpretation of divergence estimates (e.g. *Baurubatrachus* was initially considered to be the oldest record of Ceratophryidae, but after a reanalysis, it was assigned to Calyptocephalellidae). Additionally, there are putative oldest records for some frog taxa (e.g. Ranidae and Hylidae), however, such occurrences are based on unpublished or not yet formally described materials and, therefore, will not be included in this section.

Neobatrachia Reig, 1958a

Node calibration: Divergence between Neobatrachia and Anomocoela Nicholls, 1916. This corresponds to the Neobatrachia total group.

Oldest fossils: Complete skeleton assigned to *Arariphrynus placidoi* (MPSC-Ap 893), two almost complete specimens named *Kururubatrachus gondwanicus* (UFRJ-DG 08 A) and *Primaevorana cratensis* (GP/2E-9497), all from Crato Formation, Araripe Basin, Brazil.

Phylogenetic justification: The materials of *Arariphrynus placidoi* (Báez et al. 2009; Báez and Gómez 2018), *Kururubatrachus gondwanicus* (Agnolin et al., 2020), and *Primaevorana cratensis* (Moura et al., 2021) were allocated within Neobatrachia, but their phylogenetic relationships among other neobatrachians are still uncertain, as the synapomorphies of the clade were not commented on in those works or have some degree of homoplasy. The presence of palatine may be a putative character of Neobatrachia (Trueb, 1993).

Maximum/Minimum Age: 125–113 Ma.

Age Justification: Crato Formation is traditionally considered to be Early Cretaceous (late Aptian) in age, according to palynological data (Heimhofer and Hochuli, 2010). So, the maximum and minimum age are defined by the time range of Aptian, ~125 to ~113 Ma according to ICS.

Discussion: Usually, fossils are collected from the Crato Formation as mining tailings and lack precise stratigraphic control. Therefore, it is not possible to establish which of the species is the oldest. Moreover, their neobatrachian affinities need to be

better understood, and thus the utility of these fossils for the calibration of the neobatrachian crown is impaired.

Australobatrachia Frost et al., 2006

Node calibration: Divergence between Myobatrachoidea and Calyptocephalellidae Reig, 1960. This corresponds to the crown Australobatrachia.

Oldest fossil: Complete skeleton (MPSC-Ap 891) described as *Eurycephalella alcinae*, from Crato Formation, Araripe Basin, Brazil.

Phylogenetic justification: The material was positioned as sister to *Calyptocephalella gayi* (in the constrained tree with weighted characters) and as sister to *Calyptocephalella gayi* plus *Baurubatrachus pricei* in the consensus tree, with unordered and equally weighted characters (Báez and Gómez 2018). However, under other analytical conditions (e.g. constrained analysis under equal weights) it was recovered as the sister group of a large clade of nobleobatrachian hyloids. Thus, the assignment of *E. alcinae* to Australobatrachia should be viewed with caution, and its use to calibrate this node remains only tentative. There are no exclusive synapomorphies recognised for this node.

Maximum/Minimum Age: 125–113 Ma

Age Justification: same for Neobatrachia.

Discussion: Knowledge on the evolution of South American australobatrachians (i.e. Calyptocephalellidae) has improved significantly in recent years, especially due to the inclusion of molecular data in the phylogenetic analyses and the refinement in the anatomical descriptions of fossil and extant taxa. However, further studies are still necessary to clarify the affinities of such fossil forms (e.g. *Eurycephalella* and *Baurubatrachus*) with calyptocephalellids and other australobatrachians.

Ceratophryidae Tschudi, 1838

Node calibration: Divergence between *Ceratophrys* and the clade formed by *Lepidobatrachus* plus *Chacophrys*, its nearest crown sister taxon (according to Faivovich et al. 2014). This corresponds to the crown Ceratophryidae.

Oldest fossil: Incomplete interorbital region and left maxilla (MD-CH-06-165) assigned to *Ceratophrys* sp., from Arroyo Chasicó, Arroyo Chasicó Formation, Buenos Aires, Argentina (Nicoli et al. 2017).

Phylogenetic justification: The material was allocated in *Ceratophrys* (Gómez and Turazzini 2021), and the synapomorphies supporting this assignment include: labial surface of

pars dentalis of maxilla not thickened laterally, overlapped by sculpture of pars facialis; pars dentalis of maxilla short in the antorbital region (markedly short interdental ridges, height similar to interdental width, barely covered by pleura).

Maximum/Minimum Age: 9.43–9.07 Ma.

Age Justification: According to magnetostratigraphic and radiometric data, this unit was assigned to the Chasicóan of SALMA, within the late Miocene, or middle Tortonian of ICS (Zárate et al. 2007).

Discussion: For almost three decades various hyperossified extinct species were suggested as related to the Ceratophryidae (e.g. *Baurubatrachus pricei*, *Thaumastosaurus gezei*, and *Beelzebubo ampinga*). Additionally, phylogenies based on morphological characters also recovered hyperossified extant species (e.g. *Calyptocephalella gayi*) as related to this family (Wiens et al. 2005, Báez et al. 2009). Later the convergent characters recorded in both extant and extinct species with hyperossified skeletons were recognised (Paluh et al. 2020) and the phylogenetic positioning of those fossils was reinterpreted (Nicoli et al. 2016; Báez and Gómez 2018). Moreover, the current oldest record of Ceratophryidae is a specimen described by Nicoli et al. (2017) and phylogenetically allocated with that family by Gómez and Turazzini (2021).

Lepidobatrachus Budgett, 1899

Node calibration: Divergence between *Lepidobatrachus* and *Chacophrys*, its nearest crown sister taxon (according to Faivovich et al. 2014). This corresponds to *Lepidobatrachus* total group.

Oldest fossil: Fragmentary skull (MMH 85.12.2a) described as *Lepidobatrachus australis* Nicoli 2015, from Farola Monte Hermoso, Monte Hermoso Formation, Buenos Aires, Argentina.

Phylogenetic justification: The material was assigned to *Lepidobatrachus* based on a set of diagnostic features, i.e. small, round orbits located at the mid-length of the skull; robust, hourglass-shaped maxillary processes of the nasals; articulation between nasal and frontoparietal perpendicular to midline; squamosal and frontoparietal in broad contact without forming a postorbital fenestra; anterior terminus of parasphenoid anterior to the level of the planum antorbitale (Nicoli 2015). The fossil material was later allocated in the Total-Group of *Lepidobatrachus* (Gómez and Turazzini 2021).

Maximum/Minimum Age: 5.3–3.6 Ma.

Age Justification: Estimates based on biostratigraphy found an early Pliocene age for Farola Monte Hermoso,

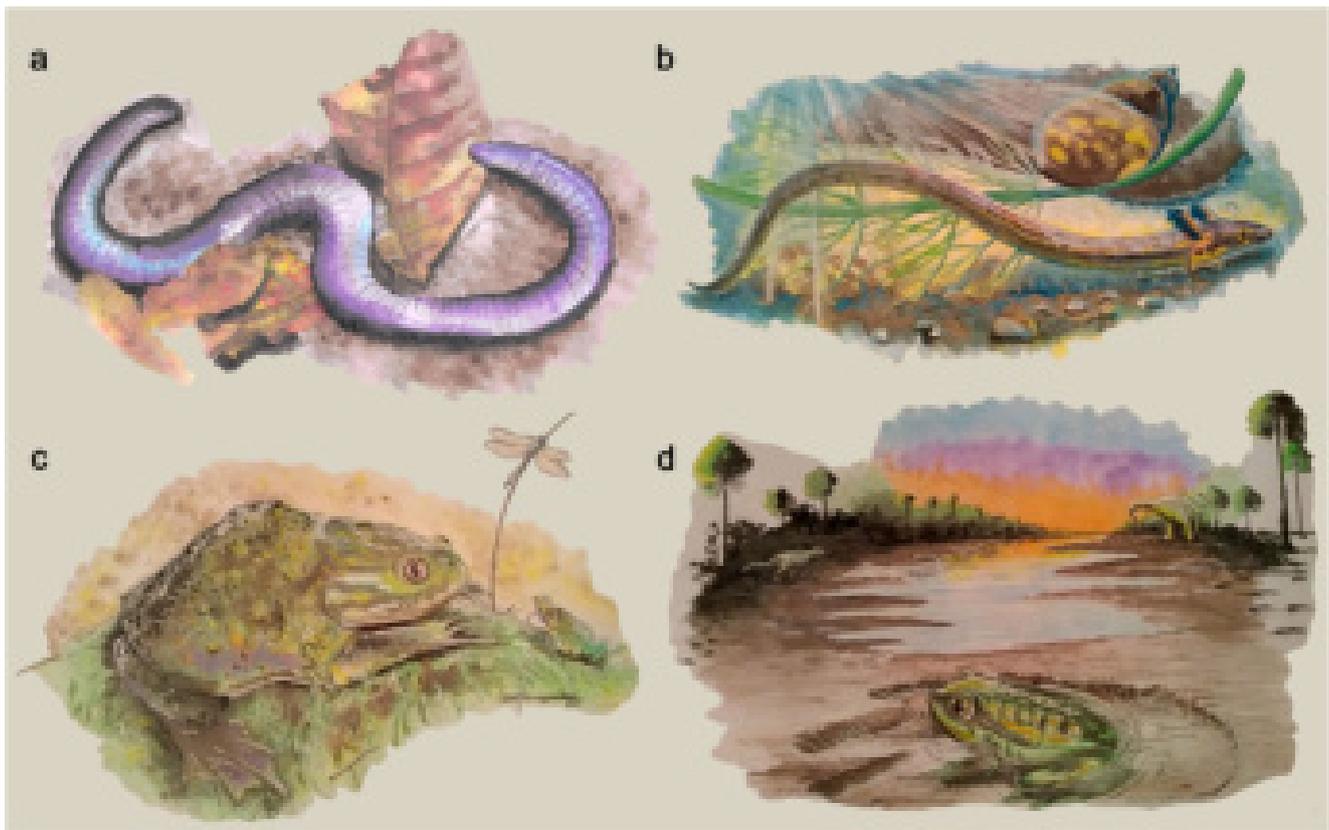


Fig. 5 Interpretative reconstructions of lissamphibian fossils from South America. **a** *Apodops pricei*, the first caecilian species described based on fossilised remains (lower Eocene of Itaboraí Basin, Brazil), South America; **b** *Noterpeton bolivianum* (upper Paleocene of Santa Lucía Formation, Bolivia), the only known salamander species in the South American fossil record; **c** *Calyptocephalella* sp., considered the largest

frog of all time (estimated SVL ~ 59 cm; lower Eocene of Río Turbio Formation, Chile) facing a specimen of the extant *Calyptocephalella gayi*; **d** *Notobatrachus degiustoi*, one of the earliest records of Anura in South America, floating inside a theropod footprint from the Jurassic floodplains of the La Matilde Formation, Argentina (life reconstruction by Gabriel Teófilo-Guedes)

corresponding to Montehermosan of SALMA, and Zanclean of ICS (Deschamps et al. 2012; Tomassini et al. 2013). Thus, the maximum and minimum age are defined by the time-span of the Zanclean, 5.3–3.6 Ma, respectively.

Discussion: *Lepidobatrachus australis* was utilised as a calibration point by Brusquetti et al. (2018) before the specimen was formally phylogenetically allocated. An earlier, in-depth study of the specimen provided a set of diagnostic characters that supported the species as an extinct species of *Lepidobatrachus* (Nicoli, 2015). The taxonomic assignment of Nicoli (2015) was later corroborated by Gómez and Turazzini (2021), and *Lepidobatrachus australis* is the earliest record for *Lepidobatrachus*.

The fossil record of Anura from South America represents a relevant landmark for the ancient-most representatives of clades within Neobatrachia. The main problem concerning those fossils is reliably establishing their phylogenetic relationships. Our estimates indicate that 83% of the fossil record of Lissamphibia from South America has not been phylogenetically allocated yet. At the supraspecific level, only the Ceratophryidae and stem-Anura present the majority of the

records phylogenetically allocated, whereas all other clades have few extinct species included in phylogenies (Fig. S2 in Supplementary Data 1).

For example, *Estesiella boliviensis* and *Chachaiphrynus lynchi* are remarkable records that should be included in a phylogenetic analysis to improve our knowledge of Hyloidea systematics and become important fossils for node calibration. Similarly, advances in the understanding of morphological diversity and phylogenetic relationships among frogs could allow the inclusion of other fossils as new calibration constraints (e.g. a left ilium assigned to *Rhinella arenarum* by Báez and Nicoli, 2004b and an ilium and a sacrum assigned to *Leptodactylus* sp. by Gómez et al., 2013). Large-scale or even a restricted scope morphological matrices for lissamphibians including extinct and extant species are still scarce in the literature (Muzzopappa and Báez 2009), preventing the use of fossils as calibration-points (Jetz and Pyron 2018). The current practice of systematic studies is to include few fossil specimens as calibration-points, e.g. Frazão et al. (2015) (12 fossils), Jetz and Pyron (2018) (14 fossils), Feng et al. (2017), (20 fossils) Hime et al. (2021) (25 fossils),

but the divergence-time estimates for clades from South America are problematic due to sparse fossil records and limited knowledge about previously described specimens and taxa.

Conclusions

Our work indicates that thanks to the description of new specimens and the re-evaluation of materials already published, the knowledge of South American lissamphibian fossils has significantly advanced since the last review efforts on this subject were published. The present contribution is the first to deal with the entire fossil record of South American lissamphibians. Our results show that fossil occurrences encompass 164 localities, spread across eight countries, filling a time interval of almost 200 million years, from the Early Jurassic to the late Holocene.

Representatives from all lissamphibian groups (Fig. 5), except albanerpetontids, are present. The fossil record comprises mostly anurans, with 266 documented occurrences. Few caecilian occurrences were reported (four records), but if we consider their world fossil record, they represent almost half of all fossils assigned to the group known so far. The fragmentary condition of these fossils hinders more precise diagnosis, and thus only a single species was described so far. For salamanders, the enigmatic record of *Noterpeton*, as well as the absence of fossil plethodontids indicates that information about fossil salamanders is still scarce and deserves more attention in further studies.

Several of the records compiled in our review comprise specimens still undescribed or not assigned to any more specific taxon. These results suggest that the diversity of fossil lissamphibians on the continent is underestimated. Additionally, we provide a comprehensive dataset encompassing all reported occurrences, as well as additional information on the age and palaeoenvironmental characteristics of the fossil deposits. We expect that the data compiled in this review and our discussion on South American lissamphibians will be useful for future studies into the phylogeny, palaeoecology, and analyses of evolutionary and biogeographic patterns of lissamphibians, both for the continent and worldwide.

Appendix

List of Institutional Abbreviations:

AMNH American Museum of Natural History, New York, USA; **AMU-CURS** Colección de Paleontología de Vertebrados de la Alcaldía de Urumaco, Estado Falcón, Venezuela; **BAR** Asociación Paleontológica Bariloche, San Carlos de Bariloche, Río Negro, Argentina; **BMNH** Natural History Museum, London, England; **CIC** Centro de

Investigaciones Científicas, Viedma, Río Negro, Argentina; **CORD-PZ** Museo de Paleontología of the Universidad Nacional de Córdoba, Argentina; **CPBA** Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina; **CP-Bar** Asociación Paleontológica Bariloche, San Carlos de Bariloche, Río Negro, Argentina; **CPPLIP** Centro de Pesquisas Paleontológicas Llewellyn Ivor Price, Minas Gerais, Brazil; **DGM** Divisão de Geologia e Mineralogia, Rio de Janeiro, Brazil; **DNPM** Departamento Nacional de Produção Mineral, Rio de Janeiro, Brazil; **FCEN-PV** Vertebrate Palaeontology, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina; **FMNH P** Paleontological Collection, The Field Museum, Chicago, USA; **GHUNLPam** Cátedra de Geología Histórica y Regional de la Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Argentina; **GP** Instituto de Geociências da Universidade de São Paulo, São Paulo, Brazil; **IBIGEO-P** Colección Paleontología Instituto de Bio y Geociencias del Noroeste Argentino, Rosario de Lerma, Argentina; **IANIGLA.PV** Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, Vertebrate Paleontology, Mendoza, Argentina; **KUVP** Paleontology collection, University of Kansas Biodiversity Institute, Lawrence, Kansas, USA; **LIEB-PV** Laboratorio de Investigaciones en Evolución y Biodiversidad, Paleovertebrados, Universidad de la Patagonia “San Juan Bosco” sede Esquel, Chubut, Argentina; **MACN** Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Ciudad Autónoma de Buenos Aires; **MBC** Museu de Biodiversidade do Cerrado, Uberlândia, Brazil; **MCN-PUCMG** Museu de Ciências Naturais da Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil; **MCNC-PV** Museo Provincial de Ciencias Naturales “Dr. Arturo U. Illia,” Córdoba, Argentina; **MCN-SCB-UFPR** Museu de Ciências Naturais of Universidade Federal do Paraná, Brazil; **MD-CH** Museo Municipal de Ciencias Naturales ‘Carlos Darwin,’ Arroyo Chasicó collection, Punta Alta, Argentina; **MDJ** Museu Diocesano Dom José, Sobral, Brazil; **MHNC** Museo de Historia Natural Alcide d'Orbigny de Cochabamba, Cochabamba, Bolivia; **MJHG** Museo Naturalístico, Antropológico e Histórico “Jorge Gerhold”, Ingeniero Jacobacci, Río Negro, Argentina; **MLG** Museo del Lago Gutierrez “Dr. Rosendo Pascual”, San Carlos de Bariloche, Argentina; **MLP** Museo de La Plata, La Plata, Argentina; **MMH** Museo de Ciencias Naturales ‘Vicente Di Martino’, Monte Hermoso, Argentina; **MML** Museo Municipal de Lamarque Río Negro, Neuquén, Argentina; **MMP** Museo Municipal de Ciencias Naturales ‘Lorenzo Scaglia’, Mar del Plata, Argentina; **MMS** Museo Municipal de Salto ‘José Bonaparte’, Salto, Argentina; **MN** Museu Nacional, Rio de Janeiro, Brazil; **MNHN** Muséum national d'Histoire naturelle, Paris, France; **MPEF** Museo Paleontológico Egidio Feruglio, Trelew, Argentina; **MPM-PV** Museu Regional Provincial

“Padre Manuel Jesús Molina”, Río Gallegos, Argentina; **MPSC** Museu de Paleontologia de Santana do Cariri, Santana do Cariri, Brazil; **MUCPV** Museo de Geología y Paleontología de la Universidad Nacional del Comahue, Sección Paleontología de Vertebrados, Neuquén, Argentina; **MZUSP** Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil; **PVL** Paleontología de Vertebrados, Instituto Miguel Lillo, Tucumán, Argentina; **PVSJ** Museo de Ciencias Naturales, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Argentina; **RTMP**, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada; **SGO.PV** Paleontología de Vertebrados, Museo Nacional de Historia Natural, Santiago, Chile; **UERN PV** Vertebrate paleontology collection, Laboratório de Sistemática e Ecologia Animal, Universidade do Estado do Rio Grande do Norte, Mossoró, Brazil; **UF** University of Florida, Gainesville, USA; **UFAC** Universidade Federal do Acre, Rio Branco, Brazil; **UFC** Universidade Federal do Ceará, Fortaleza, Brazil; **UFRJ-DG** Universidade Federal do Rio de Janeiro, Departamento de Geologia, Rio de Janeiro, Brazil; **ZUFABC** Coleção Zoológica, Universidade Federal do ABC, São Bernardo do Campo, Brazil.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12549-022-00536-0>.

Acknowledgements We thank Instituto de Biociências, Universidade de São Paulo, Museu de Zoologia da USP, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto (USP), and Universidade Federal do ABC for logistical support. We thank the funding provided by São Paulo Research Foundation (FAPESP Proc 2020/07997-4; 2019/24466-5; 2019/14153-0; 2017/04849-1 for LAB), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (88887.596134/2020-00 for ROS, and 88887.507806/2020-00 for LAB). This work was also partially supported by the CAPES–Finance Code 001. ROS is particularly grateful to José Roberto da Cunha Nobre (*in memoriam*), who first introduced him to the wonders of science. We thank R. Bantim (MPSC) for graciously providing information and photos of specimens from Araripe Basin. We are indebted to the Palaeoartist Gabriel Teófilo-Guedes who created the interpretative life-reconstitutions in Fig. 5. We are also indebted to D. Almeida-Silva (UFABC) and Janice Jarosi who revised an early version of this manuscript, on language and systematics, and Agustín Martinelli (MACN) who provided information on the holotype of *Uberabatrachus carvalhoi*. Furthermore, we are deeply grateful to the reviewers James Gardner (RTMP) and Raúl O. Gómez (UBA) for providing references and details about localities and fossil occurrences, as well as for their suggestions that substantially improved this manuscript. We dedicate this work to Ana María Báez (UBA), for her inestimable contribution to the study of fossil lissamphibians in South America.

