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AVIAN REMAINS FROM THE TORO NEGRO FORMATION (NEOGENE), CENTRAL ANDES OF ARGENTINA

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ABSTRACT: We describe new avian remains from the lower levels of the Toro Negro Formation (~7-6 Ma, U-Pb), exposed in Quebrada de la Troya between Vinchina and Jagüé towns in La Rioja Province, Argentina. The Toro Negro Formation is composed of a thick continental sequence (~2.4 km) of sandstones, conglomerates and mudstones

deposited in both fluvial and lacustrine systems at the base of the unit. The avifauna of Toro Negro is low in diversity, and the majority of the remains are fragmentary and isolated. However, it is interesting in that it includes carnivorous birds such as a new species of a large eagle (*Vinchinavis paka* gen. et sp. nov.), scavengers (condors) and large herbivores (rheas). On the whole, the occurrences documented within the Toro Negro Formation confirm the presence of taxa with strong temperate warm preferences that typically inhabits open areas with arboreal patches within an arid-semiarid zone. The palaeoenvironmental characteristics of the fauna are confirmed as fully compatible with the evidence previously obtained through sedimentology and facies analysis.

KEY WORDS: Aves, *Vinchinavis paka* gen. et sp. nov., Miocene, Quebrada de la Troya, Argentina, palaeoenvironment.

South American biotas and ecosystems were affected by major environmental modifiers such as oscillations between glacial and interglacial cycles during the Pleistocene (Lisiecki & Raymo 2007) and the pre-Pleistocene palaeogeographic rearrangements that linked South and North America, Andean orogeny, changes in continental drainage patterns of continental waters and transgressions and regressions. Neotropical avifaunas evolved in these changing scenarios. Much of the knowledge about the South American avifauna and its modifications is based on fossils from sites of latitudes ranging between S33° and S48° during two key periods: the early Miocene (Santacrucian) of Santa Cruz and the Pleistocene (Ensenadan to Lujanian) of the Pampean Region (Tambussi 2011; Tambussi & Degrange 2013). Much less is known about the fauna in Neogene units exposed in the northwest of Argentina that extend over seven million years, from the late Miocene to the Pleistocene (Marshall *et al.* 1984; Reguero *et al.* 2007; Reguero & Candela 2011; Brandoni *et al.* 2012). In particular, Neogene vertebrates from La Rioja Province have remained relatively unexplored compared to others from geographically and coeval nearby units (e.g., Chiquimil, Andalhuala, and Corral Quemado Formations).

The continental Toro Negro and Vinchina formations (Turner 1964), comprise one of the best represented Neogene sequences identified within the Andean foreland. These units, deposited from the Miocene through the early Pliocene (Ciccioli *et al.* 2014; Amidon *et al.* 2016; Collo *et al.* 2017), are located between the Precordillera terrane (to the West) and the Famatina System (to the East), separating the valleys of Vinchina and Jagüel in the northwest of the La Rioja Province (Fig. 1).

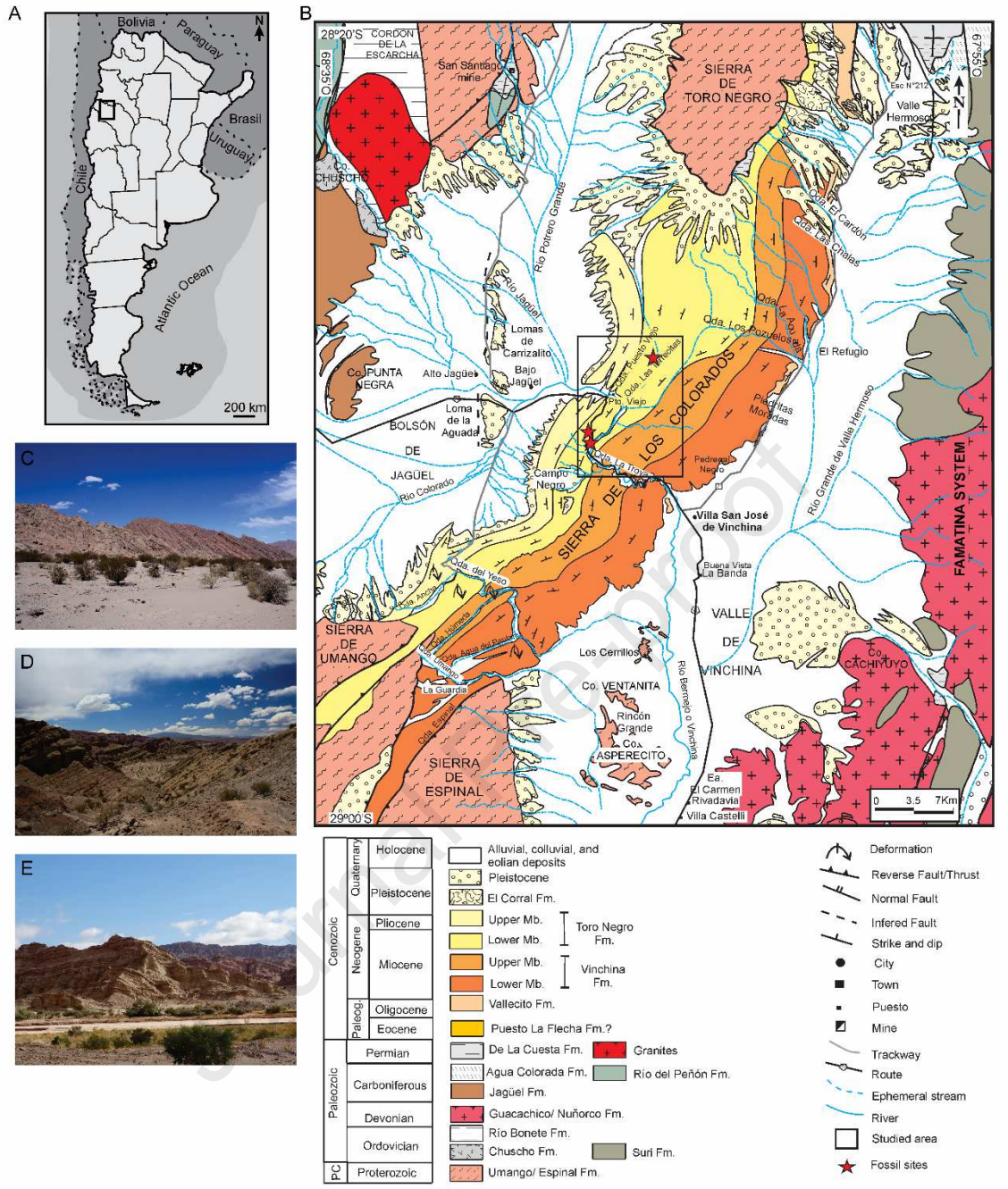

Fig. 1. Geographic and stratigraphic provenance of the avian remains. A, location of the study area; B, geological map of Vinchina Basin showing the location of the studied section; C-E, panoramic views of the fossil localities. (color only in the online version)

In the present work, we describe new avian specimens from the late Miocene of the Toro Negro Formation of La Rioja collected during ongoing field investigations.

Previous record of birds from this locality and age is limited to one Cathartidae (Rodríguez Brizuela 2004) that was provisionally assigned to the Pliocene Pampean *Dryornis*. Most of the avian remains presented here are broken and isolated but the collection is interesting insofar as it includes carnivorous birds, scavengers and large herbivores. Among the bones are those of a new species of eagle. Several mammalian fossils, including a carnivorous metatherian, ungulates and rodents, are currently under study.

Our study has two main objectives: (1) to characterize the avifauna from a taxonomic point of view; and (2) to provide new paleontological evidence to rebuild the environment with greater reliability.

GEOLOGICAL SETTING

The study area is located in the flat-slab segment of Central Andes of Argentina (Fig. 1A). In this sector, several foreland basins were formed during the Cenozoic including the Vinchina Basin (28°S and 29°S). This broken foreland basin was bounded to the west by Precordillera thrust-belt, to the east by the Sierra de Famatina (Famatina System) and to the north and south by Western Sierras Pampeanas basement blocks (Sierras de Toro Negro and Umango-Espinal, respectively, Fig. 1B). The Cenozoic stratigraphy of the Vinchina Basin reveals up to 10,000 meters deposited in continental setting during the Andean Orogeny, and includes at least the Vallecito, Vinchina, Toro Negro and El Corral Formations (Ciccioli *et al*. 2018; Fig. 1B).

The Toro Negro Formation (Turner 1964) was divided into two informal members (Ramos 1970). The lower member is composed mainly of sandstones, mudstones, muddy intra-formational breccias and extra-formational conglomerates with several tuff layers. These rocks were deposited in different types of fluvial systems

including anastomosed and braided rivers and distributive systems, siliciclastic and saline shallow lakes, as well as minor fluvial-eolian interaction systems (Ciccioli & Marenssi 2012; Ciccioli *et al.* 2018). Mostly, sedimentation occurred under semiarid to arid climatic conditions indicated by abundant desiccation cracks and intercalations of eolian-fluvial interaction deposits. The upper member presents a low-relief basal unconformity and it is mainly composed of cobble conglomerate and coarse-grained sandstones deposited in braided rivers and streamflow-dominated piedmonts with some intercalations of fine-grained sediments corresponding to a tuffaceous playa-lake.