Data availability All data generated or analysed during this review are included in this published article or its supplementary information files.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

- Ab’Saber, N. A. (1977). Os domínios morfoclimáticos da América do Sul. Primeira aproximação. *Geomorfologia*, 53, 1–23.
- Agnolin, F. (2005). Un nuevo escuerzo (Anura, Leptodactylidae) del “Ensenadense” Pleistoceno inferior–medio de la Provincia de Buenos Aires (Argentina), con notas sobre la clasificación del género *Ceratophrys*. *Studia Geologica Salmanticensia*, 41, 45–55.
- Agnolin, F. (2012). A new Calyptocephalellidae (Anura, Neobatrachia) from the Upper Cretaceous of Patagonia, Argentina, with comments on its systematic position. *Studia geologica salmanticensia*, 48, 129–178.
- Agnolin, F., & Jofré, G. (2011). Nuevos registros de Squamata (Reptilia) para el Pleistoceno superior del Norte de la provincia de Buenos Aires, Argentina. *Papéis Avulsos de Zoologia*, 51, 49–58. <https://doi.org/10.1590/S0031-10492011000400001>
- Agnolin, F., de Souza Carvalho, I., Rolando, A. M. A., Novas, F. E., Xavier-Neto, J., Andrade, J. A. F. G., & Freitas, F. I. (2020). Early Cretaceous neobatrachian frog (Anura) from Brazil sheds light on the origin of modern anurans. *Journal of South American Earth Sciences*, 101, 102633. <https://doi.org/10.1016/j.jsames.2020.102633>
- Agnolin, F. L., Bogan, S., & Ruiz, L. R. G. (2021). Fossil fishes and anurans from the Miocene of Río Chico and Cerro Zeballos, Chubut Province, Argentina. *Anais da Academia Brasileira de Ciências*, 93, e20191438. <https://doi.org/10.1590/0001-376520210191438>
- Alkmim, F. F. de (2015). Geological background: a tectonic panorama of Brazil. In A. A. R. Salgado, L. J. C. Santos & B. C. Vieira (Eds.), *Landscapes and landforms of Brazil* (pp. 9–17). Dordrecht: Springer. https://doi.org/10.1007/978-94-017-8023-0_2
- Alván, A., Tuesta, J., Navarro, J. P., Martínez, J. N., & Romero, L. (2009). Evolución sedimentaria y paleoambiental durante el Pleistoceno en la Quebrada el Muerto, La Brea, Talara. *Boletín de la Sociedad Geológica del Perú*, 103, 171–183.
- Ameghino, F. (1899). *Sinopsis geológico-paleontológica*. La Plata: Imprenta y Encuadernación “La Libertad”.
- Ameghino, F. (1901). L’âge des formations sédimentaires de Patagonie. *Anales de la Sociedad Científica Argentina*, 52, 145–250.
- AmphibiaWeb. (2021). *Information on amphibian biology and conservation*. Available at: <https://amphibiaweb.org>. Accessed 24 September 2021.
- Antoine, P. O., De Franceschi, D., Flynn, J. J., Nel, A., Baby, P., Benammi, M., Calderón, Y., Espurt, N., Goswami, A., & Salas-Gismondi, R. (2006). Amber from western Amazonia reveals Neotropical diversity during the middle Miocene. *Proceedings of the National Academy of Sciences*, 103, 13595–13600. <https://doi.org/10.1073/pnas.0605801103>
- Antoine, P. O., Abello, M. A., Adnet, S., Sierra, A. J. A., Baby, P., Billet, G., Bovin, M., Calderón, Y., Candela, A., Chabain, J., Corfu, F., Croft, D. A., Ganerød, M., Jaramillo, C., Klaus, S., Marivaux, L., Navarrete, R. E., Orliac, M. J., Parra, R., Pérez, M. E., Pujos, F., Rage, J. C., Ravel, A., Robinet, C., Roddaz, M., Tejada-Lara, J. V., Vélez-Juarbe, J., Wesselingh, F. P., & Salas-Gismondi, R. (2016). A 60-million-year Cenozoic history of western Amazonian ecosystems in Contamana, eastern Peru. *Gondwana Research*, 31, 30–59. <https://doi.org/10.1016/j.gr.2015.11.001>
- Antoine, P. O., Yans, J., Castillo, A. A., Stutz, N., Abello, M. A., Adnet, S., Custódio, M. A., Benites-Palomino, A., Billet, G., Boivin, M., Herrera, F., Jaramillo, C., Martínez, C., Moreno, F., Navarrete, R. E., Negri, F. R., Parra, F., Pujos, F., Rage, J. C., Ribeiro, A. M., Robinet, C., Roddaz, M., Tejada-Lara, J. V., Varas-Malca, R., Santos, R. V., Salas-Gismondi, R., & Marivaux, L. (2021). Biotic community and landscape changes around the Eocene–Oligocene transition at Shapaja, Peruvian Amazonia: Regional or global

- drivers?. *Global and Planetary Change*, 202, 103512. <https://doi.org/10.1016/j.gloplacha.2021.103512>
- Antonelli, A., Nylander, J. A., Persson, C., & Sanmartín, I. (2009). Tracing the impact of the Andean uplift on Neotropical plant evolution. *Proceedings of the National Academy of Sciences*, 106, 9749–9754. <https://doi.org/10.1073/pnas.0811421106>
- Antonelli, A., Zizka, A., Carvalho, F. A., Scharn, R., Bacon, C. D., Silvestro, D., & Condamine, F. L. (2018). Amazonia is the primary source of Neotropical biodiversity. *Proceedings of the National Academy of Sciences*, 115, 6034–6039. <https://doi.org/10.1073/pnas.1713819115>
- Araújo-Júnior, H. I., Porpino, K. O., Ximenes, C. L., & Bergqvist, L. P. (2013). Unveiling the taphonomy of elusive natural tank deposits: a study case in the Pleistocene of northeastern Brazil. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 378, 52–74. <https://doi.org/10.1016/j.palaeo.2013.04.001>
- Araújo-Júnior, H. I., & Moura, G. J. B. (2014). Anuros (Amphibia, Anura) do Pleistoceno Final-Holoceno inicial de Itapipoca, estado do Ceará, Brasil: taxonomia, paleoecologia e tafonomia. *Revista Brasileira de Paleontologia*, 17, 373–388. <https://doi.org/10.4072/rbp.2014.3.08>
- Araújo-Júnior, H. I., Porpino, K. O., & Bergqvist, L. P. (2015). Vertebrate taphonomy and paleoecology in an Upper Pleistocene tank deposit of Paraíba, Brazil: taphonomic modes, evidence of temporal and spatial resolutions and paleoecological patterns of the Brazilian Intertropical Region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 437, 1–17. <https://doi.org/10.1016/j.palaeo.2015.07.009>
- Araújo-Júnior, H. I., Porpino, K. O., Bergqvist, L. P., & Dardon, U. (2016). New fossil record of Bufonidae (Amphibia, Anura) in the Late Pleistocene-early Holocene of northeastern Brazil and its paleoenvironmental significance. *Journal of Sedimentary Environments*, 1, 68–77. <https://doi.org/10.12957/jse.2016.21507>
- Armas, M. P., & Sánchez, M. L. (2015). Hybrid coastal edges in the Neuquén Basin (Allen Formation, Upper Cretaceous, Argentina). *Andean Geology*, 42, 97–113. <https://doi.org/10.5027/andgeoV42n1-a06>
- Assine, M. L., Perinotto, J. D. J., Custódio, M. A., Neumann, V. H., Varejão, F. G., & Mescolotti, P. C. (2014). Sequências deposicionais do andar Alagoas da Bacia do Araripe, nordeste do Brasil. *Boletim de Geociências da PETROBRAS*, 22, 3–28. <https://doi.org/10.25249/0375-7536.1992289300>
- Bacon, C. D., Silvestro, D., Jaramillo, C., Smith, B. T., Chakrabarty, P., & Antonelli, A. (2015). Biological evidence supports an early and complex emergence of the Isthmus of Panama. *Proceedings of the National Academy of Sciences*, 112, 6110–6115. <https://doi.org/10.1073/pnas.1423853112>
- Báez, A. M. (1977). Sobre *Teracophrys* (Anura, Leptodactylidae) *nomina nuda*, de la Formación Colhué-Huapi (Oligoceno Superior). *Revista de la Asociación Geológica Argentina*, 32, 145–151.
- Báez, A. M. (1981). Redescription and relationships of *Saltenia ibanezi*, a Late Cretaceous pipid frog from Northwestern Argentina. *Ameghiniana*, 18, 127–154.
- Báez, A. M. (1986). El registro terciario de los anuros en el territorio argentino: una reevaluación. In A. J. Cuerda, J. F. Bonaparte, W. Volkheimer & H. A. Leanza (Eds.), *Actas IV Congreso Argentino de Paleontología y Bioestratigrafía* (pp. 23–27). Mendoza: El Congreso.
- Báez, A. M. (1987). Anurans. In J. F. Bonaparte (Ed.), *The Late Cretaceous fauna of Los Alamitos, Patagonia, Argentina* (pp. 121–130). Buenos Aires: Museo Argentino de Ciencias Naturales Bernardino Rivadavia.
- Báez, A. M. (1988). Un neobatraco (Amphibia, Anura) del Paleógeno del Rio Pichileufu, provincia de Rio Negro. In J. C. Quiroga, & A. L. Cione (Eds.), *Resúmenes V Jornadas Argentinas Paleontología Vertebrados* (pp. 16–19). La Plata: Universidad de La Plata.
- Báez, A. M. (1991a). A new early Paleocene neobatrachian frog from the Santa Lucía Formation in south central Bolivia, and comments on the Cretaceous and early Tertiary batrachofaunas of South America. *Revista Técnica de Yacimientos Petrolíferos Fiscales Bolivianos*, 12, 529–540.
- Báez, A. M. (1991b). Anuros en el Eogeno de los alrededores del Lago Nahuel Huapi, Neuquén meridional. *Ameghiniana*, 28, 403.
- Báez, A. M. (1995). *Estesiella*, replacement name for *Estesius*, a Paleocene neobatrachian frog from Bolivia. *Ameghiniana*, 32, 56.
- Báez, A. M. (1996). The fossil record of the Pipidae. In R. C. Tinsley & H. R. Kobel (Eds.), *The Biology of Xenopus* (pp. 329–347). Oxford: Clarendon Press.
- Báez, A. M. (2000). Tertiary anurans from South America. In H. Heatwole & R. L. Carroll (Eds.), *Amphibian Biology, The evolutionary history of amphibians* (pp. 1388–1401). Chipping Norton: Surrey Beatty and Sons.
- Báez, A. M., & Basso, N. G. (1996). The earliest known frogs of the Jurassic of South America: review and cladistic appraisal of their relationships. In G. Arratia (Ed.), *Münchner Geowissenschaftliche Abhandlungen: Contributions of Southern South America to Vertebrate Paleontology* (pp. 131–158). München: Verlag Dr. Friedrich Pfeil.
- Báez, A. M., & Calvo, J. O. (1990). Nuevo anuro pipoideo del Cretácico medio del Noroeste de Patagonia. Argentina. *Ameghiniana*, 26, 238–238.
- Báez, A. M., & Fernicola, J. C. (1999). New anuran material from Deseadan beds of Scarritt Pocket, Chubut Province, and the supposed presence of palearctic bufonids in the Oligocene of Patagonia. *Ameghiniana*, 36, 23–35.
- Báez, A. M., & Gasparini, Z. B. (1977). Orígenes y evolución de los anfibios y reptiles del Cenozoico de América del Sur. *Acta Geológica Lilloana*, 14, 149–232.
- Báez, A. M., & Gasparini, Z. N. B. (1979). An evaluation of the fossil record. In W. E. Duellman (Ed.), *The South American Herpetofauna* (pp. 29–54). Lawrence: University of Kansas.
- Báez, A. M., & Gómez, R. O. (2016). New evidence from the Lower Jurassic of Patagonia sheds light on the history of some of the earliest known frogs. In F. Holwerda, A. Madern, D. Voeten, A. Heteren, J. Liston, H. Meijer, N. Ouden, S. Spiekman, T. Trapman, F. Miedema, S. Bijl, M. Smeets, P. Kaskes, T. Rietbergen, & J. Lubeek (Eds.), *Programme and Abstract Book of the XIV Annual Meeting European Association of Vertebrate Paleontologists* (p. 19). Haarlem: Koninklijke Nederlandse Akademie van Wetenschappen.
- Báez, A. M., & Gómez, R. O. (2018). Dealing with homoplasy: osteology and phylogenetic relationships of the bizarre neobatrachian frog *Baurubatrachus pricei* from the Upper Cretaceous of Brazil. *Journal of Systematic Palaeontology*, 16, 279–308. <https://doi.org/10.1080/14772019.2017.1287130>
- Báez, A. M., & Harrison, T. (2005). A new Pipine frog from an Eocene crater lake in North-Central Tanzania. *Palaeontology*, 48, 723–737. <https://doi.org/10.1111/j.1475-4983.2005.00477.x>
- Báez, A. M., & Nicoli, L. (2004a). A new look at an old frog: the Jurassic *Notobatrachus* Reig from Patagonia. *Ameghiniana*, 41, 257–270.
- Báez, A. M., & Nicoli, L. (2004b). Bufonid toads from the Late Oligocene beds of Salla, Bolivia. *Journal of Vertebrate Paleontology*, 24, 73–79. <https://doi.org/10.1671/1900-6>
- Báez, A. M., & Nicoli, L. (2008). A new species of *Notobatrachus* (Amphibia, Salientia) from the Middle Jurassic of northwestern Patagonia. *Journal of Paleontology*, 82, 372–376. <https://doi.org/10.1666/06-117.1>
- Báez, A. M., & Peri, S. (1989). *Baurubatrachus pricei*, nov. gen. et sp., un anuro del Cretácico Superior de Minas Gerais, Brasil. *Anais da Academia Brasileira de Ciências*, 61, 447–458.
- Báez, A. M., & Peri, S. (1991). Revisión de *Wawelia gerholdi*, un anuro del Mioceno de Patagonia. *Ameghiniana*, 27, 379–386.

- Báez, A. M., & Pugener, L. A. (1998). A new Paleogene pipid frog from northwestern Patagonia. *Journal of Vertebrate Paleontology*, 18, 511–524. <https://doi.org/10.1080/02724634.1998.10011078>
- Báez, A. M., & Púgener, L. A. (2003). Ontogeny of a new Palaeogene pipid frog from southern South America and xenopodinomorph evolution. *Zoological Journal of the Linnean Society*, 139, 439–476. <https://doi.org/10.1046/j.1096-3642.2003.00085.x>
- Báez, A. M., & Trueb, L. (1997). Redescription of the Paleogene *Shelania pascuali* from Patagonia and its bearing on the relationships of fossil and Recent pipoid frogs. *Scientific Papers, Natural History Museum. The University of Kansas*, 4, 1–41. <https://doi.org/10.5962/bhl.title.37869>
- Báez, A. M., Zamalao, M. C., & Romero, E. J. (1990). Nuevos hallazgos de microfloras y anuros paleogenos en el noroeste de Patagonia: implicancias paleoambientales y paleobiogeograficas. *Ameghiniana*, 27, 83–94.
- Báez, A. M., Trueb, L., & Calvo, J. O. (2000). The earliest known pipoid frog from South America: a new genus from the middle Cretaceous of Argentina. *Journal of Vertebrate Paleontology* 20, 490–500. [https://doi.org/10.1671/0272-4634\(2000\)020\[0490:TEKPFJ\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2000)020[0490:TEKPFJ]2.0.CO;2)
- Báez, A. M., Muzzopappa, P., & Nicoli, L. (2007). Anurans from the Candeleros Formation (?Cenomanian-Turonian) of west-central Argentina: new evidence for pipoid evolution. *Cretaceous Research*, 28, 1005–1016. <https://doi.org/10.1016/j.cretres.2007.01.004>
- Báez, A. M., Scanferla, C. A., Agnolin, F. L., Cenizo, M., & Reyes, M. D. L. (2008). Pipid frog from the Pleistocene of the Pampas of southern South America. *Journal of Vertebrate Paleontology*, 28, 1195–1198. <https://doi.org/10.1671/0272-4634-28.4.1195>
- Báez, A. M., Moura, G. J., & Gómez, R. O. (2009). Anurans from the Lower Cretaceous Crato Formation of northeastern Brazil: implications for the early divergence of neobatrachians. *Cretaceous Research*, 30, 829–846. <https://doi.org/10.1016/j.cretres.2009.01.002>
- Báez, A. M., Gómez, R. O., & Taglioretti, M. L. (2012a). The archaic ilial morphology of an enigmatic pipid frog from the upper Pleistocene of the South American pampas. *Journal of Vertebrate Paleontology*, 32, 304–314. <https://doi.org/10.1080/02724634.2012.637591>
- Báez, A. M., Gómez, R. O., Ribeiro, L. C., Martinelli, A. G., Teixeira, V. P., & Ferraz, M. L. (2012b). The diverse cretaceous neobatrachian fauna of South America: *Uberabatrachus carvalhoi*, a new frog from the Maastrichtian Marília Formation, Minas Gerais, Brazil. *Gondwana Research*, 22, 1141–1150. <https://doi.org/10.1016/j.gr.2012.02.021>
- Báez, A. M., Muzzopappa, P., & de Moura, G. J. B. (2021). The earliest records of pipimorph frogs from South America (Aptian, Crato Formation, Brazil): A critical evaluation. *Cretaceous Research*, 121, 104728. <https://doi.org/10.1016/j.cretres.2020.104728>
- Barbière, F., Taglioretti, M., Pardiñas, U. F., & Ortiz, P. E. (2021). New craniodental material of the extinct sigmodontine *Olympicomys* (Rodentia, Cricetidae) allows a discussion of its tribal affiliation. *Historical Biology*, 33, 1–13. <https://doi.org/10.1080/08912963.2021.1896501>
- Barbosa, G. G., Queiroz, M. V. L., & Montefeltro, F. C. (2019). Implicações paleoecológicas de novos registros de Notosuchia na Formação Adamantina (Grupo Bauru, Cretáceo Superior) em Auriflama – SP. In H. I. D. Araújo-Júnior, Riff, A. C. S. Riff & R. C. Silva (Eds.), *Boletim de Resumos do XXVI Congresso Brasileiro de Paleontologia* (pp. 90–91). Uberlândia: Sociedade Brasileira de Paleontologia.
- Barcelos, L. A. (2016). *Sistemática e Tafonomia de uma nova espécie de Neobatrachia (Anura: Lissamphibia) para o Chattiano (Oligoceno Superior) da Bacia de Taubaté, São Paulo (Brasil)*. Undergraduate thesis. Uberlândia, Brazil: Universidade Federal de Uberlândia.
- Barcelos, L. A., & Verdade, V. K. (2020a). Reassessment of a fossil specimen of *Rhinella marina* (Linnaeus, 1758) (Anura: Bufonidae), from Early Pleistocene of Bolivia. *Zootaxa*, 4830, 392–400. <https://doi.org/10.11646/zootaxa.4830.2.10>
- Barcelos, L. A., & Verdade, V. K. (2020b). Novos registros de Pipimorpha (Anura) para a Bacia de Salta, Formação Las Curtiembres (Cretáceo Superior) de Puente Morales, Salta–Argentina. In S. S. Nihei, A. C. Morandini, S. N. Stampar, A. E. Migotto, A. R. S. Garraffoni, J. P. Botero, M. V. Kitahara (Eds.), *Resumos do XXIII Congresso Brasileiro de Zoologia* (p. 388). Águas de Lindóia, São Paulo: Sociedade Brasileira de Zoologia.
- Barcelos, L. A., & Verdade, V. K. (2022). A new fossil of *Ceratophrys* (Ceratophryidae: Anura) from Southeastern Brazil. *Zootaxa* <https://doi.org/10.11646/zootaxa.5094.3.9>
- Barcelos, L. A., Riff, D., Avilla, L. S., & Verdade, V. K. (2019). New Anura (Lissamphibia) fossil remains from Gruta do Urso (late Pleistocene-early Holocene), Tocantins, Brazil. In H. I. Araújo-Júnior, D. Riff, A. C. S. Riff & R. C. Silva (Eds.), *Boletim de Resumos do XXVI Congresso Brasileiro de Paleontologia* (p. 262). Uberlândia: Sociedade Brasileira de Paleontologia.
- Barcelos, L. A., Almeida-Silva, D., Santos, C. M., & Verdade, V. K. (2020). Description of a new species of fossil *Ceratophrys* (Anura: Ceratophryidae) from Versalles Cave, São Paulo, Brazil. *Journal of Vertebrate Paleontology*, 40, e1811293. <https://doi.org/10.1080/02724634.2020.1811293>
- Barker, P. F., & Burrell, J. (1977). The opening of Drake passage. *Marine Geology*, 25, 15–34. [https://doi.org/10.1016/0025-3227\(77\)90045-7](https://doi.org/10.1016/0025-3227(77)90045-7)
- Barrio, R. E. de, Panza, J. L., & Nullo, F. E. (1999). Jurásico y Cretácico del Macizo del Deseado, provincia de Santa Cruz. In R. Caminos (Ed.), *Geología Argentina, Anales Instituto de Geología y Recursos Naturales* (pp. 511–527). Buenos Aires: SEGEMAR.
- Beck, A. (1972). *A Variação do Conteúdo Cultural dos Sambaquis do Litoral de Santa Catarina*. PhD dissertation. São Paulo, Brazil: Universidade de São Paulo.
- Bedani, E. F., & Haddad, C. F. B. (2002). Estudos preliminares de anfíbios (Anura: Pipidae) na Formação Entrecórregos, Bacia de Aiuruoca, terciário do estado de Minas Gerais, Brasil. *Revista Geociências-UNG-Ser*, 7, 35–42.
- Bedani, E. F., & Haddad, C. F. B. (2012). Registro de formas iniciais pós-eclosão de anfíbios anuros (Pipidae) dos sedimentos terciários da Formação Entre-Córregos, Aiuruoca (MG). *Revista Geociências-UNG-Ser*, 11, 89–99.
- Behrensmeier, A. K., Kidwell, S. M., & Gastaldo, R. A. (2000). Taphonomy and paleobiology. *Paleobiology*, 26, 103–147. [https://doi.org/10.1666/0094-8373\(2000\)26\[103:TAP\]2.0.CO;2](https://doi.org/10.1666/0094-8373(2000)26[103:TAP]2.0.CO;2)
- Beilinson, E., Gasparini, G. M., Tomassini, R. L., Zárate, M. A., Deschamps, C. M., Barendregt, R. W., & Rabassa, J. (2017). The Quequén Salado river basin: Geology and biochronostratigraphy of the Mio-Pliocene boundary in the southern Pampean plain, Argentina. *Journal of South American Earth Sciences*, 76, 362–374. <https://doi.org/10.1016/j.jsames.2017.04.002>
- Bell, C. J., Gauthier, J. A., & Bever, G. S. (2010). Covert biases, circularity, and apomorphies: a critical look at the North American Quaternary Herpetofaunal Stability Hypothesis. *Quaternary International*, 217, 30–36. <https://doi.org/10.1016/j.quaint.2009.08.009>
- Belloso, E. S. (2010). Physical stratigraphy of the Sarmiento Formation (middle Eocene–lower Miocene) at Gran Barranca, central Patagonia. In R. H. Madden, A. A. Carlini, M. G. Vucetich & R. F. Kay (Eds.), *The paleontology of Gran Barranca: evolution and environmental change through the Middle Cenozoic of Patagonia* (pp. 19–31). Cambridge: Cambridge University Press.
- Belloso, E. S., Bostelmann, J. E., Ugalde, R., Alloway, B., Bobe, R., Carrasco, G., Mancuso, A., & Buldrini, K. (2014). In Ambientes asociados a la fauna Friasense (Mioceno Medio) en Alto río Cisnes