Sedimentology of the lower member of the Toro Negro Formation

A detail section of the lower part of the lower member of the Toro Negro Formation was studied at the Quebrada de La Troya, in the central part of the Sierra de Los Colorados, La Rioja, Argentina. This unit is particularly interesting due to the presence of vertebrate fossils, especially birds which are here analyzed (Fig. 2). Besides, invertebrate and vertebrate trace fossils are also frequent and were previously studied by Krapovickas et al. (2009).

Five facies associations were recognized using lithofacies, bounding surfaces, and architectural elements (Ciccioli *et al*. 2018 modified from Miall 1996). Facies association I of amalgamated and deeply incised multiple river channels are characterized by sandy channels immersed into muddy fine-grained floodplain sediments. The abandoned floodplains were exposed for a long time, allowing the development of immature paleosols (nodular and patchy-colored deposits) and the preservation of vertebrate tracks (omission surfaces) as those described by Krapovickas *et al.* (2009).

Facies association II (120 m thick) is interpreted as forming in an ephemeral anastomosing fluvial system (Gibling *et al.* 1998; Makaske 2001) where incised sandy channels were associated with floodplain deposits dominated by sandy crevasse splays (Ciccioli & Marenssi 2012). Invertebrate trace fossils represented by *Scoyenia gracilis, Taenidium barretti*, and *Palaeophycus tubularis (*Krapovickas *et al.* 2009) are very common. The presence of abundant desiccation cracks preserved in floodplain deposits at the base of channels indicates an arid environment.

Facies association III is interpreted as deposited in braided alluvial plains dominated by low-sinuosity channels showing broad muddy interchannel areas. Ribbon geometry of individual beds suggests fixed channels (Miall 2013) which would have been rapidly abandoned probably by aggradational processes (avulsion).

Facies association IV (252 m thick) shows relatively very wide interchannel areas. The environment corresponds to a distal zone of a distributive fluvial system dominated by sheetflows (Ciccioli *et al.* 2018; Santi Malnis *et al*. 2018). Abundant tuff clasts indicate contemporaneous volcanism. These deposits could represent rapid aggradational periods originated when streams were drowned by huge volcaniclastic supply (Vessell & Davies 1981; Smith 1987, 1991).

Facies association V (242 m thick) overlies transitionally Facies Association IV. The predominance of mudstones and fine-grained sandstones, the alternation of low- and high-energy structures and the scarceness of channel deposits allow interpreting this facies association as deposited in a playa lake system.

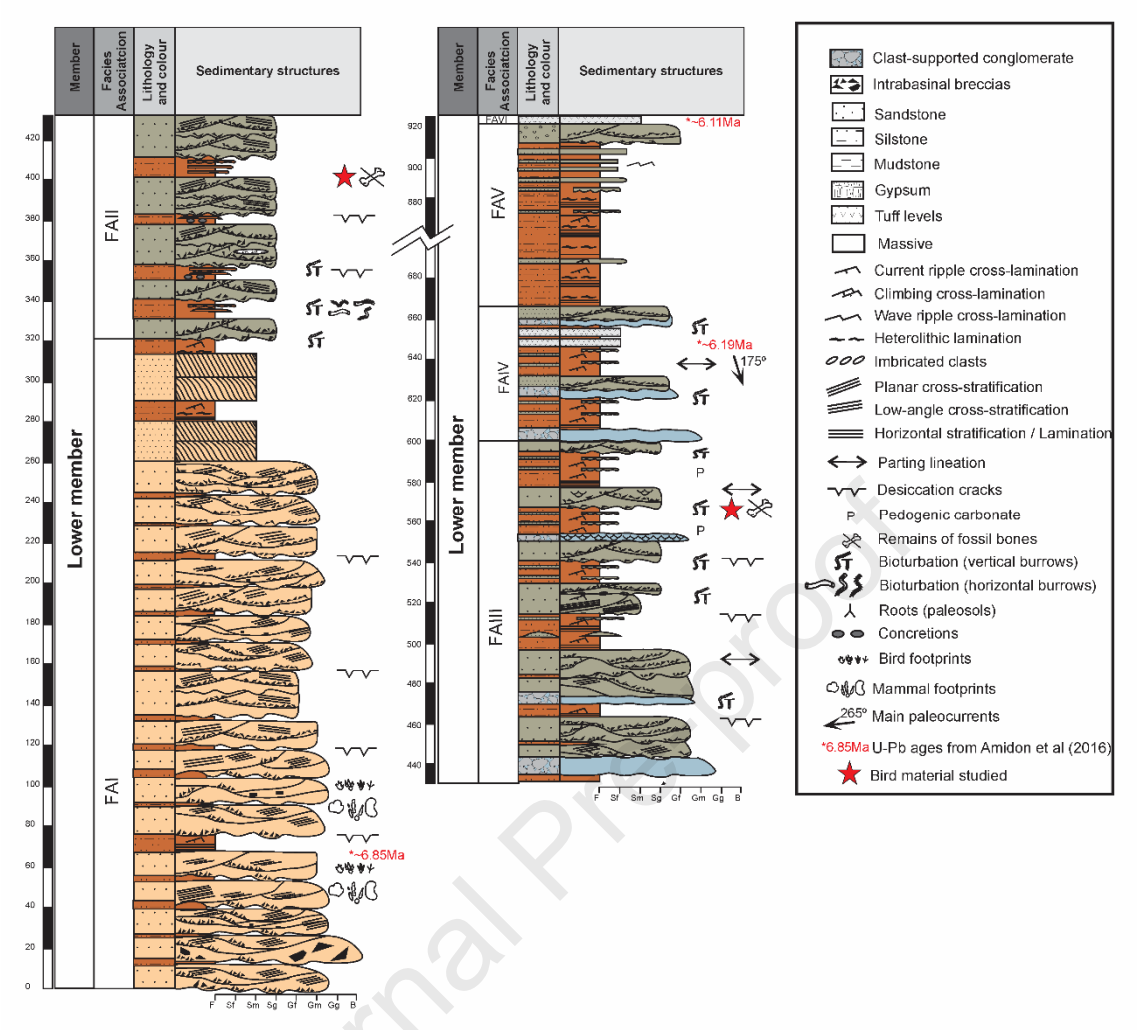

Fig. 2. Detailed stratigraphic section of the lower part of the lower member of the Toro Negro Formation in the Quebrada de La Troya area, modified from Ciccioli *et al.* (2018). U-Pb ages from Amidon *et al.* (2016). (color only in the online version)

Geochronology

Traditionally, the age of the Toro Negro Formation was considered Pliocene-Pleistocene based on stratigraphic relationships (Turner 1964; Ramos 1970). Reynolds (1987) and Tabbutt *et al.* (1989) presented a Pliocene age (4.3 ± 1.0 Ma) derived from a zircon fission-track for the lower part of the unit at the Quebrada de La Troya. Later, Ciccioli *et al.* (2005) reported two K40/Ar40 dating (8.6 ± 0.3 Ma and 6.8 ± 0.2 Ma) from the middle part of the Toro Negro Formation (near the top of the lower member).

These ages established a late Miocene age for the lower member and in turn these authors suggested an early Pliocene age for the upper member of the formation.

Recently, Amidon *et al.* (2016) presented eight U-Pb zircon ages from volcanic tephra at the Quebrada de La Troya section. These new dates refine the age of the Toro Negro Formation to ~6.87 to 2.37 Ma (late Miocene–earliest Pleistocene). Six of these tephra ages range from ~6.87 to 4.95 Ma (late Miocene–early Pliocene) and are from the lower member of the Toro Negro Formation. In addition, two new U-Pb zircons ages (6.64 ± 0.1 Ma and 5.40 ± 0.12 Ma) were reported by Ciccioli *et al.* (2018) from the Quebrada del Yeso section in the south of the Sierra de Los Colorados. These new ages were correlated with two tephra along the Quebrada de La Troya corroborating the late Miocene age for the lower member of the Toro Negro Formation.

MATERIALS AND METHODS

Fossil were collected during successive campaigns following the corresponding guidelines according to the law of Protection of Archaeological and Paleontological Heritage of Argentina (law 25,743), and requesting the pertinent permits from the provincial authorities of La Rioja Province.

Fossil materials were conditioned in the field for transport. They were subsequently cleaned by the technical staff of the CICTERRA. Fragments of bone identification may be possible by direct comparisons with avian skeletal material housed at the Argentinian Colección Osteológica de Aves of the Centro de Investigaciones en Ciencias de la Tierra and Colección Osteológica de Aves actuales of the Museo de La Plata.

Except when otherwise noted, terminology used for describing the avian remains and anatomical orientations follows Baumel & Witmer (1993).

Measurements are in millimeters and were rounded to the nearest 0.1mm.

Institutional Abbreviations. CICTERRA, Centro de Investigaciones en Ciencias de la Tierra, Córdoba, Argentina, CRILAR, Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja, La Rioja, Argentina; MPEF, Museo Paleontológico Egidio Feruglio, Trelew, Argentina; MLP, Museo de La Plata, La Plata, Argentina; PULR-V, Paleontología, Museo de Ciencias Antropológicas y Naturales de la Universidad de La Rioja, La Rioja, Argentina.