- (Aysén, Chile). In J. O. Allard, J. M. Krause & N. Foix (Eds.), *Resúmenes XIV Reunión Argentina de Sedimentología* (pp. 40–41). La Plata: Asociación Argentina de Sedimentología.
- Benton, M. J., Donoghue, P. C. J., Asher, R. J., Friedman, M., Near, T. J., & Vinther, J. (2015). Constraints on the timescale of animal evolutionary history. *Palaeontologia Electronica*, *18*, 1–116. <https://doi.org/10.26879/424>
- Bernardes-de-Oliveira, M. E. C., Garcia, M. J., Castro-Fernandes, M. C., & Pereira, K. G. (2014). Fabáceas Paleógenas da Região Sudeste de Minas Gerais, Formação Entre-Córregos, Bacia de Aiuruoca, Brasil. *Revista Brasileira de Paleontologia*, *17*, 3. <https://doi.org/10.4072/rbp.2014.3.06>
- Bewick, A. J., Chain, F. J., Heled, J., & Evans, B. J. (2012). The pipid root. *Systematic Biology*, *61*, 913–926. <https://doi.org/10.1093/sysbio/sys039>
- Bidegain, J. C., Osterrieth, M. L., Van Velzen, A. J., & Rico, Y. (2005). Geología y registros magnéticos entre arroyo La Tapera y Santa Clara del Mar, Mar del Plata. *Revista de la Asociación Geológica Argentina*, *60*, 599–604.
- Bisbee, C. A., Baker, M. A., Wilson, A. C., Haji-Azimi, I., & Fischberg, M. (1977). Albumin phylogeny for clawed frogs (*Xenopus*). *Science*, *195*, 785–787. <https://doi.org/10.1126/science.65013>
- Bogan, S., Agnolin, F., & Ramirez, J. L. (2010). Continental ichthyofauna and herpetofauna from the Upper Pleistocene of the locality of Salto, Buenos Aires Province, Argentine/Ictiofauna y herpetofauna del pleistoceno superior continental de la localidad de Salto, provincia de Buenos Aires, Argentina. *Studia Geologica Salmanticensia*, *46*, 83–98.
- Bonaparte, J. F., Franchi, M. R., Powell, J. E., & Sepulveda, E. C. (1984). La Formación Los Alamitos (Campaniano-Maastrichtiano) del sudeste de Río Negro, con descripción de *Kritosaurus australis* nov. sp. (Hadrosauridae). Significado paleogeográfico de los vertebrados. *Revista de la Asociación Geológica Argentina*, *39*, 284–299.
- Bonaparte, J. F. (1986a). A new and unusual late Cretaceous mammal from Patagonia. *Journal Vertebrate Paleontology*, *6*, 264–270. <https://doi.org/10.1080/02724634.1986.10011621>
- Bonaparte, J. F. (1986b). History of the terrestrial Cretaceous vertebrates of Gondwana. In J. F. Bonaparte (Ed.), *Actas IV Congreso Argentino de Paleontología y Bioestratigrafía* (pp. 63–95). Mendoza: El Congreso.
- Bonaparte, J. F. (1991). Asociación de vegetales y animales en estratos del Cretácico tardío del norte de la Patagonia. Variedad de restos de vertebrados fósiles. *Ameghiniana*, *28*, 201–202.
- Bonaparte, J. F., Valen, L. M. van, & Kramarz, A. (1993). La fauna local de Punta Peligro, Paleoceno Inferior, de la Provincia de Chubut, Patagonia, Argentina. *Evolutionary Monographs*, *14*, 1–61.
- Bonini, R. A. (2014). *Bioestratigrafía y diversidad de los mamíferos del Neogeno de San Fernando y Puerta de Corral Quemado (Catamarca, Argentina)*. PhD dissertation. La Plata, Argentina: Universidad Nacional de La Plata.
- Bown, T. M., & Larriestra, C. N. (1990). Sedimentary paleoenvironments of fossil platyrrhine localities, Miocene Pinturas Formation, Santa Cruz Province, Argentina. In J. G. Fleagle, & A. L. Rosenberger (Eds.), *The Platyrrhine Fossil Record* (pp. 87–119). Cambridge: Academic Press. <https://doi.org/10.1016/B978-0-12-260345-7.50008-4>
- Brambilla, L., Toledo, M. J., Haro, J. A., & Aguilar, J. L. (2019). New osteoderm morphotype (*Xenarthra*, *Mylodontidae*) from the middle Pleistocene of Argentina. *Journal of South American Earth Sciences*, *95*, 102298. <https://doi.org/10.1016/j.jsames.2019.102298>
- Brandoni, D., Ruiz, L. G., Reato, A., & Martin, G. (2017). Chronological implications of the nothrotheriid ‘*Xyophorus*’ (Mammalia, *Xenarthra*) from the Collón Curá Formation (Miocene of Patagonia, Argentina). *Historical Biology*, *31*, 879–887. <https://doi.org/10.1080/08912963.2017.1398748>
- Brandoni, D., Novo, N. M., Tarquini, J., & Tejedor, M. F. (2019). First record of *Nematherium* (*Xenarthra*, *Mylodontidae*) from the Pinturas Formation (Burdigalian, early Miocene), Santa Cruz Province, Argentina. *Journal of South American Earth Sciences*, *96*, 102324. <https://doi.org/10.1016/j.jsames.2019.102324>
- Bridge, J. S., Jalfin, G. A., & Georgieff, S. M. (2000). Geometry, lithofacies, and spatial distribution of Cretaceous fluvial sandstone bodies, San Jorge Basin, Argentina: outcrop analog for the hydrocarbon-bearing Chubut Group. *Journal of Sedimentary Research*, *70*, 341–359. <https://doi.org/10.1306/2DC40915-0E47-11D7-8643000102C1865D>
- Britannica. (2021). *Plate Tectonics: Evidence supporting the hypothesis*. Available at: <https://www.britannica.com/science/plate-tectonics/Evidence-supporting-the-hypothesis>. Accessed January 14, 2022.
- Brusquetti, F., Netto, F., Baldo, D., & Haddad, C. F. (2018). What happened in the South American Gran Chaco? Diversification of the endemic frog genus *Lepidobatrachus* Budgett, (1899) (Anura: Ceratophryidae). *Molecular Phylogenetics and Evolution*, *123*, 123–136. <https://doi.org/10.1016/j.ympev.2018.02.010>
- Bucher, J. (2018). *Tectónica, sedimentación y volcanismo del antepaís roto durante la inversión andina en la zona central de Chubut*. PhD dissertation. La Plata, Argentina: Universidad Nacional de La Plata.
- Bucher, J., López, M., García, M. R., Bilmes, A., D’Elia, L., Funes, D. S., Feo, R., & Franzese, J. R. (2018). Estructura y estratigrafía de un bajo neógeno del antepaís norpatagónico: el depocentro Paso del Sapo, provincia de Chubut. *Revista de la Asociación Geológica Argentina*, *75*, 312–324.
- Bucher, J., Milanese, F. N., López, M., García, M., D’Elia, L., Bilmes, A., Naipuer, M., Sato, A., Funes, D., Rapalini, A., Valencia, V., Ventura Santos, R., Hauser, N., Cruz Vera, L., & Franzese, J. (2019). U-PB geochronology and magnetostratigraphy of a North Patagonian synorogenic Miocene succession: tectono-stratigraphic implications for the foreland system configuration. *Tectonophysics*, *766*, 81–93. <https://doi.org/10.1016/j.tecto.2019.05.021>
- Bucher, J., Pérez, M. E., Ruiz, L. R. G., D’Elia, L., & Bilmes, A. (2021). New middle Miocene (Langhian-Serravallian) vertebrate localities in northwestern Patagonia, Argentina: A contribution to high latitude south american land mammal ages sequence. *Journal of South American Earth Sciences*, *107*, 103024. <https://doi.org/10.1016/j.jsames.2020.103024>
- Budgett, J. S. (1899). Notes on the batrachians of Paraguayan Chaco, with observations upon their breeding habits and development, especially with regard to *Phyllomedusa hypochondrialis* Cope. Also a description of a new genus. *Quarterly Journal of Microscopical Science*, *42*, 305–333. <https://doi.org/10.5962/bhl.part.11236>
- Buffetaut, E., & Rage, J. C. (1993). Fossil amphibians and reptiles and the Africa-South American connection. In W. George & R. Lavocat, (Eds.), *The Africa-South America Connection* (pp. 87–99). Oxford: Oxford University Press.
- Cabaleri, N. G., & Benavente, C. A. (2013). Sedimentology and paleoenvironments of the Las Chacritas carbonate paleolake, Cañadón Asfalto Formation (Jurassic), Patagonia, Argentina. *Sedimentary Geology*, *284*, 91–105. <https://doi.org/10.1016/j.sedgeo.2012.11.008>
- Campo, V. B. D., Nunes, I., Costa, F. R., & Anelli, L. E. (2016). A new tertiary Pipoida frog of Southeastern Brazil. In O. N. Grillo, P. S. R. Romano & G. R. Oliveira (Eds.), *Boletim de Resumos X Simpósio Brasileiro de Paleontologia de Vertebrados* (p. 51). Rio de Janeiro: Sociedade Brasileira de Paleontologia.
- Cannatella, D. (2015). *Xenopus* in space and time: fossils, node calibrations, tip-dating, and paleobiogeography. *Cytogenetic and Genome Research*, *145*, 283–301. <https://doi.org/10.1159/000438910>
- Carrillo-Briceno, J. D., Sánchez, R., Scheyer, T. M., Carrillo, J. D., Delfino, M., Georgalis, G. L., Kerber, L., Ruiz-ramoni, D., Brindelli, J. L. O., Cadena, E. A., Rincón, A. F., Chavez-Hoffmeister, M., Carlini, A. A., Carvalho, M. R., Trejos-Tamayo, R., Vallejo, F., Jaramillo, C., Jones, D. S., & Sánchez-Villagra, M.

- R. (2021). A Pliocene–Pleistocene continental biota from Venezuela. *Swiss Journal of Palaeontology*, 140(1), 1–76. <https://doi.org/10.1186/s13358-020-00216-6>
- Carnaval, A. C., & Moritz, C. (2008). Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic Forest. *Journal of Biogeography*, 35, 1187–1201. <https://doi.org/10.1111/j.1365-2699.2007.01870.x>
- Carnaval, A. C., Hickerson, M. J., Haddad, C. F. B., Rodrigues, M. T., & Moritz, C. (2009). Stability predicts genetic diversity in the Brazilian Atlantic Forest Hotspot. *Science*, 323, 785–789. <https://doi.org/10.1126/science.1166955>
- Carvalho, A. B. D. (2006). *Descrição morfológica e posição filogenética de um anuro novo (Lissamphibia, Tetrapoda) do Cretáceo Superior Continental do Brasil (Formação Adamantina, Bacia Bauru) do Município de Marília (SP)*. PhD dissertation. São Paulo, Brazil: Universidade de São Paulo.
- Carvalho, I. S., Vasconcelos, F. M., & Tavares, S. A. C. S. (2007). *Montealtosuchus arrudacamposi*, a new peirosaurid crocodile (Mesoeucrocodylia) from the Late Cretaceous Adamantina Formation of Brazil. *Zootaxa*, 1607, 35–46. <https://doi.org/10.11646/zootaxa.1607.1.3>
- Carvalho, I. S., Agnolin, F., Rolando, M. A. A., Novas, F. E., Xavier-Neto, J., Freitas, F. I., & Andrade, J. A. F. G. (2019). A new genus of pipimorph frog (anura) from the Early Cretaceous Crato formation (Aptian) and the evolution of South American tongueless frogs. *Journal of South American Earth Sciences*, 92, 222–233. <https://doi.org/10.1016/j.jsames.2019.03.005>
- Casal, G. A., Martínez, R. D., Luna, M., & Ibiricu, L. M. (2016). Ordenamiento y caracterización faunística del Cretácico Superior del Grupo Chubut, Cuenca del Golfo San Jorge, Argentina. *Revista Brasileira de Paleontologia*, 19, 53–70. <https://doi.org/10.4072/rbp.2016.1.05>
- Casamiquela, R. M. (1958). Un anuro gigante del Mioceno de Patagonia. *Revista de la Asociación Geológica Argentina*, 13, 171–184.
- Casamiquela, R. M. (1960). Datos preliminares sobre un pipoideo fósil de Patagonia. *Actas del Primer Congreso Sudamericano de Zoología La Plata*, 9, 17–22.
- Casamiquela, R. M. (1961). Nuevos materiales de *Notobatrachus degiustoi* Reig. La significación del anuro Jurásico Patagónico. *Revista del Museo de La Plata*, 4, 35–69.
- Casamiquela, R. M. (1963). Sobre un par de Anuros? del Mioceno de Rio Negro (Patagonia) *Wawelia gerholdi* n. gen. et sp. (Ceratophryidae) y *Gigantobatrachus parodii* (Leptodactylidae). *Ameghiniana*, 3, 141–160.
- Casamiquela, R. M. (1965). Nuevo material de *Vieraella herbstii* Reig. Reinterpretación de la ranita liásica de la Patagonia y consideraciones sobre filogenia y sistemática de los anuros. *Revista del Museo de La Plata*, 4, 265–317.
- Casamiquela, R. M. (1967). Sobre un nuevo *Bufo* fósil de la provincia de Buenos Aires (Argentina). *Ameghiniana*, 5, 161–169.
- Castro, M. C., Avilla, L. S., Freitas, M. L., & Carlini, A. A. (2013). The armadillo *Propraopus sulcatus* (Mammalia: Xenarthra) from the late Quaternary of northern Brazil and a revised synonymy with *Propraopus grandis*. *Quaternary International*, 317, 80–87. <https://doi.org/10.1016/j.quaint.2014.06.038>
- Castro, M. C., Montefeltro, F. C., & Langer, M. C. (2014). The Quaternary vertebrate fauna of the limestone cave Gruta do Ioiô, northeastern Brazil. *Quaternary International*, 352, 164–175.
- Cazau, L. B., Mancini, J., Cangini, J., & Spalletti, L. (1989). Cuenca de Ñirihuau. In G. A. Chebli & L. A. Spalletti (Eds.), *Cuencas sedimentarias argentinas* (pp. 299–318). Tucumán: Universidad Nacional de Tucumán.
- Cenizo, M. M., Agnolin, F. L., & Pomi, L. H. (2015). A new Pleistocene bird assemblage from the southern Pampas (Buenos Aires, Argentina). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 420, 65–81. <https://doi.org/10.1016/j.palaeo.2014.12.009>
- Cenizo, M., Soibelzon, E., & Magnussen Saffer, M. (2016). Mammalian predator–prey relationships and reoccupation of burrows in the Pliocene of the Pampean Region (Argentina): new ichnological and taphonomic evidence. *Historical Biology*, 28, 1026–1040. <https://doi.org/10.1080/08912963.2015.1089868>
- Chagas, R. B. A., Mendonça-Filho, J. G., Mendonça, J. O., & Menezes, T. R. (2009). Caracterização palinofaciológica de uma sucessão sedimentar oligocênica da Formação Tremembé, Bacia de Taubaté. *Revista Brasileira de Paleontologia*, 12, 257–266. <https://doi.org/10.4072/rbp.2009.3.08>
- Chahud, A. (2001). *Caracterização tafonômica da Fauna de Vertebrados Fósseis (Pleistoceno–Holoceno) do Abismo Ponta de Flecha, Iporanga, São Paulo*. Available at: <http://www.geocities.com/arturchahud/tafonomia.html?>(2009)31. Accessed 24 September 2021.
- Chahud, A. (2005). Paleomastozoologia do Abismo Ponta de Flecha, Iporanga, SP. In A. W. A. Kellner, D. D. R. Henriques & T. Rodrigues (Eds.), *Boletim de Resumos, Congresso Latino-Americano de Paleontologia de Vertebrados* (pp. 76–78). Rio de Janeiro: Museu Nacional/UFRJ.
- Charrier, R., Chávez, A., Elgueta, S., Hérail, G., Flynn, J. J., Croft, D. A., Wyss, A., & García, M. (2002). Rapid tectonic and paleogeographic evolution: the Chucal Anticline, Altiplano of Arica, northern Chile. In P. Baby, I. Darrozes, I. Deramond, B. Dupre, J. L. Guyot, G. Hérail, E. Jaillard, A. Lavenue, H. Miller, T. Monfret & G. Warner (Eds.), *5th International Symposium of Andean Geodynamics, Actas I* (pp. 137–140). Toulouse: Université Paul Sabatier.
- Chen, J., Bever, G. S., Yi, H. Y., & Norell, M. A. (2016). A burrowing frog from the late Paleocene of Mongolia uncovers a deep history of spadefoot toads (Pelobatidae) in East Asia. *Scientific Reports*, 6, 1–7. <https://doi.org/10.1038/srep19209>
- Chiesa, J., Bonini, R. A., Colombi, C., Brandoni, D., Basaev, A., Tauber, A., Prevosti, F. J., Olivares, I., Lucero, N., & Forasiepi, A. M. (2019). Estratigrafía, paleontología y paleoambientes del Plioceno de la región Cuyo de Argentina (San Luis, Mendoza, San Juan y La Rioja). *Opera Lilloana*, 52, 287–347.
- Churcher, C. S. (1966). The insect fauna from the Talara tar-seeps, Peru. *Canadian Journal of Zoology*, 44, 985–993. <https://doi.org/10.1139/z66-102>
- Cione, A. L., & Tonni, E. P. (2005). Bioestratigrafía basada en mamíferos del Cenozoico superior de la provincia de Buenos Aires, Argentina. *Geología y Recursos Minerales de la Provincia de Buenos Aires*, 11, 183–200.
- Cione, A. L., & Báez, A. M. (2007). Peces continentales y anfibios cenozoicos de Argentina los últimos cincuenta años. *Publicación Electrónica de la Asociación Paleontológica Argentina*, 11, 195–220.
- Cisneros, J. C., Ghilardi, A. M., Raja, N. B., & Stewens, P. P. (2021). The moral and legal imperative to return illegally exported fossils. *Nature Ecology & Evolution*, 1–2. <https://doi.org/10.1038/s41559-021-01588-9>
- Clyde, W. C., Wilf, P., Iglesias, A., Slingerland, R. L., Barnum, T., Bijl, P. K., Bralower, T. J., Brinkhuis, H., Comer, E. E., Huber, B. T., Ibañez-Mejía, M., Jicha, B. R., Krause, J. M., Schueth, J. D., Singer, B. D., Raigemborn, M. S., Schmitz, M. D., Sluijs, A., & Zamaloa, M. C. (2014). New age constraints for the Salamanca Formation and lower Río Chico Group in the western San Jorge Basin, Patagonia, Argentina: Implications for Cretaceous–Paleogene extinction recovery and land mammal age correlations. *GSA Bulletin* 126, 289–306. <https://doi.org/10.1130/B30915.1>
- Cohen, K. M., Harper, D. A. T., Gibbard, P. L., & Fan, J. X. (2021). *The ICS international chronostratigraphic chart*. Available at: <https://stratigraphy.org/ICSChart/ChronostratChart2021-05.pdf>. Accessed September 24, 2021.
- Comer, E. E. (2011). *Depositional environments of Paleocene plant localities within estuarine facies of the Salamanca Formation, Chubut*

- Province, Argentina. MSc thesis. Pennsylvania, United States of America: Pennsylvania State University.
- Contreras, V. H., & Acosta, J. C. (1998). Presencia de un anuro (Ceratophryidae) en el Mioceno Tardío de la Provincia de San Juan, Argentina: su significado paleoecológico, paleoclimático y paleozoogeográfico. *Boletín de la Sociedad de Biología de Concepción (Chile)*, 69, 83–88.
- Contreras, V. H., & Baraldo, J. A. (2010). Calibration of the Chasican-Huayquerian stages boundary (Neogene), San Juan, western Argentina. In J. A. Salfity, & R. A. Marquillas (Eds.), *Cenozoic Geology of the Central Andes of Argentina* (pp. 111–121). Salta: SCS Publisher.
- Cozzuol, M. A. (2006). The Acre vertebrate fauna: age, diversity, and geography. *Journal of South American Earth Science*, 21, 185–203. <https://doi.org/10.1016/j.jsames.2006.03.005>
- Croft, D. A., Flynn, J. J., & Wyss, A. R. (2007). A new basal glyptodontid and other Xenarthra of the early Miocene Chucal Fauna, northern Chile. *Journal of Vertebrate Paleontology*, 27, 781–797. [https://doi.org/10.1671/0272-4634\(2007\)27\[781:ANBGAO\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2007)27[781:ANBGAO]2.0.CO;2)
- Cruz, L. E. (2013). Biostratigraphy and geochronology of the late Cenozoic of Córdoba Province (central Argentina). *Journal of South American Earth Sciences*, 42, 250–259. <https://doi.org/10.1016/j.jsames.2012.06.015>
- Cruz, L. E., Femicola, J. C., & Carignano, C. A. (2018). New vertebrates of the Brochero Formation (Córdoba, Argentina): A review of the Pliocene of central Argentina. *Journal of Mammalian Evolution*, 25, 315–326. <https://doi.org/10.1007/s10914-017-9390-0>
- Cruz, R. de la, & Cortés, J. (2011). Geología del área oriental de la Hoja Puerto Cisnes, Región Aysén del Gral. Carlos Ibáñez del Campo. *Serie Geología Básica*, 127, 1–70.
- Cuitiño, J. I., Femicola, J. C., Kohn, M. J., Trayler, R., Naipauer, M., Bargo, M. S., Kay, R. F., & Vizcaino, S. F. (2016). U-Pb geochronology of the Santa Cruz Formation (early Miocene) at the Río Bote and Río Santa Cruz (southernmost Patagonia, Argentina): Implications for the correlation of fossil vertebrate localities. *Journal of South American Earth Sciences*, 70, 198–210. <https://doi.org/10.1016/j.jsames.2016.05.007>
- Davis, P. G. (1997). The bioerosion of bird bones. *International Journal of Osteoarchaeology*, 7, 388–401. [https://doi.org/10.1002/\(SICI\)1099-1212\(199707/08\)7:4%3C388::AID-OA357%3E3.0.CO;2-H](https://doi.org/10.1002/(SICI)1099-1212(199707/08)7:4%3C388::AID-OA357%3E3.0.CO;2-H)
- Daza, J. D., Stanley, E. L., Bolet, A., Bauer, A. M., Arias, J. S., Čerňanský, A., Beviitt, J. J., Wagner, P., & Evans, S. E. (2020). Enigmatic amphibians in mid-Cretaceous amber were chameleon-like ballistic feeders. *Science*, 370, 687–691. <https://doi.org/10.1126/science.abb6005>
- Delfino, M., & Georgalis, G. L. (2021). The Fossil Record of Amphibians (Amphibia: Urodela and Anura) in Greece. In E. Vlachos (Ed.), *Fossil Vertebrates of Greece* (pp. 185–203). Cham: Springer. https://doi.org/10.1007/978-3-030-68398-6_6
- Delfino, M., & Sánchez-Villagra, M. R. (2018). A Late Miocene Pipine Frog from the Urumaco Formation, Venezuela. *Ameghiniana*, 55, 210–214. <https://doi.org/10.5710/AMGH.04.10.2017.3136>
- Deschamps, C. M., Vucetich, M. G., Verzi, D. H., & Olivares, A. I. (2012). Biostratigraphy and correlation of the Monte Hermoso Formation (early Pliocene, Argentina): the evidence from caviomorph rodents. *Journal of South American Earth Sciences*, 35, 1–9. <https://doi.org/10.1016/j.jsames.2011.10.006>
- Di Giulio, A., Ronchi, A., Sanfilippo, A., Tiepolo, M., Pimentel, M., & Ramos, V. A. (2012). Detrital zircon provenance from the Neuquén Basin (south-central Andes): Cretaceous geodynamic evolution and sedimentary response in a retroarc-foreland basin. *Geology*, 40, 559–562. <https://doi.org/10.1130/G33052.1>
- Dias-Brito, D., Musacchio, E. A., Castro, J. C., Maranhão, M. S. A. S., Suárez, J. M., & Rodrigues, R. (2001). Grupo Bauru: uma unidade continental do Cretáceo no Brasil. Concepções baseadas em dados micropaleontológicos, isótopos e estratigráficos. *Revue de Paléobiologie*, 20, 245–304.
- Díaz de Gamero, M. L. D. (1996). The changing course of the Orinoco River during the Neogene: a review. *Palaeogeography, Palaeoclimatology, and Palaeoecology*, 123, 385–402. [https://doi.org/10.1016/0031-0182\(96\)00115-0](https://doi.org/10.1016/0031-0182(96)00115-0)
- Dingus, L., Clarke, J., Scott, G. R., Swisher, C. C., Chiappe, L. M., & Coria, R. A. (2000). Stratigraphy and magnetostratigraphic/faunal constraints for the age of sauropod embryo-bearing rocks in the Neuquén Group (Late Cretaceous, Neuquén Province, Argentina). *American Museum Novitates*, 2000, 1–11. [https://doi.org/10.1206/0003-0082\(2000\)290%3C0001:SAMFCF%3E2.0.CO;2](https://doi.org/10.1206/0003-0082(2000)290%3C0001:SAMFCF%3E2.0.CO;2)
- Dodson, P. (1973). The significance of small bones in paleoecological interpretation. *University of Wyoming Contributions to Geology*, 12, 5–19.
- Domínguez-Villar, D., Razola, L., Carrasco, R. M., Jennings, C. E., & Pedraza, J. (2009). Weathering phases recorded by gnammas developed since last glaciation at Serra da Estrela, Portugal. *Quaternary Research*, 72, 218–228. <https://doi.org/10.1016/j.yqres.2009.05.004>
- Donato, M., Posadas, P., Miranda-Esquivel, D. R., Jaureguizar, E. O., & Cladera, G. (2003). Historical biogeography of the Andean region: evidence from Listroderina (Coleoptera: Curculionidae: Rhytirrhini) in the context of the South American geobiotic scenario. *Biological Journal of the Linnean Society*, 80, 339–352. <https://doi.org/10.1046/j.1095-8312.2003.00243.x>
- Dong, L., Roček, Z., Wang, Y., & Jones, M. E. H. (2013). Anurans from the Lower Cretaceous Jehol Group of Western Liaoning, China. *PLoS One*, 8, e69723. <https://doi.org/10.1371/annotation/bcdc57a0-1377-43a7-8336-7796533013c3>
- Duellman, W. E. (1999). Distribution Patterns of Amphibians in South America. In W. E. Duellman (Ed.), *Patterns of Distribution of Amphibians: A Global Perspective* (pp. 255–328). Baltimore: Johns Hopkins University Press.
- Duellman, W. E., & Trueb, L. (1986). *Biology of amphibians*. McGraw-Hill, New York <https://doi.org/10.2307/1445022>
- Duque-Caro, H. (1990). Neogene stratigraphy, paleoceanography and paleobiogeography in northwest South America and the evolution of the Panama Seaway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 77, 203–234. [https://doi.org/10.1016/0031-0182\(90\)90178-A](https://doi.org/10.1016/0031-0182(90)90178-A)
- Esteban, G., Nasif, N., & Georgieff, S. M. (2014). Cronobioestratigrafía del Mioceno tardío–Plioceno temprano, Puerta de Corral Quemado y Villavil, provincia de Catamarca, Argentina. *Acta Geológica Lilloana*, 26, 165–192.
- Estes, R. (1965). Fossil salamanders and salamander origins. *American Zoologist* 5, 319–334. <https://doi.org/10.1093/icb/5.2.319>
- Estes, R. (1970). Origin of the Recent North American lower vertebrate fauna: an inquiry into the fossil record. *Forma et Functio*, 3, 139–163.
- Estes, R. (1975a). *Xenopus* from the Palaeocene of Brazil and its zoogeographic importance. *Nature*, 254, 48–50. <https://doi.org/10.1038/254048a0>
- Estes, R. (1975b). Fossil *Xenopus* from the Paleocene of South America and the zoogeography of pipid frogs. *Herpetologica*, 31, 263–278.
- Estes, R. (1981). *Encyclopedia of herpetology Part 2, Gymnophiona, Caudata*. Stuttgart: Gustav Fischer Verlag.
- Estes, R., & Baez, A. (1985). Herpetofaunas of North and South America during the Late Cretaceous and Cenozoic: evidence for interchange? In F. G. Stehli & S. D. Webb (Eds.), *The great American biotic interchange* (pp. 139–197). Boston: Springer. https://doi.org/10.1007/978-1-4684-9181-4_6
- Estes, R., & Reig, O. A. (1973). The Early Fossil Record of Frogs - a review of the evidence. In J. L. Vial (Ed.), *Evolutionary Biology of the Anurans* (pp. 11–63). Columbia: University of Missouri Press.