SYSTEMATIC PALAEONTOLOGY

All fossil materials described here come from Facies II and III (Ciccioli *et al.* 2018) in the lower levels of Toro Negro Formation (~7–6 Ma, U-Pb ages, Amidon *et al.* 2016) exposed at Quebrada de la Troya between the Vinchina and Jagüé localities in La Rioja Province.

Order RHEIFORMES (Forbes, 1884)

Family RHEIDAE Bonaparte, 1849

Genus *OPISTHODACTYLUS* Ameghino, 1891

Opisthodactylus cf. *kirchneri* Noriega *et al.*, 2017

Figure 3A-E

Material. MLP 68-III-14-2, distal end of right tibiotarsus.

Measurements. Tibiotarsus distal width: 40.6; condylus lateralis depth: 38.7; condylus medialis depth: 37.8.

Description and comparisons. Dimensions are intermediate between those of *Opisthodactylus kirchneri* Noriega *et al.* and those of *Pterocnemia* and *Rhea* (excluding *Hinasuri nehuensis* Tambussi of which the tibiotarsus is not known). In cranial view, the sulcus extensorius is markedly excavated and very well delimited, similar to the condition observed in *Opisthodactylus patagonicus* Ameghino, *O. kirchneri*, *Pterocnemia pennata*, and *P. mesopotamica* Agnolín & Noriega, and different from that of *Rhea americana*. Its distal portion is extended distally in such a way that it resulted in the separation of the attachment of the internal ligament and the ligamentum transversum (Fig. 3E) as observed in *R. americana* (Tambussi & Tonni 1985; Noriega *et al.* 2017), contrasting with *O. patagonicus*, *O. kirchneri*, *P. pennata*, and *P. mesopotamica* where both attachments are connected. The combination of these characteristics (i.e., deep sulcus extensorius and the discontinuity between the attachments), would be unique to the Toro Negro specimen within known rheiforms. According to Noriega *et al.* (2017) in their description of *O. kirchneri*, this zone is broken in the holotype although they assume the presence of continuity. The trochlea cartilaginis tibialis narrows cranially and distally and the medial margin curves medially. In caudal aspect, the trochlea cartilaginis tibialis is not delimited proximally by a well-marked horizontal ridge as seen in *R. americana*. The medial ligamentary ridge is sharp, similar to that of *O. patagonicus* and *O. kirchneri*, and continues distally until reaching the internal ligamental prominence on the medial side of condylus medialis. In lateral aspect, the surface of the diaphysis is badly crushed, the tuberculum retinaculi m. fibularis is not preserved, and the area of the sulcus m. fibularis is broken. The depressio epicondylaris lateralis is deep (but less than *R. americana*), and the edge of the condylus lateralis is subcircular without a marked posterior notch (unlike *R. americana*). The epicondylus medialis in medial aspect is less prominent, and the

depressio condylaris medialis is less excavated than in *Rhea*, similar to *Pterocnemia* sp. and *P. pennata* (see Agnolín & Noriega 2012; Tambussi & Tonni 1985). The condylar ridges are less thick than in *Rhea*. In caudal view, the intercondylar space is wide.

Remarks. In his classic work on the stratigraphy of the Sierra de los Colorados in La Rioja, Ramos (1970) mentioned the presence of bird remains exhumed in a small ravine that flows into the right bank of the Torrecillas stream, corresponding to sediments of Facies II of the Toro Negro Formation (Ciccioli *et al.* 2018). The material referred by Ramos (1970) is that described here. Rheas are large, flightless and cursorial birds. An abundant fossil record shows that the entire evolutionary history of rheas is restricted to South America and began in the Paleocene. Two living species and eight extinct species are known. Among the latter, the relationship of *Diogenornis fragilis* Alvarenga from the middle Paleocene of Brazil with Rheidae has been questioned (Alvarenga 2010). The species *Opisthodactylus horacioperezi* Agnolín & Chafrat, was based on a very fragmentary tibiotarsus and distal end of a tarsometatarsus lacking the trochleae with very few diagnostic characters. Based on this, retaining it as a valid species should be taken with caution until better materials are found. *Opisthodactylus kirchneri* of the late Miocene and *Pterocnemia mesopotamica* of the middle?–late Miocene have been recorded both outside the Pampas or Patagonia regions. In particular, the first was diagnosed based on elements of both hind limbs recovered in sediments correlated with those of Andalhuala Formation. The estimated age of this unit ranges from the late Miocene (lower levels) to early Pliocene (upper levels) and these are exposed in the Valley of Santa María at Catamarca and Tucumán Provinces. According to Picasso & Barbeitos (2018), the large intraspecific size variation in rheids prohibits the assignment of a species using only the size. One of the main characters that allows the assignment

to the *Pterocnemia-Opisthodactylus* group is the continuity of the scars of the ligament attachments between the internal ligament and the ligamentum transversum. As mentioned above, this condition is not the observed in the material from La Rioja. Even so, we decided to assume here that the differences in size contributed to morphological differences (morphodiversity in the sense of Dayrat 2005) would not be sufficient for the erection of a new species, but we are also to assign the material to *O. kirchneri* with confidence.