- Estes, R., & Wake, M. H. (1972). The first fossil record of caecilian amphibians. *Nature*, 239, 228–231. <https://doi.org/10.1038/239228b0>
- Estes, R., & Wassersug, R. J. (1963). A Miocene toad from Colombia, South America. *Breviora*, 193, 1–13.
- Evans, B. J., Kelley, D. B., Tinsley, R. C., Melnick, D. J., & Cannatella, D. C. (2004). A mitochondrial DNA phylogeny of African clawed frogs: phylogeography and implications for polyploid evolution. *Molecular Phylogenetics and Evolution*, 33, 197–213. <https://doi.org/10.1016/j.ympev.2004.04.018>
- Evans, S. E., & Borsuk-Bialynicka, M. (1998). A stem-group frog from the Early Triassic of Poland. *Acta Palaeontologica Polonica*, 43, 573–580.
- Evans, S. E., & Sigogneau-Russell, D. (2001). A stem-group caecilian (Lissamphibia: Gymnophiona) from the Lower Cretaceous of North Africa. *Palaeontology*, 44, 259–273. <https://doi.org/10.1111/1475-4983.00179>
- Evans, S. E., Milner, A. R., & Werner, C. (1996). Sirenid salamanders and a gymnophionan amphibian from the Cretaceous of the Sudan. *Palaeontology*, 39, 77–95.
- Evans, S. E., Groenke, J. R., Jones, M. E., Turner, A. H., & Krause, D. W. (2014). New material of *Beelzebufo*, a hyperossified frog (Amphibia: Anura) from the Late Cretaceous of Madagascar. *PLoS One*, 9, e87236. <https://doi.org/10.1371/journal.pone.0087236>
- Faivovich, J., Nicoli, L., Blotto, B. L., Pereyra, M. O., Baldo, D., Barrionuevo, J. S., Fabrezi, M., Wild, E. R., & Haddad, C. F. (2014). Big, bad, and beautiful: phylogenetic relationships of the horned frogs (Anura: Ceratophryidae). *South American Journal of Herpetology*, 9, 207–227. <https://doi.org/10.2994/SAJH-D-14-00032.1>
- Fara, E. (2004). Estimating minimum global species diversity for groups with a poor fossil record: a case study of Late Jurassic–Eocene lissamphibians. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 207, 59–82. <https://doi.org/10.1016/j.palaeo.2004.02.001>
- Fasano, J., Isla, F., & Schnack, E. (1994). Significado paleoambiental de los depósitos del Pleistoceno tardío de Camet Norte (partido de Mar Chiquita, provincia de Buenos Aires). *Revista de la Asociación Geológica Argentina*, 39, 244–250.
- Feder, M. E., & Burggren, W. W. (1992). *Environmental physiology of the amphibians*. Chicago: University of Chicago Press.
- Feng, Y. J., Blackburn, D. C., Liang, D., Hillis, D. M., Wake, D. B., Cannatella, D. C., & Zhang, P. (2017). Phylogenomics reveals rapid, simultaneous diversification of three major clades of Gondwanan frogs at the Cretaceous–Paleogene boundary. *Proceedings of the National Academy of Sciences*, 114(29), E5864–E5870. <https://doi.org/10.1073/pnas.1704632114>
- Fernandes, L. A., Giannini, P. C., & Góes, A. M. (2003). Araçatuba Formation: palustrine deposits from the initial sedimentation phase of the Bauru Basin. *Anais da Academia Brasileira de Ciências*, 75, 173–187. <https://doi.org/10.1590/S0001-37652003000200006>
- Fernicola, J. C. (2001). Una nueva especie de *Ceratophrys* (Anura, Leptodactylidae) en el Neógeno de la provincia de Buenos Aires, Argentina. *Ameghiniana*, 38, 385–391.
- Fernicola, J. C., & Albino, A. M. (2012). Amphibians and squamate reptiles from the Santa Cruz Formation (late Early Miocene), Santa Cruz Province, Argentina: paleoenvironmental and paleobiological considerations. In S. F. Vizcaíno, R. F. Kay & M. S. Bargo (Eds.), *Early Miocene Paleobiology in Patagonia High-Latitude Paleocommunities of the Santa Cruz Formation* (pp. 129–137). Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9780511667381.009>
- Fidalgo, F., Gentile, O., & Correa, H. (1986). Geología y Geomorfología en la cuenca del Arroyo Tapalqué. *Comisión de Investigaciones Científicas, Provincia de Buenos Aires, Informe*, 30, 1–73.
- Figari, C. E., Scasso, R. A., Cúneo, N. R., & Escapa, I. H. (2016). Estratigrafía y evolución geológica de la Cuenca de Cañadón Asfalto, Provincia del Chubut, Argentina. *Latin American Journal of Sedimentology and Basin Analysis*, 22, 135–169.
- Fingini, A., Huarte, R., Carbonari, J., & Tonni, E. P. (1998). Edades C-14 en un perfil del Arroyo Tapalqué, Provincia de Buenos Aires, Argentina. Contribución a la cronología de acontecimientos faunístico-ambientales. *Actas X Congreso Latinoamericano de Geología y VI Congreso Nacional de Geología Económica*, 1, 27–31.
- Fish, S. K., DeBlasis, P., Gaspar, M. D., & Fish, P. R. (2000). Eventos incrementais na construção de sambaquis, litoral sul do Estado de Santa Catarina. *Revista do Museu de Arqueologia e Etnologia*, 10, 69–87. <https://doi.org/10.11606/issn.2448-1750.revmae.2000.109378>
- Flegenheimer, N., & Zárate, M. (1993). The archaeological record in Pampean loess deposits. *Quaternary International*, 17, 95–100. [https://doi.org/10.1016/1040-6182\(93\)90085-T](https://doi.org/10.1016/1040-6182(93)90085-T)
- Flynn, J. J., & Swisher, C. C. (1995). Cenozoic South American Land Mammal Ages: Correlation to global geochronologies. In W. A. Berggren, D. V. Kent, M. P. Aubry & J. Hardenbol (Eds.), *Geochronology. Time Scales and Global Stratigraphic Correlation* (pp. 317–334). Tulsa: Society for Sedimentary Geology Special Publication No. 54. <https://doi.org/10.2110/pec.95.04.0317>
- Flynn, J. J., Guerrero, J., & Swisher, C. C. (1997). Geochronology of the Honda Group. In R. F. Kay, R. H. Madden, R. L. Cifelli & J. J. Flynn (Eds.), *Vertebrate paleontology in the neotropics* (pp. 44–59). Washington: Smithsonian Institution Press.
- Flynn, J. J., Croft, D. A., Charrier, R., Hérail, G., & Wyss, A. R. (2002). The first Cenozoic mammal fauna from the Chilean Altiplano. *Journal of Vertebrate Paleontology*, 22, 200–206. [https://doi.org/10.1671/0272-4634\(2002\)022\[0200:TFCMFF\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2002)022[0200:TFCMFF]2.0.CO;2)
- Fouquet, A., Cornuault, J., Rodrigues, M. T., Werneck, F. P., Hrbek, T., Acosta-Galvis, A. R., ... & Ernst, R. (2022). Diversity, biogeography, and reproductive evolution in the genus *Pipa* (Amphibia: Anura: Pipidae). *Molecular Phylogenetics and Evolution*, 170, 107442. <https://doi.org/10.1016/j.ympev.2022.107442>
- Frailey, D., & Campbell, K. E. (1980). A Pleistocene record of *Bufo spinulosus* from Peru. *Copeia*, 4, 935–936. <https://doi.org/10.2307/1444495>
- Frazaõ, A., Silva, H. R. D., & Russo, C. A. D. M. (2015). The Gondwana breakup and the history of the Atlantic and Indian oceans unveils two new clades for early neobatrachian diversification. *PLoS One*, 10, e0143926. <https://doi.org/10.1371/journal.pone.0143926>
- Freitas, R. C., Ribeiro, D. C., Alhalabi, W. A., Langer, M. C., & Montefeltro, F. C. (2017). Novos registros revelam uma maior diversidade taxonômica para o Grupo Bauru na região de Araçatuba-SP. In M. C. Langer, W. A. Alhalabi, G. S. Ferreira, G. Hermanson J. C. A. Marsola & S. Y. Onary-Alves (Eds.), *Paleontologia em Destaque - Edição Especial XXV Congresso Brasileiro de Paleontologia* (p. 118). Ribeirão Preto: Gráfica Editora São Francisco.
- Freitas, R. C., Sousa, L. N. F., & Montefeltro, F. C. (2019). Três novos úmeros de Anura fósseis da Formação Adamantina (Grupo Bauru, Cretáceo Superior). In C. F. O. Graeff, C. R. N. Camargo, A. S. Simões, D. H. Sumida, E. R. Oliveira & W. M. A. Storolli (Eds.), *Anais do XXXI Congresso de Iniciação Científica da UNESP* (p. 1). Ilha Solteira: Universidade Estadual Paulista Júlio de Mesquita Filho.
- Freguelli, J. (1921). Los terrenos de la costa atlántica en los alrededores de Miramar (prov. de Buenos Aires) y sus correlaciones. *Boletín de la Academia Nacional de Ciencias de Córdoba*, 24, 325–485.
- Frost, D. R. (2021). *Amphibian species of the world: an online reference*. New York, USA: American Museum of Natural History. Version

- 6.1. Available at: <https://amphibiansoftheworld.amnh.org/>. Accessed 24 September 2021.
- Frost, D. R., Taran, G., Faivovich, J., Bain, R. H., Haas, A., Haddad, C. F. B., De Sá, R. O., Channing, A., Wilkinson, M., Donnellan, S. C., Raxworthy, C. J., Campbell, J. A., Blotto, B. L., Moler, P., Drewes, R. C., Nussbaum, R. A., Lynch, J. D., Green, D. M., & Wheeler, W. C. (2006). The amphibian tree of life. *Bulletin of the American Museum of Natural History*, 297, 1–370. [https://doi.org/10.1206/0003-0090\(2006\)297\[0001:TATOL\]2.0.CO;2](https://doi.org/10.1206/0003-0090(2006)297[0001:TATOL]2.0.CO;2)
- Fucks, E., & Deschamps, C. M. (2008). Depósitos continentales cuaternarios en el noroeste de la provincia de Buenos Aires. *Revista de la Asociación Geológica Argentina*, 63, 326–343.
- Fuente, M. S. de la, Salgado, L., Albino, A., Báez, A. M., Bonparte, J. F., Calvo, J. O., Chiappe, L. M., Codorníu, L. S., Coria, R. A., Gasparini, Z., González-Riga, B. J., Novas, F. E., & Pol, D. (2007). Tetrápodos continentales del Cretácico de la Argentina. Una síntesis actualizada. *Asociación Paleontológica Argentina, Publicación Especial*, 11, 137–153.
- Gao, K. Q., Chen, J., & Jia, J. (2013). Taxonomic diversity, stratigraphic range, and exceptional preservation of Juro-Cretaceous salamanders from northern China. *Canadian Journal of Earth Sciences*, 50, 255–267. <https://doi.org/10.1139/e2012-039>
- Gardner E., & Walker, S. (2009). Climate matters: comparing avian bone taphonomy in warm temperate vs subtropical environments. *Geological Society of America Abstract Programs*, 41, 628.
- Gardner, J. D. (2003). Revision of *Habrosaurus* Gilmore (Caudata; Sirenidae) and relationships among sirenid salamanders. *Palaeontology*, 46, 1089–1122. <https://doi.org/10.1046/j.0031-0239.2003.00335.x>
- Gardner, J. D. (2016). The fossil record of tadpoles. *Fossil Imprint*, 72, 17–44. <https://doi.org/10.14446/FI.2016.17>
- Gardner, J. D., & Böhme, M. (2008). Review of the Albanerpetontidae (Lissamphibia), with comments on the paleoecological preferences of European Tertiary albanerpetontids. In J. T. Sankey, & S. Saszko (Eds.), *Vertebrate microfossil assemblages: their role in paleoecology and paleobiogeography* (pp. 178–218). Indianapolis: Indiana University Press.
- Gardner, J. D., & DeMar, D. G. (2013). Mesozoic and Palaeocene lissamphibian assemblages of North America: a comprehensive review. In J. D. Gardner, & R. L. Nydam (Eds.), *Mesozoic and Cenozoic Lissamphibian and Squamate assemblages of Laurasia. Palaeobiodiversity and Palaeoenvironments*, 93(4), 459–515. <https://doi.org/10.1007/s12549-013-0130-z>
- Gardner, J. D., & Rage, J. C. (2016). The fossil record of lissamphibians from Africa, Madagascar, and the Arabian Plate. In J. D. Gardner, & T. Prikryl (Eds.), *Contributions in honour of Zbyněk Roček. Palaeobiodiversity and Palaeoenvironments*, 96(1), 169–220. <https://doi.org/10.1007/s12549-015-0221-0>
- Gardner, J. D., Evans, S. E., & Sigogneau-Russell, D. (2003). New albanerpetontid amphibians from the Early Cretaceous of Morocco and Middle Jurassic of England. *Acta Palaeontologica Polonica*, 48, 301–319.
- Gasparini, Z., de la Fuente, M., & Donadío, O. (1986). Los reptiles cenozoicos de la Argentina: implicancias paleoambientales y evolución biogeográfica. In A. J. Cuerda, J. F. Bonaparte, W. Volkheimer & H. A. Leanza (Eds.), *Actas IV Congreso Argentino de Paleontología y Bioestratigrafía* (pp. 119–130). Mendoza: El Congreso.
- Gasparini, G. M., Soibelzon, E., Deschamps, C., Francia, A., Beilinson, E., Soibelzon, L. H., & Tonni, E. P. (2016). Continental vertebrates during the marine isotope stage 3 (MIS 3) in Argentina. In G.M. Gasparini, J. Rabassa, M.C. Deschamps, E.P. Tonni (Eds.), *Marine Isotope Stage 3 in Southern South America, 60 ka BP-30 ka BP* (pp. 227–247). Cham: Springer. https://doi.org/10.1007/978-3-319-40000-6_13
- Gayet, M. (1991). Holostean and teleostean fish from Bolivia R. In R. Suárez-Soruco (Ed.), *Fósiles y Facies de Bolivia vol. I Vertebrados* (pp. 453–494). Santa Cruz: Yacimientos Petrolíferos Fiscales Bolivianos.
- Gayet, M., Marshall, L. G., Sempere, T., Meunier, F. J., Cappetta, H., & Rage, J. C. (2001). Middle Maastrichtian vertebrates (fishes, amphibians, dinosaurs and other reptiles, mammals) from Pajcha Pata (Bolivia). Biostratigraphic, palaeoecologic and palaeobiogeographic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 169, 39–68. [https://doi.org/10.1016/S0031-0182\(01\)00214-0](https://doi.org/10.1016/S0031-0182(01)00214-0)
- Geroto, C. F. C., & Bertini, R. J. (2019). New material of *Pepesuchus* (Crocodyliformes; Mesoeucrocodylia) from the Bauru Group: implications about its phylogeny and the age of the Adamantina Formation. *Zoological Journal of the Linnean Society*, 185, 312–334. <https://doi.org/10.1093/zoolinnean/zly037>
- Gilmore, C. W. (1928). Fossil lizards of North America. *Memoirs of the National Academy of Sciences*, 22, 1–97.
- Giusto, J. M. de, Di Persia, C. A., & Pezzi, E. (1980). Nesocratón del Desado. *Geología Regional Argentina*, 2, 1389–1430.
- Gobbo-Rodrigues, S. R., Petri, S., & Bertini, R. J. (1999). Ocorrências de ostracodes na Formação Adamantina do Grupo Bauru, Cretáceo Superior da Bacia do Paraná e possibilidades de correlação com depósitos isócronos argentinos. Parte I - Família Ilyocyprididae. *Acta Geologica Leopoldensia*, 23, 3–13.
- Gómez, R. O. (2011). *Los neobatracios (Amphibia: anura) del paleoceno de la formación Santa Lucía, Bolivia: aportes a la historia evolutiva y paleobiogeográfica de los anuros sudamericanos*. PhD Dissertation. Buenos Aires, Argentina: Universidad de Buenos Aires.
- Gómez, R. O. (2016). A new pipid frog from the Upper Cretaceous of Patagonia and early evolution of crown-group Pipidae. *Cretaceous Research*, 62, 52–64. <https://doi.org/10.1016/j.cretres.2016.02.006>
- Gómez, R. O., & Báez, A. M. (2010). The anuran pelvis: Evidence for the phylogenetic placement of the Tiupampa *Estesiella boliviensis*. *Ameghiniana (suplemento resúmenes)*, 47, 13R–14R.
- Gómez, R. O., & Turazzini, G. F. (2021). The fossil record and phylogeny of South American horned frogs (Anura, Ceratophryidae). *Journal of Systematic Palaeontology*, 19, 91–130. <https://doi.org/10.1080/14772019.2021.1892845>
- Gómez, R. O., & Turazzini, G. F. (2016). An overview of the ilium of anurans (Lissamphibia, Salientia), with a critical appraisal of the terminology and primary homology of main ilial features. *Journal of Vertebrate Paleontology*, 36, e1030023. <https://doi.org/10.1080/02724634.2015.1030023>
- Gómez, R. O., Báez, A. M., & Céspedes, R. (2008). Reappraisal of the evolutionary relationships of *Estesiella boliviensis* (Anura, Neobatrachia) from the Paleocene of Tiupampa, Bolivia. In J. O. Calvo, R. J. Valieri, J. D. Porfiri & D. dos Santos (Eds.), *Libro de Resúmenes, III Congreso Latinoamericano de Paleontología de Vertebrados* (p. 57). Neuquén: Asociación Paleontológica Argentina.
- Gómez, R. O., Báez, A. M., & Céspedes, R. (2010). *Osteología de una rana del Paleoceno de Bolivia y la evolución de la fosorialidad en anuros*. Available at: https://www.conicet.gov.ar/new_scp/detalle.php?keywords=&id=34793&congresos=yes&detalles=yes&congr_id=1668189. Accessed January 14, 2022.
- Gómez, R. O., Báez, A. M., & Muzzopappa, P. (2011). A new helmeted frog (Anura: Calyptocephalellidae) from an Eocene subtropical lake in northwestern Patagonia, Argentina. *Journal of Vertebrate Paleontology*, 31, 50–59. <https://doi.org/10.1080/02724634.2011.539654>
- Gómez, R. O., Pérez-Ben, C. M., & Stefanini, M. I. (2013). Oldest record of *Leptodactylus* Fitzinger, 1826 (Anura, Leptodactylidae), from the early Pliocene of the South American Pampas. *Journal of Vertebrate Paleontology*, 33, 1321–1327. <https://doi.org/10.1080/02724634.2013.771779>