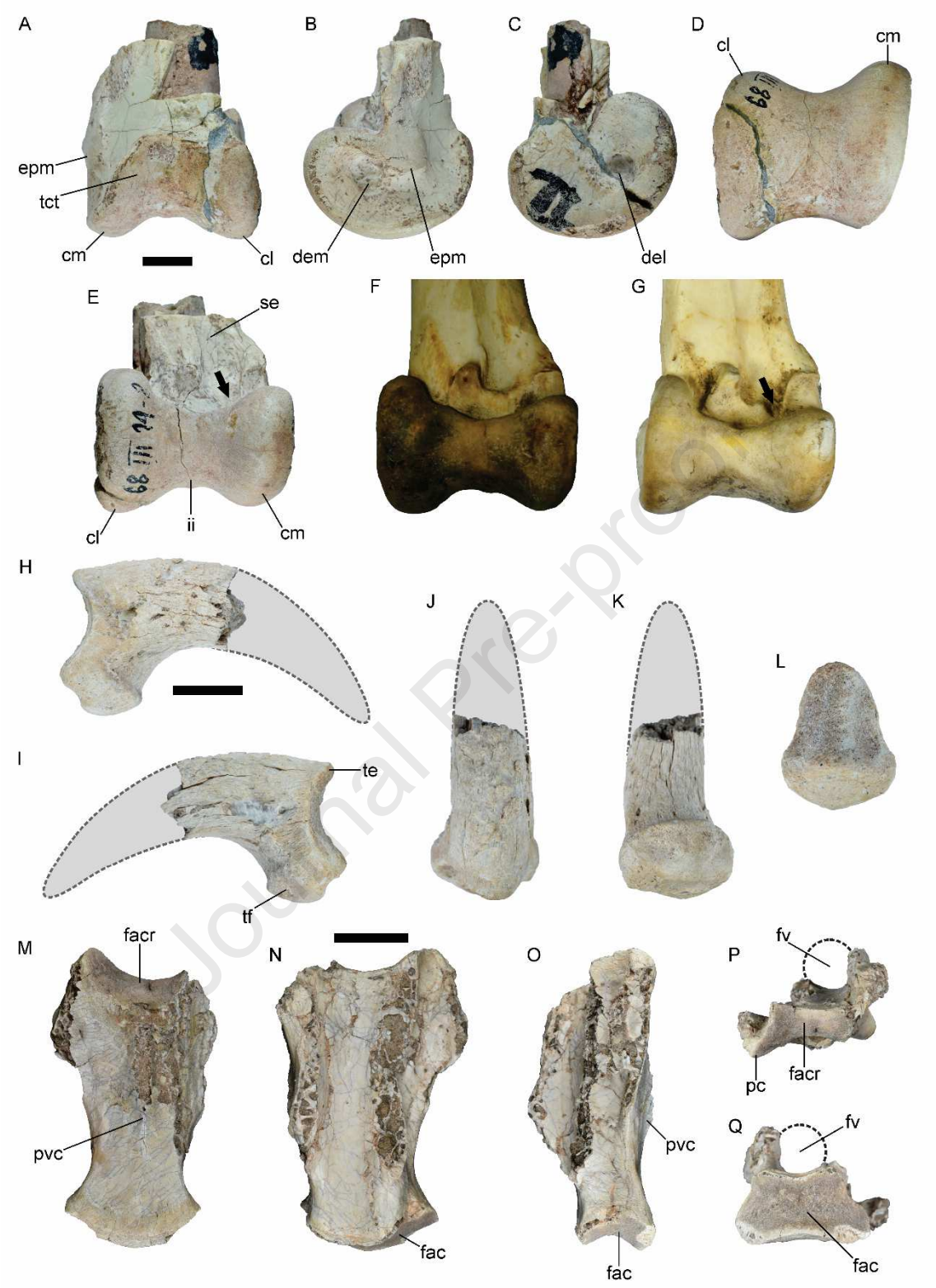

Fig. 3. A-E, *Opisthodactylus* cf. *kirchneri*, MLP 68-III-14-2, distal end of right tibiotarsus in caudal (A), medial (B), lateral (C), distal (D) and cranial (E) views. F-G, extant Rheidae for comparisons. F, detail of the distal portion of the tibiotarsus of

Pterocnemia pennata in cranial view. G, detail of the distal portion of the tibiotarsus of *Rhea americana* in cranial view. The black arrow indicates the division between the attachment of the internal ligament and the ligamentum transversum. H-L, Cathartiformes, ungual phalanx, PV-TN 9-2017 of Cathartidae in right (H) and left (I) lateral, dorsal (J), ventral (K) and proximal (L) views. Dashed line represents a probable reconstruction of the ungual's original shape in full. M-Q, Aves *incerti ordinis*, cervical vertebra, PULR-V 131 of cathartiforms (?) in ventral (M), dorsal (N), right lateral (O), cranial (P) and caudal (Q) views. Abbreviations: cl, condylus lateralis; cm, condylus medialis; del, depressio epicondylaris lateralis; dem, depressio epicondylaris medialis; epm, epicondylus medialis; fac, facies articularis caudalis; facr, facies articularis cranialis; fv, foramen vertebrale; ii, incisura intercondylaris; pc, processus caroticus; pvc, processus ventralis corporis; se, sulcus extensorius; tct, trochlea cartilaginis tibialis; te, tuberculum extensorium; tf, tuberculum flexorium. All scale bars equals 1 cm except B and C that are not at scale for comparisons. (color only in the online version)

Order CATHARTIFORMES Coues, 1894

Family CATHARTIDAE Lafresnaye, 1839

Figure 3H-L

Material and provenience. CRILAR Pv-TN 9-2017, left ungual phalanx, Toro Negro Formation, Facies III, near Vinchina town, La Rioja Province, Argentina, 28° 41′ 32.9″ S, 68° 18′ 22.8″ W.

Description and comparisons. The presence of a stout, wide and caudally directed tuberculum flexorium, together with the absence of lateral grooves indicate that

CRILAR Pv-TN 9-2017 can be referred to Cathartiformes. We based our assessment of the general morphology and digit identity on Mosto & Tambussi (2014) and comparisons with bones of the Andean condor *Vultur gryphus* and accipitrids. As it is pointed out by Mosto & Tambussi (2014), accipitrids (and falconids) shows two well-marked edges that delimit the ventral surface of the phalanx. In the ungual of Toro Negro these ridges do not exist. In accipitrids, the ungual phalanx of digit 4 is generally characterized by symmetry whereas that of digit 3 presents a medial edge, absent in the phalanx of Toro Negro.

In the material CRILAR Pv-TN 9-2017, the articular facet is moderately symmetrical; the lateral and medial cotylae have a similar distal extension. The medial cotyla is deeper than the lateral one; its medial margin is concave dorsally. The tuberculum extensorium is inconspicuous. The tuberculum flexorium is massive, distally oriented; a well-marked groove of dorsal position and ventral to the middle prominence, furrows the tuberculum flexorium lateromedially. A dorsoventral ridge separates the lateral and medial sides of the tubercle, both sides being slightly excavated. The middle prominence is laterally displaced as occurs in the talons of most Accipitridae. No ventral foramina are visible. A short proximodistal furrow is exposed on the lateral surface of the talon. In its most distal portion, a conspicuous foramen is located.

Remarks. The size of the phalanx is conspicuously greater than that of the Andean condor *Vultur gryphus*. Remains of condors recovered in the same locality were previously described (Rodríguez Brizuela 2004). The material is a fragmentary right humerus (CRILAR-PZ 250) that was assigned with doubts to *Dryornis*. *Dryornis pampeanus* (the only known species of the genus) is an extinct condor originally recognized from the Pliocene of the Pampean Region (Moreno and Mercerat 1891;

Degrange *et al*. 2018) and is of considerable size. Regrettably, we do not have any tool to assign the phalanx to this extinct species.

Aves *INCERTI ORDINIS*

Figure 3M-Q

Material and provenience. PULR-V 131, portion of the corpus of a cervical vertebra, Facies III, 28° 41´ 23″ S, 68° 18´ 09″ W.

Remarks. The morphology roughly resembles that of Cathartiformes, but the material is heavily eroded, limiting precise identification.

Order ACCIPITRIFORMES Voous, 1973

Family ACCIPITRIDAE Vieillot, 1816

Genus *VINCHINAVIS* nov.

Figure 4

Derivation of name. Relative to Vinchina valley, where the Toro Negro Formation is exposed; Avis is Latin for bird.

Type and only known species. *Vinchinavis paka* sp. nov.

Diagnosis. As for the type and only species.

Vinchinavis paka sp. nov.