- González-Riga, B. J. (1999). Hallazgo de vertebrados fósiles en la Formación Loncoche, Cretácico Superior de la Provincia de Mendoza, Argentina. *Ameghiniana*, 36, 401–410.
- Granot, R., & Dymont, J. (2015). The Cretaceous opening of the South Atlantic Ocean. *Earth and Planetary Science Letters*, 414, 156–163. <https://doi.org/10.1016/j.epsl.2015.01.015>
- Grimaldi, D., Bonwich, E., Delannoy, M., & Doberstein, S. (1994). Electron microscopic studies of mummified tissues in amber fossils. *American Museum Novitates*, 3097, 1–31.
- Gross, M., Piller, W. E., Ramos, M. I., & da Silva Paz, J. D. (2011). Late Miocene sedimentary environments in south-western Amazonia (Solimões formation; Brazil). *Journal of South American Earth Sciences*, 32, 169–181. <https://doi.org/10.1016/j.jsames.2011.05.004>
- Guerrero, J. (1997). Stratigraphy, sedimentary environments, and the Miocene uplift of the Colombian Andes. In R. F. Kay, R. H. Madden, R. L. Cifelli & J. J. Flynn (Eds.), *Vertebrate paleontology in the neotropics* (pp. 1–12). Washington: Smithsonian Institution Press.
- Guevara, J.P., Alarcón-Muñoz, J., Soto-Acuña, S., Suazo-Lara, F., Buldrini, K. E., Rubilar-Rogers, D., & Sallaberry, M. (2018). Primer registro de un anuro fósil en el Neógeno de Chile. In M. A. L. Cartes, A. M. A. Vásquez & R. V. Martínez (Eds.), *Avances en Paleontología Chilena* (pp. 314–316). Punta Arenas: Instituto Antártico Chileno.
- Günther, A. C. L. G. 1859. Sexual differences found in bones of some Recent and fossil species of frogs and fishes. *Annals and Magazine of Natural History*, 3, 1–13.
- Gutiérrez, N. M., Le Roux, J. P., Vásquez, A., Carreño, C., Pedroza, V., Araos, J., Oyarzún, J. L., Pino, J. P., Rivera, H. A., & Hinojosa, L. F. (2017). Tectonic events reflected by palaeocurrents, zircon geochronology, and palaeobotany in the Sierra Baguales of Chilean Patagonia. *Tectonophysics*, 695, 76–99. <https://doi.org/10.1016/j.tecto.2016.12.014>
- Haddad, C. F. B., Toledo, L. F., Prado, C. P. A., Loebmann, D., Gasparini, J. L., & Sazima, I. (2013). *Guide to the amphibians of the Atlantic Forest: diversity and biology*. São Paulo: Anolisbooks.
- Haddoumi, H., Allain, R., Meslouh, S., Metais, G., Monbaron, M., Pons, D., Rage, J. C., Vullo, R., Zouhri, S., & Gheerbrant, E. (2016). Guelb el Ahmar (Bathonian, Anoual Syncline, eastern Morocco): first continental flora and fauna including mammals from the Middle Jurassic of Africa. *Gondwana Research*, 29, 290–319. <https://doi.org/10.1016/j.gr.2014.12.004>
- Hambalek, N., Rull, V., De Digiaco, E. D., & Díaz de Gamero, M. L. (1994). Evolución paleoecológica y paleoambiental de la secuencia del Neógeno en el surco de Urumaco. Estudio palinológico y litológico. *Boletín de la Sociedad Venezolana de Geología*, 191, 7–19.
- Hecht, M. K. (1963). A reevaluation of the early history of the frogs. Part II. *Systematic Zoology*, 12, 20–35. <https://doi.org/10.2307/2411892>
- Hecht, M. K., & LaDuke, T. C. (1997). Limbless tetrapods. In R. F. Kay, R. H. Madden, R. L. Cifelli & J. J. Flynn (Eds.), *Vertebrate paleontology in the Neotropics The Miocene fauna of La Venta, Colombia* (pp. 95–99). Washington: Smithsonian Institution Press.
- Heimhofer, U., & Hochuli, P. A. (2010). Early Cretaceous angiosperm pollen from a low-latitude succession (Araripe Basin, NE Brazil). *Review of Palaeobotany and Palynology*, 161, 105–126. <https://doi.org/10.1016/j.revpalbo.2010.03.010>
- Henrici, A. C., Báez, A. M., & Grande, L. (2013). *Aerugoamnis paulus*, new genus and new species (Anura: Anomocoela): first reported anuran from the early Eocene (Wasatchian) Fossil Butte Member of the Green River Formation, Wyoming. *Annals of Carnegie Museum*, 81, 295–309. <https://doi.org/10.2992/007.081.0402>
- Herbst, R. (1965). La flora fósil de la Formación Roca Blanca, provincia de Santa Cruz, Patagonia, con consideraciones geológicas y estratigráficas. *Opera Lilloana*, 12, 1–101.
- Hernández, R. M., Jordan, T. E., Farjat, A. D., Echavarría, L., Idelman, B. D., & Reynolds, J. H. (2005). Age, distribution, tectonics, and eustatic controls of the Paranense and Caribbean marine transgressions in southern Bolivia and Argentina. *Journal of South American Earth Sciences*, 19, 495–512. <https://doi.org/10.1016/j.jsames.2005.06.007>
- Hime, P. M., Lemmon, A. R., Lemmon, E. C. M., Prendini, E., Brown, J. M., Thomson, R. C., Kratovil, J. D., Noonan, B. P., Pyron, R. A., Peloso, P. L. V., Kortyna, M. L., Keogh, J. S., Donnellan, S. C., Mueller, R. L., Raxworthy, C. J., Kunte, K., Ron, S. R., Das, S., Gaitonde, N., Green, D. M., Labisko, J., Che, J., & Weisrock, D. W. (2021). Phylogenomics reveals ancient gene tree discordance in the amphibian tree of life. *Systematic Biology*, 70, 49–66. <https://doi.org/10.1093/sysbio/syaa034>
- Hirschfeld, S. E., & Marshall, L. G. (1976). Revised faunal list of the La Venta fauna (Friasian-Miocene) of Colombia, South America. *Journal of Paleontology*, 50, 433–436.
- Hoffstetter, R. (1963). La faune pléistocène de Tarija (Bolivie). *Note préliminaire. Bulletin Muséum National d'Histoire Naturelle*, 35, 194–203.
- Hoffstetter, R. (1968). Ñapua, un gisement de vertébrés pléistocènes dans le Chaco bolivien. *Bulletin Du Muséum National d'Histoire Naturelle*, 40, 823–836.
- Hoffstetter, R. (1971). Los vertebrados cenozoicos de Colombia: yacimientos, faunas, problemas planteados. *Geología Colombiana*, 8, 37–62.
- Holman, J. A. (2003). *Fossil frogs and toads of North America*. Bloomington: Indiana University Press.
- Holman, J. A. (2006). *Fossil salamanders of North America*. Bloomington: Indiana University Press.
- Hopkins, G. R., & Brodie, E. D. J. (2015). Occurrence of amphibians in saline habitats: a review and evolutionary perspective. *Herpetological Monographs*, 29, 1–27. <https://doi.org/10.1655/HERPMONOGRAPHS-D-14-00006>
- Hoom, C., Wesselingh, F. P., Ter Steege, H., Bermudez, M. A., Mora, A., Sevinck, J., Sanmartín, I., Sanchez-Meseguer, A., Anderson, C. L., Figueiredo, J. P., Jaramillo, C., Riff, D., Negri, F. R., Hooghiemstral, H., Lundberg, J., Stadler, T., Särkinen, T., & Antonelli, A. (2010). Amazonia through time: Andean uplift, climate change, landscape evolution, and biodiversity. *Science*, 330, 927–931. <https://doi.org/10.1126/science.1194585>
- Hoorn, C., Mosbrugger, V., Mulch, A., & Antonelli, A. (2013). Biodiversity from mountain building. *Nature Geoscience*, 6, 154. <https://doi.org/10.1038/ngeo1742>
- Hubbe, A., Hubbe, M., & Neves, W. A. (2009). New Late-Pleistocene dates for the extinct megafauna of Lagoa Santa, Brazil. *Current Research in the Pleistocene*, 26, 154–156.
- Hurt, W. R. (1974). The Interrelationships between the natural environment and four sambaquis, coast of Santa Catarina, Brazil. *Occasional Papers and Monographs, Indiana University Museum*, 1, 1–23.
- Iniesto, M., Villalba, I., Buscalioni, A. D., Guerrero, M. C., & López-Archilla, A. I. (2017). The effect of microbial mats in the decay of anurans with implications for understanding taphonomic processes in the fossil record. *Scientific reports*, 7, 1–12. <https://doi.org/10.1038/srep45160>
- Isla, F., Dondas, A., & Taglioretti, M. L. (2010). Médanos relictos intrapampeanos en Daireaux y Centinela del Mar, Buenos Aires. *Revista de la Asociación Geológica Argentina*, 67, 58–64.
- Isla, F. I., Dondas, A., & Oliva, C. (2014). Sedimentología de las formaciones Irene y la toma del neógeno de la cuenca de Claromeco, Buenos Aires. *GEOACTA*, 39, 1–12.
- IUCN. (2021). *The IUCN Red List of Threatened Species*. Version 2021-1. Available at: <https://www.iucnredlist.org>. Accessed 24 September 2021.

- Janzen, D. H. (1967). Why mountain passes are higher in the tropics. *The American Naturalist*, 101, 233–249. <https://doi.org/10.1086/282487>
- Jenkins, P. A., & Walsh, D. M. (1993). An Early Jurassic caecilian with limbs. *Nature*, 365, 246–250. <https://doi.org/10.1038/365246a0>
- Jetz, W., & Pyron, R. A. (2018). The interplay of past diversification and evolutionary isolation with present imperilment across the amphibian tree of life. *Nature Ecology and Evolution*, 2, 850–858. <https://doi.org/10.1038/s41559-018-0515-5>
- Jiménez-Huidobro, P., & Sallabaerry, M. (2015). Tetrápodos basales y anfibios fósiles de Chile. In D. Rubilar-Rogers, R. Otero, A. Vargas & M. Salaberry (Eds.), *Vertebrados fósiles de Chile* (pp. 85–98). Santiago: Museo Nacional de Historia Natural.
- Johnson, E., Holliday, V. T., Martínez, G., Gutiérrez, M., & Politis, G. (2012). Geochronology and Landscape Development Along the Middle Río Quequén Grande at the Paso Otero Locality, Pampa Interserrana, Argentina. *Geoarchaeology*, 27, 300–323. <https://doi.org/10.1002/gea.21410>
- Johnson, L. M., & Hembree, D. I. (2015). Neoichnology of the eastern spadefoot toad, *Scaphiopus holbrookii* (Anura: Scaphiopodidae): criteria for recognising anuran burrows in the fossil record. *Palaeontologia Electronica*, 18, 1–29. <https://doi.org/10.26879/558>
- Kay, R. F., MacFadden, B. J., Madden, R. H., Sandeman, H., & Anaya, F. (1998). Revised age of the Salla Beds, Bolivia, and its bearing on the age of the Deseadan South American Land Mammal “age”. *Journal of Vertebrate Paleontology*, 18, 189–199. <https://doi.org/10.1080/02724634.1998.10011043>
- Kellner, A. W. A., & Campos, D. A. (1986). Primeiro registro de Amphibia (Anuro) no Cretáceo Inferior da Bacia do Araripe, Nordeste do Brasil. *Anais da Academia Brasileira de Ciências*, 58, 610.
- Kim, K. S., Lockley, M. G., Lim, J. D., & Kim, D. H. (2019). The oldest known anuran (frog) trackways from the Jinju Formation, Lower Cretaceous, Korea. *Cretaceous Research*, 96, 142–148. <https://doi.org/10.1016/j.cretres.2018.12.008>
- Kraglievich, L. (1952). El perfil geológico de Chapadmalal y Miramar, Provincia de Buenos Aires. *Resumen preliminar Revista Museo Ciencias Naturales Tradicionalista Mar del Plata*, 1, 8–37
- Kramarz, A. G., & Bellosi, E. S. (2005). Hystricognath rodents from the Pinturas Formation, Early–Middle Miocene of Patagonia, biostratigraphic and paleoenvironmental implications. *Journal of South American Earth Sciences*, 18, 199–212. <https://doi.org/10.1016/j.jsames.2004.10.005>
- Kramarz, A. G., Forasiepi, A. M., Bond, M. (2011). Vertebrados cenozoicos. In H. A. Leanza, C. Arregui, O. Carbone, J. C. Danielli, J. & M. Vallés (Eds.), *Relatorio del XVIII Congreso Geológico Argentino, Abstracts* (pp. 557–572). Neuquén: Geología y Recursos Naturales de la Provincia del Neuquén, Argentina.
- Kumar, S., Stecher, G., Suleski, M., & Hedges, S. B. (2017). TimeTree: a resource for timelines, timetrees, and divergence times. *Molecular Biology and Evolution*, 34, 1812–1819. <https://doi.org/10.1093/molbev/msx116>
- Labarca, R., González-Guarda, E., Lizama-Catalán, Á., Villavicencio, N. A., Alarcón-Muñoz, J., Suazo-Lara, F., Oyanadel-Urbina, P., Soto-Huenchuman, P., Salazar, C., Soto-Acuña, S., & Buldrini, K. E. (2020). Taguatagua 1: New insights into the late Pleistocene fauna, paleoenvironment, and human subsistence in a unique lacustrine context in central Chile. *Quaternary Science Reviews*, 238, 106282. <https://doi.org/10.1016/j.quascirev.2020.106282>
- Laloy, F., Rage, J. C., Evans, S. E., Boistel, R., Lenoir, N., & Laurin, M. (2013). A re-interpretation of the Eocene anuran *Thaumastosaurus* based on microCT examination of a ‘mummified’ specimen. *PLoS One*, 8, e74874. <https://doi.org/10.1371/annotation/f7988d67-24b9-493c-9aef-c5c715948a1e>
- Latorre, C., Quade, J., & McIntosh, W. C. (1997). The expansion of C4 grasses and global change in the late Miocene: stable isotope evidence from the Americas. *Earth and Planetary Science Letters*, 146, 83–96. [https://doi.org/10.1016/S0012-821X\(96\)00231-2](https://doi.org/10.1016/S0012-821X(96)00231-2)
- Leal, M., & Brito, P. M. M. (2006). Anura do Cretáceo Inferior da Bacia do Araripe, nordeste do Brasil. In V. Gallo, P. M. M. Brito, H. M. A. Silva & F. J. Figueiredo (Eds.), *Paleontologia de Vertebrados: Grandes Temas e Contribuições Científicas* (pp. 145–152). Rio de Janeiro: Interciência.
- Leal, M. E. S. C., Martill, D. M., & Brito, P. M. M. (2007). Anurans of the Crato Formation. In D. M. Martill, G. Bechly, & R. F. Loveridge (Eds.), *The Crato fossil beds of Brazil Window Into an Ancient World* (pp. 444–451). Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9780511535512.014>
- Legarreta, L., & Uliana, M. A. (1998). Anatomy of hinterland depositional sequences: Upper Cretaceous fluvial strata, Neuquén basin, west-central Argentina. In K. W. Shanley & P. J. McCabe (Eds.), *Relative role of eustasy, climate, and tectonism in continental rocks* (pp. 83–92). Broken Arrow: Society for Sedimentary Geology Special Publication 59. <https://doi.org/10.2110/pec.98.59.0083>
- Leite, K. J. G. (2013). *Novo anuro do membro Crato (Aptiano) da formação Santana, Bacia do Araripe*. MSc thesis. Fortaleza, Brazil: Universidade Federal do Ceará.
- Lessa, G., Cartelle, C., Faria, H. D., & Gonçalves, P. R. (1998). Novos achados de mamíferos carnívoros do Pleistoceno final-Holoceno em grutas calcárias do estado da Bahia. *Acta Geologica Leopoldensia*, 21, 157–169.
- Lezcano, M. J., Pardiñas, U. F., & Tonni, E. P. (1993). Restos de vertebrados en el Holoceno del nordeste de la provincia de Buenos Aires, Argentina. Sistemática y paleoambiente. *Ameghiniana*, 30, 332.
- Liais, E. (1872). *Climats, géologie, faune et géographie botanique du Brésil*. Paris: Garnier. <https://doi.org/10.5962/bhl.title.1515>
- Lima, M. S., Moura, J. L. R., Santos, J. M., Souza, I. R., Viana, M. S. S., & Oliveira, P. V. (2016). Análise do material de Amphibia da Gruta do Urso Fóssil (Holoceno), Ceará: Resultados preliminares. In M. C. Langer, W. A. Alhalabi, G. S. Ferreira, G. Hermanson, J. C. A. Marsola & S. Y. Onary-Alves (Eds.), *Paleontologia em Destaque - Edição Especial XXV Congresso Brasileiro de Paleontologia* (p. 174). Ribeirão Preto: Gráfica Editora São Francisco.
- Linares, O. J. (2004). Bioestratigrafía de la fauna de mamíferos de las formaciones Socorro, Urumaco y Codore (Mioceno Medio–Plioceno Temprano), de la región de Urumaco, Falcón, Venezuela. *Paleobiología Neotropical*, 1, 1–26.
- Lockley, M. G., & Milner, A. R. (2014). The ichnotaxonomy of hopping vertebrate trackways from the Cenozoic. In M. G. Lockley & S. G. Lucas (Eds.), *Fossil Footprints of Western North America: Bulletin 62* (pp. 489–500). Albuquerque: New Mexico Museum of Natural History and Science.
- Lodolo, E., Donda, F., & Tassone, A. (2006). Western Scotia Sea margins: improved constraints on the opening of the Drake Passage. *Journal of Geophysical Research: Solid Earth*, 111, 1–14. <https://doi.org/10.1029/2006JB004569>
- Lomolino, M. V., Riddle, B. R., & Whittaker, R. J. (2017). *Biogeography*. Oxford University Press, Sunderland.
- Louca, S., & Pennell, M. W. (2020). Extant timetrees are consistent with a myriad of diversification histories. *Nature*, 580, 502–505. <https://doi.org/10.1038/s41586-020-2176-1>
- Lydekker R. 1890. *Catalogue of the fossil Reptilia and Amphibia in the British Museum, part IV, containing the orders Anomodontia, Ecaudata, Caudata and Labyrinthodontia*. London: British Museum (Natural History).
- Lyman, R. L., & Lyman, C. (1994). *Vertebrate taphonomy*. Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9781139878302>
- Lynch, J. D. (1971). *Evolutionary relationships, osteology, and zoogeography of leptodactyloid frogs*. Lawrence: University of Kansas.

- MacFadden, B. J., Campbell, K. E., Cifelli, R. L., Siles, O., Jhonson, N. M., Naeser, C. W., & Zeiler, P. K. (1985). Magnetic polarity stratigraphy and mammalian fauna of Deseadan (late Oligocene) Salla Beds of northern Bolivia. *Journal of Geology*, *93*, 223–250. <https://doi.org/10.1086/628950>
- MacFadden, B. J., Zeitler, P. K., Anaya, F., & Cottle, J. M. (2013). Middle Pleistocene age of the fossiliferous sedimentary sequence from Tarija, Bolivia. *Quaternary Research*, *79*, 268–273. <https://doi.org/10.1016/j.yqres.2012.12.009>
- Magalhães, C. M. (2012). *Descrição e Posicionamento Filogenético de um Anuro Fóssil (Lissamphibia, Tetrapoda) da Formação Crato, Bacia do Araripe*. Undergraduation thesis. Rio de Janeiro, Brazil: Escola de Ciências da Saúde, Unigranrio.
- Magalhães, C. M. (2014). *Problemática da Preservação de Anuros Fóssis: Tafonomia e Actuopaleontologia*. Undergraduation thesis. Rio de Janeiro, Brazil: Universidade Federal do Rio de Janeiro.
- Magalhães, C. M. (2018). *Descrição e posicionamento filogenético de um novo anuro fóssil da Formação Crato*. MSc thesis. Rio de Janeiro, Brazil: Museu Nacional.
- Maisey, J. G. (1991). Undetermined Santana frog. In J. G. Maisey (Ed.), *Santana Fossils, An Illustrated Atlas* (pp. 324–325). Tropical Fish Hobbyist. Neptune City.
- Malumian, N., & Nález, C. (2011). The Late Cretaceous–Cenozoic transgressions in Patagonia and the Fuegian Andes: foraminifera, palaeoecology, and palaeogeography. *Biological Journal of the Linnean Society*, *103*, 269–288. <https://doi.org/10.1111/j.1095-8312.2011.01649.x>
- Marcus, H. (1945). Contribución al conocimiento de los Gymnophiona, no. 32. *Prohyopogeophis tunariensis* (n. sp.), un fósil de la era paleozoica. *Revista de Agricultura Boliviana*, *2*, 29–40.
- Marjanović, D., & Laurin, M. (2008). Assessing confidence intervals for stratigraphic ranges of higher taxa: the case of Lissamphibia. *Acta Palaeontologica Polonica*, *53*, 413–432. <https://doi.org/10.4202/app.2008.0305>
- Marjanović, D., & Laurin, M. (2014). An updated paleontological timetree of lissamphibians, with comments on the anatomy of Jurassic crown-group salamanders (Urodela). *Historical Biology*, *26*, 535–550. <https://doi.org/10.1080/08912963.2013.797972>
- Marquillas, R. A., Del Papa, C., & Sabino, I. F. (2005). Sedimentary aspects and paleoenvironmental evolution of a rift basin: Salta Group (Cretaceous–Paleogene), northwestern Argentina. *International Journal of Earth Sciences*, *94*, 94–113. <https://doi.org/10.1007/s00531-004-0443-2>
- Marramà, G., & Carnevale, G. (2017). The relationships of *Gastero-clupea branisai* Signeux, 1964, a freshwater double-armed herring (Clupeomorpha, Ellimmichthyiformes) from the Late Cretaceous–Paleocene of South America. *Historical Biology*, *29*, 904–917. <https://doi.org/10.1080/08912963.2016.1262855>
- Marshall, L. G., & Patterson, B. (1981). Geology and geochronology of the mammal-bearing Tertiary of the Valle de Santa María and río Corral Quemado, Catamarca province, Argentina. *Fieldiana, Geology*, *9*, 1–80. <https://doi.org/10.5962/bhl.title.3461>
- Marshall, L. G., Butler, R. F., Drake, R. E., & Curtis, G. H. (1982). Geochronology of type Uquian (Late Cenozoic) land mammal age, Argentina. *Science*, *216*, 986–989. <https://doi.org/10.1126/science.216.4549.986>
- Marshall, L. G., Berta, A., Hofstetter, R., Pascual, R., Reig, O., Bombin, M., & Mones, A. (1984). Mammals and stratigraphy: geochronology of the continental mammal-bearing Quaternary of South America. Laboratoire de paléontologie des vertébrés de l'École pratique des hautes études. *Palaeovertebrata, Montpellier, Mem. Extr*, *13*, 1–76.
- Marshall, L. G., Cifelli, R. L., Drake, R. E., & Curtis, G. H. (1986). Vertebrate paleontology, geology, and geochronology of the Tapera de Lopez and Scarritt Pocket, Chubut Province, Argentina. *Journal of Paleontology*, *60*, 920–951. <https://doi.org/10.1017/S0022336000043080>
- Martill, D. M., Tischlinger, H., & Frey, E. (2013). Small, enigmatic lissamphibian from the Crato Formation of Brazil: a preliminary analysis of the first articulated caudatan from the Mesozoic of South America. In S. Walsh, N. Fraser, S. Brusatte, J. Liston, & V. Carrió (Eds.), *Programme and Abstracts of the 61st Symposium on Vertebrate Palaeontology and Comparative Anatomy* (p. 32). Edinburgh: Geological Curators' Group.
- Martinelli, A. G., & Forasiepi, A. M. (2004). Late Cretaceous vertebrates from Bajo de Santa Rosa (Allen Formation), Río Negro province, Argentina, with the description of a new sauropod dinosaur (Titanosauridae). *Revista del Museo Argentino de Ciencias Naturales*, *6*, 257–305. <https://doi.org/10.22179/REVMACN.6.88>
- Matthew, W. D. (1915). Climate and Evolution. *Annals of the New York Academy of Sciences*, *24*, 171. <https://doi.org/10.1111/j.1749-6632.1914.tb55346.x>
- Matthews, T., & du Plessis, A. (2016). Using X-ray computed tomography analysis tools to compare the skeletal element morphology of fossil and modern frog (Anura) species. *Palaeontologia Electronica*, *19*, 1–46. <https://doi.org/10.26879/557>
- Matthews, T., Keffe, R., & Blackburn, D. C. (2019). An identification guide to fossil frog assemblages of southern Africa based on extant taxa. *Zoologischer Anzeiger*, *283*, 46–57. <https://doi.org/10.1016/j.jcz.2019.08.005>
- May, G., Hartley, A. J., Chong, G., Stuart, F., Turner, P., & Kape, S. J. (2010). Eocene to Pleistocene lithostratigraphy, chronostratigraphy and tectono-sedimentary evolution of the Calama Basin, northern Chile. *Andean Geology*, *32*, 33–58. <https://doi.org/10.4067/S0716-02082005000100003>
- Mazzoni, M. M., & Benvenuto, A. (1990). Radiometric ages of tertiary ignimbrites and the Collon Cura Formation, northwestern Patagonia. Pp. 87–90. *Actas IX Congreso Geológico Argentino*. Maipú: Asociación Geológica Argentina.
- Mazzoni, M. M. (1994). Conos de cinder y facies volcánicas miocenas en la Meseta del Canquel (Scarritt Pocket), provincia de Chubut, Argentina. *Revista de la Asociación Argentina de Sedimentología*, *1*, 15–31.
- Melchor, R. N., Casadío, S., & Visconti, G. (1992). Análisis estratigráfico secuencial de los depósitos lacustres Eocenos de la Formación Vaca Mahuida, SO de la provincia de La Pampa, Argentina. (pp. 151–158). *Actas de la Cuarta Reunión Argentina de Sedimentología*. La Plata: Asociación Argentina de Sedimentología.
- Melchor, R. N., de Valais, S., & Genise, J. F. (2004). Middle Jurassic mammalian and dinosaur footprints and petrified forests from the volcanoclastic La Matilde Formation. In E. S. Bellosi & R. N. Melchor (Eds.), *Fieldtrip guidebook* (pp. 47–63). 1^o International Congress on Ichnology. Trelew: Museo Egidio Feruglio.
- Melendi, D. L., Scafati, L. H., & Volkheimer, W. (2003). Palynostratigraphy of the Paleogene Huitrera Formation in N-W Patagonia, Argentina. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, *228*, 205–273. <https://doi.org/10.1127/njgpa/228/2003/205>
- Mendes, A. B., & Rodrigues, T. (2019). Tetrapods in sambaquis of Santa Catarina state, Brazil. In H. I. Araújo-Júnior, D. Riff, A. C. S. Riff & R. C. Silva (Eds.), *Boletim de Resumos do XXVI Congresso Brasileiro de Paleontologia* (p. 239). Uberlândia: Sociedade Brasileira de Paleontologia.
- Mendivil, E. S., & Manrique, D. D. (1994). *Geología de los cuadrángulos de Cuzco y Livitaca, hojas 28-s y 29-s*. Lima: Instituto Geológico, Minero y Metalúrgico.
- Mercadal de Barrio, I. T., & Barrio, A. (2002). Tetraploidia en *Ceratophrys* (Anura, Leptodactylidae), análisis del registro fósil. *Iheringia. Série Zoologia*, *92*, 17–31. <https://doi.org/10.1590/S0073-47212002000300003>
- Messineo, P. G., Dubois, C. M. F., Politis, G. G., & Vitale, P. (2021). Site formation process and megamammal bone radiocarbon dates in

- Campo Laborde (Pampas of Argentina): Contribution towards a research methodology. *Quaternary International*, 586, 53–65. <https://doi.org/10.1016/j.quaint.2021.01.007>
- Metcalf, M. M. (1923). The origin and distribution of the Anura. *The American Naturalist*, 57, 385–411. <https://doi.org/10.1086/279933>
- Milner, A. R. (1983). The biogeography of salamanders in the Mesozoic and Early Cenozoic: a cladistic-vicariance model. In R. W. Sims, J. H. Price & P. E. S. Whalley, (Eds.), *Evolution, Time and Space: The Emergence of the Biosphere* (pp. 431–468). New York: Academic Press.
- Milner, A. R. (2000). Mesozoic and Tertiary Caudata and Albanerpetontidae. In H. Heatwole & R. L. Carroll (Eds.), *Amphibian Biology*, Volume 4, *Paleontology: The evolutionary history of amphibians* (pp. 1412–1444). Chipping Norton: Surrey Beatty and Sons.
- Mones, A. (1975). Notas paleontológicas uruguayas, III. Vertebrados fósiles nuevos o poco conocidos (Chondrichthyes, Osteichthyes, Amphibia, Mammalia). *Ameghiniana*, 12, 343–349.
- Montalvo, C. I., & Bond, M. (1998). Un notoungulata de la Formación Vaca Mahuida (Eoceno), provincia de La Pampa, Argentina. *Publicación Electrónica de la Asociación Paleontológica Argentina*, 5, 55–60.
- Moreira, J. K. R. (2016). *Estado da arte dos anuros fósseis do mesozóico mundial e descrição de nova espécie de anuro da Formação Crato, Bacia do Araripe, Nordeste do Brasil*. PhD dissertation. Fortaleza, Brazil: Universidade Federal do Ceará.
- Mörs, T., Reguero, M., & Vasilyan, D. (2020). First fossil frog from Antarctica: implications for Eocene high latitude climate conditions and Gondwanan cosmopolitanism of Australobatrachia. *Scientific Reports*, 10, 1–11. <https://doi.org/10.1038/s41598-020-61973-5>
- Moura, G. J. B., & Barreto, A. M. F. (2006). Aspectos tafonômicos da anurofauna da Formação Crato, Eocretáceo da Bacia do Araripe, Nordeste do Brasil. *Estudos Geológicos*, 16, 3–15.
- Moura, P. H. A., Costa, F. R., Anelli, L. E., & Nunes, I. (2021). A new genus of fossil frog (Anura) from lower Cretaceous deposits in South America. *Anais da Academia Brasileira de Ciências*, 93, e20191560. <https://doi.org/10.1590/0001-3765202120201560>
- Moyano-Paz, D., Rozadilla, S., Agnolín, F., Vera, E., Coronel, M. D., Varela, A. N., Gómez-Dacal, A. R., Aranciaga-Rolando, A. M., D'Angelo, J., Pérez-Loínaze, V., Richiano, S., Chimento, N., Motta, M. J., Sterli, J., Manabe, M., Tsuihiji, T., Isasi, M. P., Poiré, D. G., & Novas, F. E. (2022). The uppermost Cretaceous continental deposits at the southern end of Patagonia, the Chorrillo Formation case study (Austral-Magallanes Basin): Sedimentology, fossil content and regional implications. *Cretaceous Research*, 130, 105059. <https://doi.org/10.1016/j.cretres.2021.105059>
- Muizon, C., Gayet, M., Lavenue, A., Marshall, L. G., Sigé, B., & Villaroel, C. (1983). Late Cretaceous vertebrates, including mammals, from Tiupampa, southcentral Bolivia. *Geobios*, 16, 747–753. [https://doi.org/10.1016/S0016-6995\(83\)80091-6](https://doi.org/10.1016/S0016-6995(83)80091-6)
- Muniz, F. P., Bissaro Júnior, M. C., Souza-Filho, J. P., Negrio, F. R., Guilherme, E., Maciente, A. A., & Hsiou, A. S. (2016). First record of Anura (Lissamphibia) from the Solimões Formation (Upper Miocene, Acre Basin, Brazil). In O. N. Grillo, P. S. R. Romano & G. R. Oliveira (Eds.), *Boletim de Resumos X Simpósio Brasileiro de Paleontologia de Vertebrados* (p. 116). Rio de Janeiro: Sociedade Brasileira de Paleontologia.
- Muniz, F. P., Ferreira, G. E. M., Onary, S., Castro, M. C., & Langer M. C. (2020). A herpetofauna quaternária da Gruta do Ioiô (Bahia, Nordeste do Brasil). In S. Silvio, S. S. Nihei, A. C. Morandini, S. N. Stampar, A. E. Migotto, A. R. S. Garraffoni, J. P. Botero & M. V. Kitahara (Eds.), *Resumos do XXXIII Congresso Brasileiro de Zoologia* (p. 391). Águas de Lindoia: Sociedade Brasileira de Zoologia.
- Muzzopappa, P. (2019). *Calyptocephalella* (Anura, Australobatrachia) remains from Río Santa Cruz (Early–Middle Miocene, Santa Cruz Formation), Santa Cruz Province, Argentina. *Publicación Electrónica de la Asociación Paleontológica Argentina*, 19, 47–54. <https://doi.org/10.5710/PEAPA.27.06.2019.282>
- Muzzopappa, P., & Báez, A. M. (2009). Systematic status of the mid-Tertiary neobatrachian frog *Calyptocephalella canqueli* from Patagonia (Argentina), with comments on the evolution of the genus. *Ameghiniana*, 46, 113–125.
- Muzzopappa, P., & Nicoli, L. (2010). A glimpse at the ontogeny of the fossil neobatrachian frog *Calyptocephalella canqueli* from the Deseadan (Oligocene) of Patagonia, Argentina. *Acta Paleontologica Polonica*, 55, 645–654. <https://doi.org/10.4202/app.2009.0093>
- Muzzopappa, P., Martinelli, A. G., Garderes, J. P., & Rougier, G. W. (2021). Exceptional avian pellet from the paleocene of Patagonia and description of its content: a new species of calyptocephalellid (Neobatrachia) anuran. *Papers in Palaeontology*, 7(2), 1133–1146. <https://doi.org/10.1002/spp2.1333>
- Narváez, P. L., & Sabino, I. F. (2008). Palynology of the Las Curtiembres Formation (Late Cretaceous, Salta Group Basin), Las Conchas Creek area, northwestern Argentina. *Ameghiniana*, 45, 473–482.
- Nevo, E., & Estes, R. (1969). *Ramonellus longispinus*, an Early Cretaceous salamander from Israel. *Copeia*, 1969, 540–547. <https://doi.org/10.2307/1441934>
- Nicholls, G. E. (1916). The structure of the vertebral column in the Anura *Phaneroglossa* and its importance as a basis of classification. *Proceedings of the Linnean Society of London*, 128, 80–92. <https://doi.org/10.1111/j.1095-8312.1916.tb00038.x>
- Nicoli, L. (2012). On the putative presence of *Eupsophus* (Anura: Cycloramphidae) in Central Patagonia during the Oligocene. *Herpetologica*, 68, 236–243. <https://doi.org/10.1655/HERPETOLOGICA-D-11-00060.1>
- Nicoli, L. (2015). New fossil species of the extant genus *Lepidobatrachus* (Anura, Ceratophryidae) from the Late Miocene–Early Pliocene of central Argentina. *Journal of Vertebrate Paleontology*, 35, e981636. <https://doi.org/10.1080/02724634.2015.981636>
- Nicoli, L. (2016). A fossil ceratophryid anuran from the Late Miocene of west-central Argentina. *SALAMANDRA*, 52(2), 153–160.
- Nicoli, L. (2017). New clues on anuran evolution: the oldest record of an extant hyloid clade in the Oligocene of Patagonia. *Historical Biology*, 29, 1031–1044. <https://doi.org/10.1080/08912963.2017.1282475>
- Nicoli, L. (2019). The fossil record of *Ceratophrys* Wied-Neuwied (Anura: Ceratophryidae): a revision and update of fossil South American horned frogs. *Zootaxa*, 4658, 37–68. <https://doi.org/10.11646/zootaxa.4658.1.2>
- Nicoli, L., Muzzopappa, P., & Faivovich, J. (2016). The taxonomic placement of the Miocene Patagonian frog *Wawelia gerholdi* (Amphibia: Anura). *Alcheringa: An Australasian Journal of Palaeontology*, 40, 153–160. <https://doi.org/10.1080/03115518.2016.1101998>
- Nicoli, L., Tomassini, R. L., & Montalvo, C. I. (2017). The oldest record of *Ceratophrys* (Anura, Ceratophryidae) from the Late Miocene of central Argentina. *Journal of Vertebrate Paleontology*, 37, e1261360. <https://doi.org/10.1080/02724634.2017.1261360>
- Novas, F. E., Agnolín, F., Rozadilla, S., Aranciaga Rolando, A. M., Brissón Egli, F., Motta, M. J., Cerroni, M., Ezcurra, M., Martinelli, A., Angelo, J., Álvarez-Herrera, G., Gentil, A., Bogan, S., García-Marsà, J., Coco, G. L., Miguel, S., Brito, F., Vera, E., Loínaze, V., Fernandez, M., & Salgado, L. (2019). Paleontological discoveries in the Chorrillo Formation (upper Campanian–lower Maastrichtian, Upper Cretaceous), Santa Cruz Province, Patagonia, Argentina. *Revista del Museo Argentino de Ciencias Naturales Nueva Serie*, 21, 217–293. <https://doi.org/10.22179/REVMACN.21.655>
- Nullo, F., Blasco, G., Risso, C., Combina, A., & Otamendi, J. (2006). Hoja Geológica 5172-I y 5175-II, El Calafate, provincia de Santa Cruz. *Boletín del Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino*, 396, 86.

- Nunes-de-Almeida, C. H. L., Haddad, C. F. B., & Toledo, L. F. (2021). A revised classification of the amphibian reproductive modes. *Salamandra*, 57, 413–427.
- Núñez, L., Varela, J., & Casamiquela, R. (1987). Ocupación paleoindio en el Centro-Norte de Chile: adaptación circunlacustre en las tierras bajas. *Estudios Atacameños*, 8, 142–185. <https://doi.org/10.22199/S07181043.1987.0008.00010>
- Núñez, L., Varela, J., Casamiquela, R., & Villagrán, C. (1994). Reconstrucción Multidisciplinaria de la ocupación prehistórica de Quereo, Centro de Chile. *Latin American Antiquity*, 5, 99–118. <https://doi.org/10.2307/971558>
- Oliveira, P. V., Ribeiro, A. M., Viana, M. S. S., & Holanda, E. C. (2014). Tayassuidae, Cervidae e Tapiridae da Gruta do Urso Fóssil, Holoceno, Parque Nacional de Ubajara, Ceará, Brasil. *Revista Brasileira de Paleontologia*, 17, 417–434. <https://doi.org/10.4072/rbp.2014.3.11>
- Ortiz, P. E., López, D. A. G., Babot, M. J., Pardiñas, U. F., Muruaga, P. J. A., & Jayat, J. P. (2012). Exceptional Late Pliocene microvertebrate diversity in northwestern Argentina reveals a marked small mammal turnover. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 361, 21–37. <https://doi.org/10.1016/j.palaeo.2012.07.012>
- Ortiz-Jaureguizar, E., & Cladera, G. A. (2006). Paleoenvironmental evolution of southern South America during the Cenozoic. *Journal of Arid Environments* 66, 498–532. <https://doi.org/10.1016/j.jaridenv.2006.01.007>
- Otero, R. A., Jimenez-Huidobro, P., Soto-Acuna, S., & Yury-Yáñez, R. E. (2014). Evidence of a giant helmeted frog (Australobatrachia, Calyptocephalellidae) from Eocene levels of the Magallanes Basin, southernmost Chile. *Journal of South American Earth Sciences*, 55, 133–140. <https://doi.org/10.1016/j.jsames.2014.06.010>
- Paleobiology Database. (2021). *Checklist dataset*. Available at: <https://paleobiodb.org/classic>. Accessed 24 September 2021.
- Paluh, D. J., Stanley, E. L., & Blackburn, D. C. (2020). Evolution of hyperossification expands skull diversity in frogs. *Proceedings of the National Academy of Sciences*, 117, 8554–8562. <https://doi.org/10.1073/pnas.2000872117>
- Panti, C. (2016). Myrtaceae fossil leaves from the Río Turbio Formation (Middle Eocene), Santa Cruz Province, Argentina. *Historical Biology*, 28, 459–469. <https://doi.org/10.1080/08912963.2014.976635>
- Panza, J. L., & Haller, M. J. (2002). El volcanismo jurásico. In M. J. Haller (Ed.), *Geología y recursos Naturales de Santa Cruz, Reportorio del XV Congreso Geológico Argentino* (pp. 89–102). Maipú: Asociación Geológica Argentina.
- Pardiñas, U. F. (2001). Condiciones áridas durante el Holoceno Temprano en el sudoeste de la provincia de Buenos Aires (Argentina): vertebrados y tafonomía. *Ameghiniana*, 38, 227–236.
- Parham, J. F., Donoghue, P. C., Bell, C. J., Calway, T. D., Head, J. J., Holroyd, P. A., Inoue, J. G., Irmis, R. B., Joyce, W. G., Ksepka, D. T., Patané, J. S., Smith, N. D., Tarver, J. E., van Tuinen, M., Yang, Z., Angielczyk, K. D., Greenwood, J. M., Hipsley, C. A., Jacobs, L., Makovicky, P. J., Müller, J., Smith, K. T., Theodor, J. M., Warnock, R. C., & Benton M. J. (2012). Best practices for justifying fossil calibrations. *Systematic Biology*, 61, 346–359. <https://doi.org/10.1093/sysbio/syr107>
- Park, W. M., Lockley, M. G., Kim, J. Y., & Kim, K. S. (2018). Anuran (frog) trackways from the Cretaceous of Korea. *Cretaceous Research*, 86, 135–148. <https://doi.org/10.1016/j.cretres.2018.02.002>
- Parodi Bustos, R. M., Caprini, F., Kraglievich, J., & del Corro, G. (1960). Noticia preliminar acerca del yacimiento de anuros extinguidos de Puente Morales (Dep. Guachipas, Salta). *Revista de la Facultad de Ciencias Naturales de Salta*, 1, 5–25.
- Parra-Olea, G., García-París, M., & Wake, D. B. (2004). Molecular diversification of salamanders of the tropical American genus *Bolitoglossa* (Caudata: Plethodontidae) and its evolutionary and biogeographical implications. *Biological Journal of the Linnean Society*, 81, 325–346. <https://doi.org/10.1111/j.1095-8312.2003.00303.x>
- Pascual, R., Goin, F. J., González, P., Ardolino, A., & Puerta, P. F. (2000). A highly derived docodont from the Patagonian Late Cretaceous: evolutionary implications for Gondwanan mammals. *Geodiversitas*, 22, 395–414.
- Paula-Couto, C. (1980). Fossil Pleistocene to sub-recent mammals from northeastern Brazil. I-Edentata Megalonychidae. *Anais da Academia Brasileira de Ciências*, 52, 143–151
- Pedroza, V., Le Roux, J. P., Gutiérrez, N. M., & Vicencio, V. E. (2017). Stratigraphy, sedimentology, and geothermal reservoir potential of the volcanoclastic Cura-Mallín succession at Lonquimay, Chile. *Journal of South American Earth Sciences*, 77, 1–20. <https://doi.org/10.1016/j.jsames.2017.04.011>
- Pereira, G. C. R., de Oliveira, E. C., & Bergamaschi, S. (2017). Continental carbonates from Itaboraí Formation in southeastern Brazil. *Quaternary International*, 437, 199–211. <https://doi.org/10.1016/j.quaint.2016.12.006>
- Pereira, R., Carvalho, I. S., Azevedo, D. A., & Fernandes, A. C. S. (2007). Ocorrências de âmbar nas bacias sedimentares brasileiras – uma revisão. In I. S. Carvalho, R. C. T. Cassab, C. Swanke, M. A. Carvalho, A. C. S. Fernandes, M. A. C. Rodrigues, M. S. S. Carvalho, M. Arai, M. E. Q. Oliveira (Eds.), *Paleontologia: Cenários de Vida*, 1, (pp. 251–264). Rio de Janeiro: Editora Interciência
- Pérez-Ben, C. M., Gómez, R. O., & Báez, A. M. (2014). Intraspecific morphological variation and its implications in the taxonomic status of ‘*Bufo pisanoi*,’ a Pliocene anuran from eastern Argentina. *Journal of Vertebrate Paleontology*, 34, 767–773. <https://doi.org/10.1080/02724634.2014.839452>
- Pérez-Ben, C. M., Gómez, R. O., & Báez, A. M. (2019a). A new Pliocene true toad (Anura: Bufonidae): first record of an extinct species from South America. *Journal of Vertebrate Paleontology*, 39, e1576183. <https://doi.org/10.1080/02724634.2019.1576183>
- Pérez-Ben, C. M., Turazzini, G. F., & Gómez, R. O. (2019b). A Last Glacial anuran assemblage from the inland Pampas of South America provides insights into climate and environments during Marine Isotope Stage 3. *Journal of Vertebrate Paleontology*, 39, e1627365. <https://doi.org/10.1080/02724634.2019.1627365>
- Peri, S. I. (1993). *Ceratophrys* (Anura, Leptodactylidae) en el Holoceno de Laguna Los Tres Reyes, provincia de Buenos Aires, Argentina. *Ameghiniana*, 30, 3–7.
- Perônico, C., & Araújo, A. C. S. (2002). Diversidade faunística baseada em escavação tafonômica orientada de material sub-recente preservado em caverna da região cárstica de Lagoa Santa, Minas Gerais. *Arquivos do Museu Nacional*, 6, 195–198.
- Petrulevičius, J., Salas-Gismondí, R., Flynn, J., Nel, A., Antoine, P. O., & De Franceschi, D. (2011). First fossil blood sucking Psychodidae in South America: a scyoracine moth fly (Insecta: Diptera) in the middle Miocene Amazonian amber. *Insect Systematics & Evolution*, 42, 87–96. <https://doi.org/10.1163/187613211X560919>
- Pingel, H., Strecker, M. R., Alonso, R. N., & Schmitt, A. K. (2013). Neotectonic basin and landscape evolution in the Eastern Cordillera of NW Argentina, Humahuaca Basin (~24°S). *Basin Research*, 25, 554–573. <https://doi.org/10.1111/bre.12016>
- Pinto, W. A. (2010). *Classificação taxonômica dos elementos ósseos de anuros (Tetrapoda, Lissamphibia) coletados no Abismo Gêmeo, Parque Estadual Turístico do Alto Ribeira, Iporanga (SP)*. Undergraduate thesis, São Paulo, Brazil: Universidade de São Paulo.
- Pinto-Llona, A. C., & Andrews, P. J. (1999). Amphibian taphonomy and its application to the fossil record of Dolina (middle Pleistocene, Atapuerca, Spain). *Palaeogeography, Palaeoclimatology, Palaeo-*

- ecology*, 149, 411–429. [https://doi.org/10.1016/S0031-0182\(98\)00215-6](https://doi.org/10.1016/S0031-0182(98)00215-6)
- Poinar, G. O. (1992). *Life in amber*. Redwood City: Stanford University Press. <https://doi.org/10.1515/9781503623545>
- Poinar, G. O., & Cannatella, D. C. (1987). An Upper Eocene frog from the Dominican Republic and its implication for Caribbean biogeography. *Science*, 237, 1215–1216. <https://doi.org/10.1126/science.237.4819.1215>
- Poinar, G. O., & Wake, D. B. (2015). *Palaeoplethodon hispaniolae* gen. n., sp. n. (Amphibia: Caudata), a fossil salamander from the Caribbean. *Palaeodiversity*, 8, 21–29.
- Pol, D., Ramezani, J., Gomez, K., Carballido, J. L., Carabajal, A. P., Rauhut, O. W. M., Escapa, I. H., & Cúneo, N. R. (2020). Extinction of herbivorous dinosaurs linked to Early Jurassic global warming event. *Proceedings of the Royal Society B*, 287, 2020, 2310. <https://doi.org/10.1098/rspb.2020.2310>
- Poole, I., & Cantrill, D. J. (2006). Cretaceous and Cenozoic vegetation of Antarctica integrating the fossil wood record. *Geological Society, London, Special Publications*, 258, 63–81. <https://doi.org/10.1144/GSL.SP.2006.258.01.05>
- Porta, J. D. (1969). Les Vertébrés fossiles de Colombie et les problèmes posés par l'isolement du continent Sud-Américain. *Paleovertebrata*, 2, 77–94. <https://doi.org/10.18563/pv.2.2.77-94>
- Prado, L. P., & Alberdi, M. T. (1999). The mammalian record and climatic change over the last 30,000 years in the Pampean Region, Argentina. *Quaternary International*, 57, 165–174. [https://doi.org/10.1016/S1040-6182\(98\)00057-3](https://doi.org/10.1016/S1040-6182(98)00057-3)
- Prado, G., Muniz, F. P., Onary, S., Osés, G. L., Domingues, R. P., Pinheiro, F. L., Becker-Kleber, B., & Anelli, L. E. (2019). A diversidade de anuros da Formação Crato (Bacia do Araripe, Ne Brasil) e suas implicações bioestratigráficas, paleoecológicas e taxonômicas. In H. I. Araújo-Júnior, D. Riff, A. C. S. Riff & R. C. Silva (Eds.), *Boletim de Resumos do XXVI Congresso Brasileiro de Paleontologia* (pp. 71–72). Uberlândia: Sociedade Brasileira de Paleontologia.
- Pramuk, J. B. (2006). Phylogeny of South American *Bufo* (Anura: Bufonidae) inferred from combined evidence. *Zoological Journal of the Linnean Society*, 146, 407–452. <https://doi.org/10.1111/j.1096-3642.2006.00212.x>
- Pramuk, J. B., Robertson, T., Sites Jr, J. W., & Noonan, B. P. (2008). Around the world in 10 million years: biogeography of the nearly cosmopolitan true toads (Anura: Bufonidae). *Global Ecology and Biogeography*, 17, 72–83. <https://doi.org/10.1111/j.1466-8238.2007.00348.x>
- Purcino, H. G. (2015). *Correlação das assinaturas tafonômicas entre microvertebrados preservados em depósito recente e em paleopiso da cavidade ES-08, Prudente de Moraes, MG*. Undergraduate thesis. Belo Horizonte, Brazil: Universidade Federal de Minas Gerais.
- Pyron, R. A. (2014). Biogeographic analysis reveals ancient continental vicariance and recent oceanic dispersal in amphibians. *Systematic Biology*, 63, 779–797. <https://doi.org/10.1093/sysbio/syu042>
- Pyron, R. A., & Burbrink, F. T. (2009). Can the tropical conservatism hypothesis explain temperate species richness patterns? An inverse latitudinal biodiversity gradient in the New World snake Tribe Lamproleptini. *Global Ecology and Biogeography*, 18, 406–415. <https://doi.org/10.1111/j.1466-8238.2009.00462.x>
- Quantum Gis (2021). *Quantum GIS Geographic Information System, version 3.20.1 'Odense'*. Open-Source Geospatial Foundation Project. Available at: <http://qgis.osgeo.org>. Accessed 24 September 2021
- Quintana, C. (1994). Notas para una actualización del conocimiento de la fauna de la 'Formación' San Andrés (Pleistoceno inferior), provincia de Buenos Aires. *Ameghiniana*, 31, 331–332.
- Rage, J. C. (1991). Gymnophionan Amphibia from the Early Paleocene (Santa Lucía Formation) of Tiupampa (Bolivia): the oldest known Gymnophiona. *Revista Técnica de YPF*, 12, 3–4.
- Rage, J. C., Marshall, L. G., & Gayet, M. (1993). Enigmatic Caudata (Amphibia) from the Upper Cretaceous of Gondwana. *Geobios*, 26, 515–519. [https://doi.org/10.1016/S0016-6995\(06\)80234-2](https://doi.org/10.1016/S0016-6995(06)80234-2)
- Rage, J. C., Prasad, G. V., Verma, O., Khosla, A., & Parmar, V. (2020). Anuran Lissamphibian and squamate reptiles from the Upper Cretaceous (Maastrichtian) Deccan Intertrappean Sites in Central India, with a review of Lissamphibian and squamate diversity in the northward drifting Indian plate. In G. V. R. Prasad & R. Patnaik (Eds.), *Biological Consequences of Plate Tectonics New perspectives on post-Gondwana break-up* (pp. 99–121). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-49753-8_6
- Raigemborn, M., Brea, M., Zucol, A., & Matheos, S. (2009). Early Paleogene climate at mid latitude in South America: Mineralogical and paleobotanical proxies from continental sequences in Golfo San Jorge basin (Patagonia, Argentina). *Geologica Acta*, 7, 125–145.
- Raigemborn, M. S., Matheos, S. D., Krapovickas, V., Vizcaino, S. F., Bargo, M. S., Kay, R. F., Femicola, J. C., & Zapata, L. (2015). Paleoenvironmental reconstruction of the coastal Monte León and Santa Cruz formations (early Miocene) at Rincón del Buque, southern Patagonia: A revisited locality. *Journal of South American Earth Sciences*, 60, 31–55. <https://doi.org/10.1016/j.jsames.2015.03.001>
- Rangel, T. F., Edwards, N. R., Holden, P. B., Diniz-Filho, J. A. F., Gosling, W. D., Coelho, M. T. P., Cassemiro, F. A. S., Rahbek, C., & Colwell, R. K. (2018). Modeling the ecology and evolution of biodiversity: Biogeographical cradles, museums, and graves. *Science*, 361, eaar5452. <https://doi.org/10.1126/science.aar5452>
- Rauhut, O. W. M. (1999). A dinosaur fauna from the Late Cretaceous (Cenomanian) of northern Sudan. *Palaeontologica Africana*, 35, 61–84.
- Ré, G. H., Bellosi, E. S., Heizler, M., Vilas, J. F., Madden, R. H., Carlini, A. A., Kay, R. F., & Vucetich, M. G. (2010). A geochronology for the Sarmiento Formation at Gran Barranca. In R. H. Madden, A. A. Carlini, M. G. Vucetich & R. F. Kay (Eds.), *The Paleontology of Gran Barranca Evolution and Environmental Change through the Middle Cenozoic of Patagonia* (pp 46–59). Cambridge: Cambridge University Press.
- Reguero, M. A., Candela, A. M., & Alonso, R. N. (2007). Biochronology and biostratigraphy of the Uquía Formation (Pliocene–early Pleistocene, NW Argentina) and its significance in the Great American Biotic Interchange. *Journal of South American Earth Sciences*, 23, 1–16. <https://doi.org/10.1016/j.jsames.2006.09.005>
- Reig, O. (1958a). Proposiciones para una nueva macrosistemática de los Anuros (nota preliminar). *Physis*, 21, 109–118.
- Reig, O. A. (1958b). Notas para una actualización del conocimiento de la fauna de la formación Chapadmalal. II Amphibia Reptilia Aves Mammalia (Marsupialia: Didelphiidae Borhyianidae). *Acta Geológica Lillona*, 2, 255–283.
- Reig, O. A. (1959). Primeros Datos Descriptivos sobre los Anuros del Eocretaceo de la Provincia de Salta (Rep. Argentina). *Ameghiniana*, 1, 3–8.
- Reig, O. A. (1960). Las relaciones genéricas del anuro chileno *Calyptocephalella gayi* (Dum. and Bibr.). In R. A. Ringuelet, S. R. Olivier, R. Ronderos & J. A. V. Sarmiento (Eds.), *Actas y trabajos del primer Congreso sudamericano de Zoología* (pp. 113–131). La Plata: Universidad Nacional de La Plata.
- Reig, O. A. (1961). Noticia sobre un nuevo anuro fósil del Jurásico de Santa Cruz (Patagonia). *Ameghiniana*, 2, 73–78.
- Riccomini, C., Coimbra, A. M., Sant'anna, L. G., Neto, M. B., & Valarelli, J. V. (1996). Argilominerais do paleolito Tremembé e sistemas deposicionais relacionados (Paleógeno, Rift Continental do Sudeste do Brasil). *Revista Brasileira de Geociências*, 26, 167–180. <https://doi.org/10.25249/0375-7536.1996167180>
- Riccomini, C., Sant'Anna, L. G., & Ferrari, A. L. (2004). Evolução geológica do rift continental do sudeste do Brasil. In *Geologia do*

- continente Sul-Americano: evolução da obra de Fernando Flávio Marques de Almeida, 383–405
- Richter, R. (1928). Aktuopaläontologie und Paläobiologie, eine Abgrenzung. *Senckenbergiana*, 10, 285–292.
- Rincón, A. D. (2000). Algunos resultados preliminares de la expedición a Cerro Pintado (1997), Zu. 16-Cueva de los Huesos (Sierra de Perijá, Venezuela). *Boletín de la Sociedad Venezolana de Espeleología*, 34, 44–46.
- Rincón, A. D., Alberdi, M. T., & Prado, J. L. (2006). Nuevo registro de *Equus (Amerhippus) santaelenae* (Mammalia, Perissodactyla) del pozo de asfalto de Inciarte (Pleistoceno superior), estado Zulia, Venezuela. *Ameghiniana*, 43, 529–538.
- Rincón, A. D., White, R. S., & McDonald, H. G. (2008). Late Pleistocene cingulates (Mammalia: Xenarthra) from Mene de inciarte tar pits, Sierra de Perijá, western Venezuela. *Journal of Vertebrate Paleontology*, 28, 197–207. [https://doi.org/10.1671/0272-4634\(2008\)28\[197:LPCMXF\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2008)28[197:LPCMXF]2.0.CO;2)
- Rinderknecht, A. (1998). Nuevos microvertebrados fósiles para el Pleistoceno Superior del Uruguay (Amphibia, Reptilia, Aves). *Comunicaciones Paleontológicas del Museo de Historia Natural de Montevideo*, 30, 133–144.
- Robinson, S. F. (1991). Bird and frog tracks from the Late Cretaceous Blackhawk Formation in east-central Utah. *Utah Geological Association Publication*, 19, 325–334.
- Roček, Z. (1994). A review of the fossil Caudata of Europe. *Abhandlungen und Berichte für Naturkunde*, 17, 51–56.
- Roček, Z. (2000). Mesozoic anurans. In H. Heatwole & R. L. Carroll (Eds.), *Amphibian Biology, Volume 4, Paleontology: The evolutionary history of amphibians* (pp. 1295–1331). Chipping Norton: Surrey Beatty and Sons.
- Roček, Z. (2013). Mesozoic and Tertiary Anura of Laurasia. In J. D. Gardner, & R. L. Nydam (Eds.), *Mesozoic and Cenozoic Lissamphibian and Squamate assemblages of Laurasia. Palaeobiodiversity and Palaeoenvironments*, 93(4), 397–439. <https://doi.org/10.1007/s12549-013-0131-y>
- Roček, Z., & Rage, J. C. (2000). Tertiary Anura of Europe, Africa, Asia, North America, and Australia. In H. Heatwole & R. L. Carroll (Eds.), *Amphibian biology, Volume 4, Paleontology: The evolutionary history of amphibians* (pp. 1332–1387). Chipping Norton: Surrey Beatty and Sons.
- Rodríguez, L. M., & Galán, C. (2008). Las zonas kársticas de la Sierra de Perijá, Venezuela: Cavidades estudiadas y rasgos geológico-estructurales. *Boletín de la Sociedad Venezolana de Espeleología*, 42, 7–19.
- Rodríguez, M. F., Leanza, H. A., & Salvarredy Aranguren, M. (2007). Hoja Geológica 3969-II, Neuquén, provincias del Neuquén, Río Negro y La Pampa. *Boletín del Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino*, 370, 1–172.
- Rolando, A. M. A., Agnolin, F. L., & Corsolini, J. (2019). A new pipoid frog (Anura, Pipimorpha) from the Paleogene of Patagonia. *Paleobiogeographical implications. Comptes rendus Palevol*, 18, 725–734. <https://doi.org/10.1016/j.crpv.2019.04.003>
- Rovereto, C. (1914). Los estratos araucanos y sus fósiles. *Anales del Museo Nacional de Buenos Aires*, 25, 1–247.
- Ruggiero, A., & Hawkins, B. A. (2008). Why do mountains support so many species of birds? *Ecography*, 31, 306–315. <https://doi.org/10.1111/j.0906-7590.2008.05333.x>
- Rusconi, C. (1932). La presencia de anfibios ("Ecaudata") y de aves fósiles en el piso ensenadense de Buenos Aires. *Anales de la Sociedad Científica Argentina*, 113, 145–149.
- Sabaj, M. H. (2019). *Standard symbolic codes for institutional resource collections in herpetology and ichthyology: an Online Reference. Version 7.1*. Available at: <https://asih.org/standard-symbolic-codes>. Accessed 24 September 2021.
- Sabaj, M. H. (2020). Codes for natural history collections in ichthyology and herpetology. *Copeia*, 108, 593–669. <https://doi.org/10.1643/ASIHCODONS2020>
- Salgado, A. A. R., de Andrade Rezende, E., Bourles, D., Braucher, R., da Silva, J. R., & Garcia, R. A. (2016). Relief evolution of the continental rift of Southeast Brazil revealed by in situ-produced ¹⁰Be concentrations in river-borne sediments. *Journal of South American Earth Sciences*, 67, 89–99. <https://doi.org/10.1016/j.jsames.2016.02.002>
- San Mauro, D. (2010). A multilocus timescale for the origin of extant amphibians. *Molecular Phylogenetics and Evolution*, 56, 554–561. <https://doi.org/10.1016/j.ympev.2010.04.019>
- Sanchiz, B. (1998). *Encyclopedia of paleoherpetology. Part 4. Salientia*. München: Dr. Friedrich Pfeil.
- Sanchiz, B., & Rey, J. M. (2005). Differential anuran bone preservation in a taphocenotic sample of Barn owl pellets. *Munibe Antropologia-Arkeologia*, 57, 505–509.
- Sanchiz, B., & Roček, Z. (1996). An overview of the anuran fossil record. In R. C. Tinsley & H. R. Kobel (Eds.), *The Biology of Xenopus* (pp. 317–328). Oxford: Clarendon Press.
- Santos, M. (1999). *Serra da Mantiqueira e Planalto do Alto Rio Grande: a bacia terciária de Aiuruoca e evolução morfotectônica*. PhD dissertation. Rio Claro, Brazil: Universidade Estadual Paulista Júlio de Mesquita Filho.
- Santos, R. O., Laurin, M., & Zaher, H. (2020). A review of the fossil record of caecilians (Lissamphibia: Gymnophionomorpha) with comments on its use to calibrate molecular timetrees. *Biological Journal of the Linnean Society*, 131, 737–755. <https://doi.org/10.1093/biolinnean/blaa148>
- Savage, D. E. (1951). Report on fossil vertebrates from the Upper Magdalena Valley, Colombia. *Science*, 114, 186–187. <https://doi.org/10.1126/science.114.2955.186>
- Savage, J. M. (1973). The geographical distributions of frogs: patterns and predictions. In J. L. Vial (Ed.), *Evolutionary biology of the anurans. Contemporary research on major problems* (pp. 351–445). Columbia: University of Missouri Press.
- Scanferla, A., & Agnolin, F. L. (2015). Nuevos aportes al conocimiento de la herpetofauna de la formación Cerro Azul (Mioceno Superior), provincia de La Pampa, Argentina. *Papeis avulsos de Zoologia*, 55, 323–333. <https://doi.org/10.1590/0031-1049.2015.55.23>
- Scanferla, A., Agnolin, F., Novas, F., de la Fuente, M., Bellosi, E., Báez, A. M., & Cione, A. (2011). A vertebrate assemblage of Las Curtiembres Formation (Upper Cretaceous) of Northwestern Argentina. *Revista del Museo Argentino de Ciencias Naturales nueva serie*, 13, 195–204. <https://doi.org/10.22179/REVMACN.13.222>
- Schaeffer, B. (1949). Anurans from the early Tertiary of Patagonia. *Bulletin of the American Museum of Natural History*, 93, 41–68.
- Scherer, C. S., Gomes, A. C. F., & Oliveira, T. V. (2012). A fauna de vertebrados de pequeno porte do Pleistoceno/Holoceno da Toca dos Ossos, Bahia, Brasil: dados preliminares. In J. M. Sayão, E. V. Oliveira, K. O. Porpino & P. S. R. Romano (Eds.), *Boletim de Resumos VIII Simpósio Brasileiro de Paleontologia de Vertebrados* (p. 62). Recife: Universidade Federal de Pernambuco.
- Schoch, R. R. (2014). *Amphibian evolution: the life of early land vertebrates*. New Jersey: John Wiley and Sons. <https://doi.org/10.1002/9781118759127>
- Schubert, C. (1975). Evidencia de una glaciación antigua en la Sierra de Perijá, estado Zulia. *Boletín de la Sociedad Venezolana de Espeleología*, 6, 71–75.
- Schwartz, T. M., & Graham, S. A. (2015). Stratigraphic architecture of a tide-influenced shelf-edge delta, Upper Cretaceous Dorotea Formation, Magallanes-Austral basin, Patagonia. *Sedimentology*, 62, 1039–1077. <https://doi.org/10.1111/sed.12176>
- Sedor, F. A., Oliveira, É. V., Silva, D. D., Fernandes, L. A., Cunha, R. F., Ribeiro, A. M., & Dias, E. V. (2014). A new South American

- Paleogene fauna, Guabirotuba Formation (Curitiba, Paraná State, South of Brazil). In *International Palaeontological Congress, 2014. Abstract of the International Palaeontological Congress, Mendoza, Argentina*: IPA, CONICET Mendoza. 4, 614.
- Sedor, F. A., Oliveira, É. V., Silva, D. D., Fernandes, L. A., Cunha, R. F., Ribeiro, A. M., & Dias, E. V. (2017). A new south American paleogene land mammal fauna, Guabirotuba Formation (southern Brazil). *Journal of Mammalian Evolution*, 24(1), 39–55. <https://doi.org/10.1007/s10914-016-9364-7>
- Seersholm, F. V., Hansen, K. L., Heydenrych, M., Hansen, A. J., Bunce, M., & Allentoft, M. E. (2021). Ancient DNA preserved in small bone fragments from the PW Lund collection. *Ecology and evolution*, 11, 2064–2071. <https://doi.org/10.1002/ece3.7162>
- Sempere, T., Butler, R. F., Richards, D. R., Marshall, L. G., Sharp, W., & Swisher Iii, C. C. (1997). Stratigraphy and chronology of Upper Cretaceous–lower Paleogene strata in Bolivia and northwest Argentina. *Geological Society of America Bulletin*, 109, 709–727. [https://doi.org/10.1130/0016-7606\(1997\)109<0709:SACOU>2.3.CO;2](https://doi.org/10.1130/0016-7606(1997)109<0709:SACOU>2.3.CO;2)
- Sepúlveda, E., Papú, O. H., & Volkheimer, W. (1989). Importancia estratigráfica y paleobiogeográfica del género *Granelispora* (Stover and Patridge), en el Cretácico tardío del hemisferio austral. *Boletín Instituto de Geociencias Universidade de São Paulo*, 7, 163–171. <https://doi.org/10.11606/issn.2317-8078.v0i7p163-171>
- Seymour, K. L. (2015). Perusing Talara: Overview of the Late Pleistocene fossils from the tar seeps of Peru. *Natural History Museum of Los Angeles County, Science Series*, 42, 97–109.
- Sigé, B. (1968). Dents de micromammifères et fragments de coquilles d'oeufs de dinosaures dans la faune de vertébrés du Crétacé supérieur de Laguna Umayo (Andes péruviennes). *Comptes rendus de l'Académie des Sciences*, 267, 1495–1498.
- Sigé, B., Sempere, T., Butler, R. F., Marshall, L. G., & Crochet, J. Y. (2004). Age and stratigraphic reassessment of the fossil-bearing Laguna Umayo red mudstone unit, SE Peru, from regional stratigraphy, fossil record, and paleomagnetism. *Geobios*, 37, 771–794. <https://doi.org/10.1016/j.geobios.2003.06.006>
- Silva, F. O. C., Lopes, A. G., & Riff, D. (2018). Novos registros de anura (Lissamphibia) para duas localidades na região do Triângulo Mineiro (Bacia Bauru). In F. P. Muniz (Ed.), *Anais do Evento IX Encontro de Biologia Comparada e III Workshop de Extensão em Biologia Comparada* (p. 26). Ribeirão Preto: FFCLRP-USP.
- Silva, M. L. D., Batezelli, A., & Ladeira, F. S. B. (2017). Micromorphology of Paleosols of the Marília formation and their significance in the paleoenvironmental evolution of the Bauru Basin, upper Cretaceous, southeastern Brazil. *Revista Brasileira de Ciência do Solo*, 41, 1–20. <https://doi.org/10.1590/18069657rbcs20160287>
- Silva, R. P. D., Anelli, L. E., & Prado, G. M. E. M. (2019). A anurofauna da Formação Crato (Cretáceo, Bacia do Araripe, NE Brasil): aspectos tafonômicos e pigmentação. 27° *SIICUSP – Simpósio Internacional de Iniciação Científica e Tecnológica da USP*. São Paulo: USP.
- Skutschas, P. P. (2013). Mesozoic salamanders and albanerpetontids of Middle Asia, Kazakhstan, and Siberia. In J. D. Gardner, & R. L. Nydam (Eds.), *Mesozoic and Cenozoic Lissamphibian and Squamate assemblages of Laurasia. Palaeobiodiversity and Palaeoenvironments*, 93(4), 441–457. <https://doi.org/10.1007/s12549-013-0126-8>
- Smith, S. A., Stephens, P. R., & Wiens, J. J. (2005). Replicate patterns of species richness, historical biogeography, and phylogeny in Holarctic treefrogs. *Evolution*, 59(11), 2433–2450. <https://doi.org/10.1111/j.0014-3820.2005.tb00953.x>
- Solórzano, A., Rincon, A. D., & McDonald, H. G. (2015). A new mammal assemblage from the Late Pleistocene El Breal de Orocuál, northeast of Venezuela. In J. M. Harris (Ed.), *La Brea and beyond: The paleontology of Asphalt-preserved biotas, Science Series 42* (pp. 125–150). Los Angeles: Natural History Museum of Los Angeles County.
- Souza, D. H., Stuart, F. M., Rodés, Á., Pupim, F. N., & Hackspacher, P. C. (2019). Controls on the erosion of the continental margin of southeast Brazil from cosmogenic ¹⁰Be in river sediments. *Geomorphology*, 330, 163–176. <https://doi.org/10.1016/j.geomorph.2019.01.020>
- Souza, D. H., Hackspacher, P. C., Silva, B. V., Siqueira-Ribeiro, M. C., & Hiruma, S. T. (2021). Temporal and spatial denudation trends in the continental margin of southeastern Brazil. *Journal of South American Earth Sciences*, 105, 102931. <https://doi.org/10.1016/j.jsames.2020.102931>
- Sperry, S. W. (1980). *The Flagstaff formation: Depositional environment and paleoecology of clastic deposits near Salina, Utah*. PhD dissertation. Provo, United States of America: Brigham Young University.
- Spinar, Z. V. (1972). *Tertiary frogs from central Europe*. Berlin: Springer Science and Business Media. <https://doi.org/10.1007/978-94-010-2932-2>
- Stipanovic, P., & Bonetti, M. (1970). Posiciones estratigráficas y edades de las principales floras jurásicas argentinas. II Floras doggerianas y málmicas. *Ameghiniana*, 7, 101–118.
- Stipanovic, P., & Reig, O. A. (1955). Breve noticia sobre el hallazgo de anuros en el denominado “Complejo porfirico de la Patagonia extraandina,” con consideraciones acerca de la composición geológica del mismo. *Revista de la Asociación Geológica Argentina*, 10, 215–233.
- Stipanovic, P., & Reig, O. A. (1957). El “Complejo porfirico de la Patagonia extraandina” y su fauna de anuros. *Acta Geológica Lilloana*, 1, 185–298.
- Stirton, R. A. (1953). Vertebrate paleontology and continental stratigraphy in Colombia. *Geological Society of America Bulletin*, 64, 603–622. [https://doi.org/10.1130/0016-7606\(1953\)64\[603:VPACSI\]2.0.CO;2](https://doi.org/10.1130/0016-7606(1953)64[603:VPACSI]2.0.CO;2)
- Stoessel, L., Bogan, S., Martínez, G., & Agnolin, F. L. (2008). Implicaciones paleoambientales de la presencia del género *Ceratophrys* (Anura, Ceratophryinae) en contextos arqueológicos de la transición Pampeano-Patagónica en el Holoceno Tardío (curso inferior del Río Colorado, Argentina). *Magallania (Punta Arenas)*, 36, 195–203. <https://doi.org/10.4067/S0718-22442008000200015>
- Suárez-Montero, M. (1996). Geología del Cuaternario de la cuenca pleistocena de Tarija. In E. Díaz-Martínez (Ed.), *Memorias del XII Congreso Geológico de Bolivia* (pp. 455–463). Cochabamba: Sociedad Geológica Boliviana.
- Suazo-Lara, F. (2019). *Estudio de los anuros fósiles de Chile y sus relaciones paleobiogeográficas*. MSc thesis. Santiago, Chile: Universidad de Chile.
- Suazo-Lara, F., & Gómez, R. O. (2022). In the shadow of dinosaurs: Late Cretaceous frogs are distinct components of a widespread tetrapod assemblage across Argentinean and Chilean Patagonia. *Cretaceous Research*, 131, 105085. <https://doi.org/10.1016/j.cretres.2021.105085>
- Suazo-Lara, F., Fernández-Jiménez, R., Soto-Acuña, S., Manríquez, L., Alarcón-Muñoz, J., Aravena, B., Vargas, A. O., & Leppe, M. (2017). Primer registro de Calyptocephalellidae (Anura, Australobatrachia) en el Cretácico Superior de Chile. In D. Rubilar-Rogers & R. A. Otero (Eds.), *I Primera Reunión de Paleontología de Vertebrados de Chile – Libro de Resúmenes* (p. 17). Santiago: Museo Nacional de Historia Natural.
- Suazo-Lara, F., Alarcon, J., Fernandez-Jimenez, R., & Kaluzan, J. (2018). Nuevos registros de anuros del Valle del Río de las Chinas (Formación Dorotea, Cretácico Superior), región de Magallanes, Chile. In M. A. L. Cartes, A. M. A. Vásquez & R. V. Martínez (Eds.), *Avances en Paleontología Chilena* (pp. 344–346). Punta Arenas: Instituto Antártico Chileno.
- Suazo-Lara, F., Lizama, A., & Muzzopappa, P. (2020). *Presencia de una probable nueva especie fósil de Calyptocephalella* (Anura,

- Neobatrachia* en la Laguna Tagua Tagua (Pleistoceno superior-Holoceno), región de O'Higgins, Chile. Available at: https://www.conicet.gov.ar/new_scp/detalle.php?keywords=&id=43357&congresos=yes&detalles=yes&congr_id=8691501. Accessed September 24, 2021.
- Tanner, K. (1971). Notizen zur Pflege und zum Verhalten einiger Blindwühlen (Amphibia: Gymnophiona). *Salamandra*, 7, 91–100.
- Tappen, M. (1994). Bone weathering in the tropical rainforest. *Journal of Archaeological Science*, 21, 667–673. <https://doi.org/10.1006/jasc.1994.1066>
- Tauber, A. A. (1999). Los vertebrados de la Formación Santa Cruz (Mioceno inferior-medio) en el extremo sureste de la Patagonia y su significado paleoecológico. *Revista española de Paleontología*, 14, 173–182. <https://doi.org/10.7203/sjp.23767>
- Taylor, E. H. (1968). *The Caecilians of the World: a taxonomic review*. Lawrence: University of Kansas Press.
- Tettamanti C., Moyano Paz, D., Varela, A.N., Tineo, D.E., Gómez-Peral, L.E., Poiré, D.G., Cereceda, A. & Odino Barreto, A. L. (2018). Sedimentology and fluvial styles of the Uppermost Cretaceous Continental Deposits of the Austral-Magallanes Basin, Patagonia, Argentina. *Latin American Journal of Sedimentology and Basin Analysis*, 25, 149–168.
- Thomé, M. T. C., Zamudio, K. R., Giovanelli, J. G., Haddad, C. F., Baldissera Jr, F. A., & Alexandrino, J. (2010). Phylogeography of endemic toads and post-Pliocene persistence of the Brazilian Atlantic Forest. *Molecular Phylogenetics and Evolution*, 55, 1018–1031. <https://doi.org/10.1016/j.ympev.2010.02.003>
- Tihen, J. A. (1962). A review of New World fossil bufonids. *American Midland Naturalist*, 1–50. <https://doi.org/10.2307/2422634>
- Tomassini, R. L., & Montalvo, C. I. (2013). Taphonomic modes on fluvial deposits of the Monte Hermoso Formation (early Pliocene), Buenos Aires province, Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 369, 282–294. <https://doi.org/10.1016/j.palaeo.2012.10.035>
- Tomassini, R. L., Agnolin, F., & Oliva, C. (2011). First fossil record of the genus *Lepidobatrachus* Budgett, (1899) (Anura, Ceratophryidae), from the early Pliocene of Argentina. *Journal of Vertebrate Paleontology*, 31, 1005–1009. <https://doi.org/10.1080/02724634.2011.596602>
- Tomassini, R. L., Montalvo, C. I., Deschamps, C. M., & Manera, T. (2013). Biostratigraphy and biochronology of the Monte Hermoso Formation (early Pliocene) at its type locality, Buenos Aires Province, Argentina. *Journal of South American Earth Sciences*, 48, 31–42. <https://doi.org/10.1016/j.jsames.2013.08.002>
- Tonni, E. P. (1990). Mamíferos del Holoceno, en la provincia de Buenos Aires. *Paula-Coutiana*, 4, 43–20.
- Tonni, E. P., & Fidalgo, F. (1978). Consideraciones sobre los cambios climáticos durante el Pleistoceno tardío-Reciente en la provincia de Buenos Aires. Aspectos ecológicos y zoogeográficos relacionados. *Ameghiniana*, 15, 235–253.
- Tonni, E. P., Nabel, P., Cione, A. L., Etchichury, M., Tófaló, R., Yané, G. S., Cristóbal, J. S., Carlini, A., & Vargas, D. (1999a). The ensenada and buenos aires formations (Pleistocene) in a quarry near la plata, Argentina. *Journal of South American Earth Sciences*, 12, 273–291. [https://doi.org/10.1016/S0895-9811\(99\)00021-8](https://doi.org/10.1016/S0895-9811(99)00021-8)
- Tonni, E. P., Cione, A. L., & Figini, A. J. (1999b). Predominance of arid climates indicated by mammals in the pampas of Argentina during the Late Pleistocene and Holocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 147, 257–281. [https://doi.org/10.1016/S0031-0182\(98\)00140-0](https://doi.org/10.1016/S0031-0182(98)00140-0)
- Trueb, L. (1973). Bones, frogs, and evolution. In J. L. Vial (Ed.), *Evolutionary Biology of the Anurans: Contemporary Research on Major Problems* (pp. 65–132). Columbia: University of Missouri Press.
- Trueb, L. (1993). Patterns of cranial diversity among the Lissamphibia. In J. Hanken & B. K. Hall (Eds.), *The skull, Volume 2* (pp. 255–343). Chicago: University of Chicago Press.
- Trueman, C.N., & Martill, D. M. (2002). The long-term survival of bone: the role of bioerosion. *Archaeometry*, 44, 371–382. <https://doi.org/10.1111/1475-4754.t01-1-00070>
- Tschudi, J. J. (1838). *Classification der Batrachier mit Berücksichtigung der fossilen Thiere diese Abtheilung der Reptilien*. Neuchatel: Petitpierre. <https://doi.org/10.5962/bhl.title.4883>
- Turazzini, G. F. (2015). Registro de un nuevo taxón fósil afín a *Lepidobatrachus* (Anura: Ceratophryidae) en la Formación Huayquerías (Mioceno Superior), provincia de Mendoza, Argentina. *Ameghiniana*, 53, 39.
- Turazzini, G. F., Gómez, R. O., & Taglioretti, M. (2014). El inusual hallazgo de una asociación diversa de anuros en Yacimiento Constitución (Pleistoceno Tardío, Mar del Plata) con el primer registro fósil de *Pseudis* Wagler (Hylidae, Anura). *Ameghiniana*, 51, 22.
- Turazzini, G. F., Báez, A. M., Martinelli, A., & Jofré, G. C. (2015). Anuros del Pleistoceno Superior del noreste de la Provincia de Buenos Aires. *Ameghiniana*, 52, 39.
- Turazzini, G. F., Taglioretti, M. L., & Gómez, R. O. (2016). First fossil record of the South American frog genus *Odontophrynus* Reinhardt and Lütken, 1862 (Anura, Neobatrachia). *Journal of Vertebrate Paleontology*, 36, e1228657. <https://doi.org/10.1080/02724634.2017.1228657>
- Turazzini, G. F., Appella-Guiscafre, L. S., Lires, A. I., Garberoglio, F., Canessa Leandro, A., Gómez, R. O., & Rougier, G. W. (2017). Promising future: a new mammal-bearing microvertebrate locality from the Cañadón Asfalto formation (Jurassic; Chubut, Argentina). *Ameghiniana*, 54, 52.
- Ubilla, M., & Martínez, S. (2016). *Geology and Paleontology of the Quaternary of Uruguay*. Montevideo: Springer International Publishing. <https://doi.org/10.1007/978-3-319-29303-5>
- Ubilla, M., Perea, D., Lorenzo, N., Gutierrez, M., & Rinderknecht, A. (2011). Fauna Cuaternaria Continental. In D. Perea (Ed.), *Fósiles de Uruguay* (pp. 283–314). DIRAC - Facultad de Ciencias, Montevideo.
- Uliana, M. A. (1979). *Geología de la región comprendida entre los ríos Colorado y Negro, provincias del Neuquén y Río Negro*. PhD dissertation. La Plata, Argentina: Universidad Nacional de La Plata.
- Uliana, M. A., & Camacho, H. H. (1975). Estratigrafía y paleontología de la Formación Vaca Mahuida (Provincia de Río Negro). In Asociación Geológica Argentina (Ed.), *I Congreso Argentino de Paleontología y Biostratigrafía, Actas* (pp. 357–376). San Miguel de Tucumán: Universidad Nacional de Tucumán.
- Urbani, F., & Galarraga, F. (1991). *Inventario de menes de la Sierra de Perijá*. Caracas: Escuela de Geología, Minas y Geofísica.
- Urrutia, J. J., & Rosset, S. D. (2006). Primer registro de *Ceratophrys* Wied-Neuwied (Anura, Ceratophryidae) en la Formación Arroyo Chasicó (Mioceno Tardío) de la provincia de Buenos Aires, Argentina. *Ameghiniana*, Suplemento Resúmenes, 43, 56R.
- Valero-Garcés, B. L., Jenny, B., Rondanelli, M., Delgado-Huertas, A., Burns, S. J., Veit, H., & Moreno, A. (2005). Palaeohydrology of Laguna de Tagua Tagua (34° 30' S) and moisture fluctuations in Central Chile for the last 46 000 yr. *Journal of Quaternary Science*, 20, 625–641. <https://doi.org/10.1002/jqs.988>
- Van Dijk, D. E. (1995). African fossil Lissamphibia. *Palaeontologica Africana*, 32, 39–43.
- Vanzolini, P. E. (1963). Problemas faunísticos do Cerrado. In M. G. Ferri (Ed.), *Simpósio sobre o Cerrado* (pp. 307–320). Universidade de São Paulo, São Paulo.
- Vasconcelos T. S. (2019). Biogeographic Regionalization of South American Anurans. In T. S. Vasconcelos, F. R. Da Silva, T. G. Dos Santos, V. H. Prado & D. B. Provete (Eds.), *Biogeographic patterns of South American anurans* (pp. 125–135). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-26296-9_6

- Vasconcelos, T. S., da Silva, F. R., dos Santos, T. G., Prado, V. H., & Provete, D. B. (2019). South American Anurans: Species Diversity and Description Trends Through Time and Space. In T. S. Vasconcelos, F. R. Da Silva, T. G. Dos Santos, V. H. Prado & D. B. Provete (Eds.), *Biogeographic Patterns of South American Anurans* (pp. 9–84). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-26296-9_2
- Veevers, J. J. (2004). Gondwanaland from 650–500 Ma assembly through 320 Ma merger in Pangea to 185–100 Ma breakup: supercontinental tectonics via stratigraphy and radiometric dating. *Earth-Science Reviews*, 68, 1–132. <https://doi.org/10.1016/j.earscirev.2004.05.002>
- Vences, M., & Wake, D. B. (2007). Speciation, species boundaries and phylogeography of amphibians. In H. H. Heatwole & M. Tyler (Eds.), *Amphibian Biology, Volume 7, Systematics* (pp. 2613–2669). Chipping Norton: Surrey Beatty and Sons.
- Vergnaud-Grazzini, C. (1968). Amphibiens pléistocènes de Bolivie. *Bulletin de la Société géologique de France*, 7, 688–695. <https://doi.org/10.2113/gssgfbull.S7-X.5.688>
- Verzi, D. H., Deschamps, C. M., & Tonni, E. P. (2004). Biostratigraphic and palaeoclimatic meaning of the Middle Pleistocene South American rodent *Ctenomys kraglievichi* (Caviomorpha, Octodontidae): *Palaeogeography, Palaeoclimatology, Palaeoecology*, 212, 315–329. [https://doi.org/10.1016/S0031-0182\(04\)00328-1](https://doi.org/10.1016/S0031-0182(04)00328-1)
- Verzi, D. H., Montalvo, C. I., & Deschamps, C. M. (2008). Biochronology and Biostratigraphy of the Upper Miocene of central Argentina: evidence from rodents and taphonomy. *Geobios*, 41, 145–155. <https://doi.org/10.1016/j.geobios.2006.09.005>
- Vieira, K. S., Montenegro, P. F. G., Santana, G. G., & Vieira, W. L. D. S. (2018). Effect of climate change on distribution of species of common horned frogs in South America. *PloS one*, 13, e0202813. <https://doi.org/10.1371/journal.pone.0202813>
- Villa, A., Blain, H. A., & Delfino, M. (2018). The Early Pleistocene herpetofauna of Rivoli Veronese (Northern Italy) as evidence for humid and forested glacial phases in the Gelasian of Southern Alps. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 490, 393–403. <https://doi.org/10.1016/j.palaeo.2017.11.016>
- Visconti, G., Melchor, R. N., Montalvo, C. I., Umazano, A. M., & de Elorriaga, E. E. (2010). Análisis litoestratigráfico de la Formación Cerro Azul (Mioceno Superior) en la provincia de La Pampa. *Revista de la Asociación Geológica Argentina*, 67, 257–265.
- Vizcaino, S. F., Pascual, R., Reguero, M. A., & Goin, F. J. (1998). Antarctica as background for mammalian evolution. *Asociación Paleontológica Argentina, Publicación Especial*, 5, 199–209.
- Wake, D. B., & Koo, M. S. (2018). Amphibians. *Current Biology*, 28, 1237–1241. <https://doi.org/10.1016/j.cub.2018.09.028>
- Wake, M. H. (1980). Morphometrics of the skeleton of *Dermophis mexicanus* (Amphibia: Gymnophiona). Part I. The vertebrae, with comparisons to other species. *Journal of Morphology*, 165, 117–130. <https://doi.org/10.1002/jmor.1051650202>
- Wake, T. A., Wake, M. H., & Lesure, R. G. (1999). First Quaternary fossil record of caecilians from a Mexican archaeological site. *Quaternary Research*, 52, 138–140. <https://doi.org/10.1006/qres.1999.2046>
- Wall, R., Alvarenga, H.M.F., Marshall, L.G., & Salinas, P. (1991). Hallazgo del primer ave fósil del Terciario de Chile: Un Ánade (Pelecaniformes: Anhingidae), preservado en un ambiente deltaico-fluvial del Mioceno de Lonquimay, Región de la Araucanía, Chile. In F. J. S. Román (Ed.), *Actas 6 Congreso Geológico Chileno* (pp. 394–397). Santiago: Servicio Nacional de Geología y Minería.
- Wang, Y., & Gao K. (2011). Amphibians. In M. M. Chang (Ed.), *The Jehol fossils: the emergence of feathered dinosaurs, beaked birds and flowering plants* (pp. 77–86). Cambridge: Academic Press. <https://doi.org/10.1016/B978-0-12374173-8.50011-9>
- Wang, Y., Roček, Z., & Dong, L. (2018). A new pelobatoid frog from the lower Eocene of southern China. *Palaeobiodiversity and Palaeoenvironments*, 98(2), 225–242. <https://doi.org/10.1007/s12549-017-0304-1>
- Weems, R. E., & Bachman, J. M. (1997). Cretaceous anuran and dinosaur footprints from the Patuxent Formation of Virginia. *Proceedings of the Biological Society of Washington*, 110, 1–17.
- Wells, K. D. (2010). *The ecology and behavior of amphibians*. Chicago: University of Chicago Press.
- Wiens, J. J. (2012). Why biogeography matters: historical biogeography vs. phylo-geography and community phylogenetics for inferring ecological and evolutionary processes. *Frontiers of Biogeography*, 4, 128–135. <https://doi.org/10.21425/F54313269>
- Wiens, J. J., & Donoghue, M. J. (2004). Historical biogeography, ecology and species richness. *Trends in Ecology and Evolution*, 19, 639–644. <https://doi.org/10.1016/j.tree.2004.09.011>
- Wiens, J. J., Fetzner Jr, J. W., Parkinson, C. L., & Reeder, T. W. (2005). Hylid frog phylogeny and sampling strategies for speciose clades. *Systematic Biology*, 54, 778–807. <https://doi.org/10.1080/10635150500234625>
- Wilf, P. (2012). Rainforest conifers of Eocene Patagonia: attached cones and foliage of the extant Southeast Asian and Australasian genus *Dacrycarpus* (Podocarpaceae). *American Journal of Botany*, 99, 562–584. <https://doi.org/10.3732/ajb.1100367>
- Wilf, P., Cúneo, N. R., Johnson, K. R., Hicks, J. F., Wing, S. L., & Obradovich, J. D. (2003). High plant diversity in Eocene South America: evidence from Patagonia. *Science*, 300, 122–125. <https://doi.org/10.1126/science.1080475>
- Wilf, P., Johnson, K. R., Cuneo, N. R., Smith, M. E., Singer, B. S., & Gandolfo, M. A. (2005). Eocene plant diversity at Laguna del Hunco and Río Pichileufú, Patagonia, Argentina. *The American Naturalist*, 165, 634–650. <https://doi.org/10.1086/430055>
- Wilf, P., Singer, B. S., del Carmen Zamalao, M., Johnson, K. R., & Cúneo, N. R. (2010). Early Eocene 40Ar/39Ar age for the Pampa de Jones plant, frog, and insect biota (Huitrera Formation, Neuquén Province, Patagonia, Argentina). *Ameghiniana*, 47, 207–216. <https://doi.org/10.5710/AMGH.v47i2.7>
- Wilkinson, M., San Mauro, D., Sherratt, E., & Gower, D. J. (2011). A nine-family classification of caecilians (Amphibia: Gymnophiona). *Zootaxa*, 2874, 41–64. <https://doi.org/10.11646/zootaxa.2874.1.3>
- Woodburne, M. O., & Case, J. A. (1996). Dispersal, vicariance, and the Late Cretaceous to early Tertiary land mammal biogeography from South America to Australia. *Journal of Mammalian Evolution*, 3, 121–161. <https://doi.org/10.1007/BF01454359>
- Woodburne, M. O., Goin, F. J., Raigemborn, M. S., Heizler, M., Gelfo, J. N., & Oliveira, E. V. (2014). Revised timing of the South American early Paleogene land mammal ages. *Journal of South American Earth Sciences*, 54, 109–119. <https://doi.org/10.1016/j.jsames.2014.05.003>
- Wuttke, M. (1983). Weichteil-Erhaltung durch lithifizierte Microorganismen bei mittel-eozänen Vertebraten aus den Ölschiefern der Grube Messel bei Darmstadt. *Senckenbergiana lethaea*, 64, 509–527.
- Ximenes, C. L. (2008). Tanques Fossilíferos de Itapipoca, CE: Bebedouros e cemitérios de megafauna pré-histórica. In M. Winge (Ed.), *Sítios Geológicos e Paleontológicos do Brasil* (pp. 465–478). Brasília: CPRM.
- Xing, L., Stanley, E. L., Bai, M., & Blackburn, D. C. (2018). The earliest direct evidence of frogs in wet tropical forests from Cretaceous Burmese amber. *Scientific Reports*, 8, 1–8. <https://doi.org/10.1038/s41598-018-26848-w>
- Xing, L., Wang, D., Li, G., McKellar, R. C., Bai, M., Chen, H., & Evans, S. E. (2019a). Possible egg masses from amphibians, gastropods, and insects in mid-Cretaceous Burmese amber. *Historical Biology*, 31, 1–10. <https://doi.org/10.1080/08912963.2019.1677642>

- Xing, L., Niu, K., & Evans, S. E. (2019b). Inter-amphibian predation in the Early Cretaceous of China. *Scientific Reports*, 9, 1–5. <https://doi.org/10.1038/s41598-019-44247-7>
- Yuan, Z. Y., Zhang, B. L., Raxworthy, C. J., Weisrock, D. W., Hime, P. M., Jin, J. Q., Lemmon, E. M., Lemmon, A. R., Holland, S. D., Kortyna, M. L., Zhou, W. W., Peng, M. S., Che, J., & Prendini, E. (2018). Natatanuran frogs used the Indian Plate to step-stone disperse and radiate across the Indian Ocean. *National Science Review*, 6, 10–14. <https://doi.org/10.1093/nsr/nwy092>
- Zaher, H., Pol, D., Carvalho, A. B., Riccomini, C., Campos, D., & Nava, W. (2006). Redescription of the cranial morphology of *Mariliasuchus amarali*, and its phylogenetic affinities (Crocodyliformes, Notosuchia). *American Museum Novitates*, 3512, 1–40. [https://doi.org/10.1206/0003-0082\(2006\)3512\[1:ROTCMO\]2.0.CO;2](https://doi.org/10.1206/0003-0082(2006)3512[1:ROTCMO]2.0.CO;2)
- Zárate, M. A. (2005). El Cenozoico tardío continental de la Provincia de Buenos Aires. In R. de Barrio R. Etcheverry M. Caballé & E. Llambías (Eds.), *Geología y Recursos Minerales de la Provincia de Buenos Aires (La Plata), Relatorio del XVI Congreso Geológico Argentino* (pp. 139–158). Buenos Aires: Asociación Geológica Argentina.
- Zárate, M. A., & Fasano, J. L. (1989). The Plio-Pleistocene record of the central eastern Pampas, Buenos Aires province, Argentina: The Chapadmalal case study. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 72, 27–52. [https://doi.org/10.1016/0031-0182\(89\)90130-2](https://doi.org/10.1016/0031-0182(89)90130-2)
- Zárate, M. A., Schultz, P. H., Blasi, A., Heil, C., King, J., & Hames, W. (2007). Geology and geochronology of type Chasicuan (late Miocene) mammal-bearing deposits of Buenos Aires (Argentina). *Journal of South American Earth Sciences*, 23, 81–90. <https://doi.org/10.1016/j.jsames.2006.09.018>
- Zavala, C. A. (1993). Estratigrafía de la localidad de Farola Monte Hermoso (Plioceno Reciente). Provincia de Buenos Aires. In A. Lork & H. Bahlburg (Eds.), *Actas XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos* (pp. 228–235). Buenos Aires: Asociación Geológica Argentina.
- Zavala, C.A., & Navarro, E. (1993). Depósitos fluviales en la Formación Monte Hermoso (Plioceno inferior-medio) Provincia de Buenos Aires. In A. Lork & H. Bahlburg (Eds.), *Actas XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos* (pp. 236–244). Buenos Aires: Asociación Geológica Argentina.
- Zimicz, N., Payrola, P., & del Papa, C. (2018). New, Late Miocene mammalian assemblage from the Palo Pintado Formation (Northwestern Argentina). *Journal of South American Earth Sciences*, 81, 31–44. <https://doi.org/10.1016/j.jsames.2017.11.003>

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