Derivation of name. The species name is after “paka”, meaning eagle in quechua, reflecting its proposed affinities to the eagles. Quechua was the language of the Capayanos who were part of the largest settlement in the Vinchina area. Towards the end of the 18h century, the government forced the use of Spanish and Quechua fell into disuse. Taken from Quechua Dictionary available at https://www.inkatour.com/dico

Holotype. PULR-V 130, left ulna and radius lacking the proximal ends.

Locality and Horizon. Toro Negro Formation, Facies III, 150 m from the road, on the left side of the route from Vinchina to Jagüé, 28° 42´ 03″ S, 68° 18´19″ W.

Measurements. Ulna, maximum width of shaft: 11; minimum depth of shaft: 9.2; distal width, 16.9. Radius, maximum width of shaft: 6.8; minimum depth of shaft; 4.5; distal width: 11; distal depth: 6.3.

Diagnosis. A large raptor with the following combination of features: condylus dorsalis ulnae flattened, condylus ventralis ulnae and condylus dorsalis ulnae equally projected distally, absence of foramen at the distal end of the ulna, radius with facies articularis ulnaris flanked by a well-marked ridge extended proximally, long and deep sulcus tendinosus limited by marked ridges, presence of a second and shorter groove running between the sulcus tendinosus and the margin of the shaft, shallow depressio ligamentosa, presence of a well-marked tubercle proximally to the depressio ligamentosa (corresponding to a scar of the lig. interosseum radiocarpale distale).

Description and comparison. The new taxon shares with the Accipitridae the presence of a proximally elongated condylus dorsalis ulnae, a shallow depressio ligamentosa and a continuous ventral tuberculum aponeurosis with the facies articularis radiocarpalis. The holotype, PULR-V 130 (Fig. 4), shows significant morphological variations with other large eagles. The absence of a pneumatic foramina in the depressio ligamentosa of the radius indicates that PULR-V 130 is not assignable to Cathartidae.

The preserved ulnar shaft of the new taxon is robust, straight (curved in *Accipiter*), and has an elliptical cross-section that bends slightly ventrally. There is no evidence of a foramen in the incisura tuberculi carpalis. The tuberculum carpale is not preserved. The condylus ventralis ulnae is rounded and projects distally to the same level as the condylus dorsalis ulnae (more extended distally in *Aquila*, *Haliaeetus* and *Circus*). This condition is shared with *Geranoaetus melanoleucus*, but not with *Buteogallus coronatus* and *Elanus leucurus* in which it is flattened and broad. The condylus dorsalis ulnae is robust, strongly extended ventrally and also extended only slightly proximally. Its external ridge is marked and rounded. These features discourage the assignation to *Geranoaetus*, *Halieetus* and *Spizaetus*, in which the condylus dorsalis ulnae has a larger proximal extension (especially in the later), and also to *Buteogallus* which has a poorly developed ventrally condylus, and to *Accipiter* which has a pointed external ridge of the condylus. On the dorsolateral surface of the condylus, there is a shallow rounded pit. This scar is elongated and very well marked in other large eagles such as *Geranoaetus* and *Buteogallus*. The depressio radialis is deep as in *B. coronatus* (shallow in *G. melanoleucus*). Five ventral papillae remigales are visible and separated from each other by about 15 mm. Only two dorsal papillae remigales can be identified.

The number of caudal and ventral papillae remigales seems to indicate that there were few secondary remiges.

The shaft of the radius of *V. paka* has an elliptical cross-section (more flattened in *B. coronatus*); the preserved section is slightly curved laterally and dorsally. In ventral view, the depressio ligamentosa is shallow. The facies articularis ulnaris extends from the ventro-lateral surface around the medial margin, where it is flanked by a well-marked ridge (more marked than *B. coronatus* and *G. melanoleucus*) that continues proximally and dorsally. In dorsal view, the sulcus tendinosus is very well-marked, wide and deep (deeper in *Accipiter*), extending about 3 cm towards the proximal area through a single groove limited by marked ridges, especially the lateral one. Distally, it widens and forms an excavated fossa. Another small parallel groove (shorter than the sulcus tendinosus) is delimited between this lateral prominent ridge and the lateral margin of the shaft. This character seems to be exclusive to *Vinchinavis paka*. In both *B. coronatus* and *G. melanoleucus*, the area corresponding to this groove is smooth. Although somewhat eroded, it can be inferred that the tuberculum aponeurosis ventralis, thinner than that of *Spizaetus*, is continuous with the facies articularis radiocarpalis, and endowed with a very well-marked scar dorsally. The facies articularis radiocarpalis is rounded and thick (thinner in *Buteo*), with a smooth surface, not exhibiting sharp limits with the diaphysis towards the ventral side as in *Buteogallus*. Intermuscular lines are not visible.

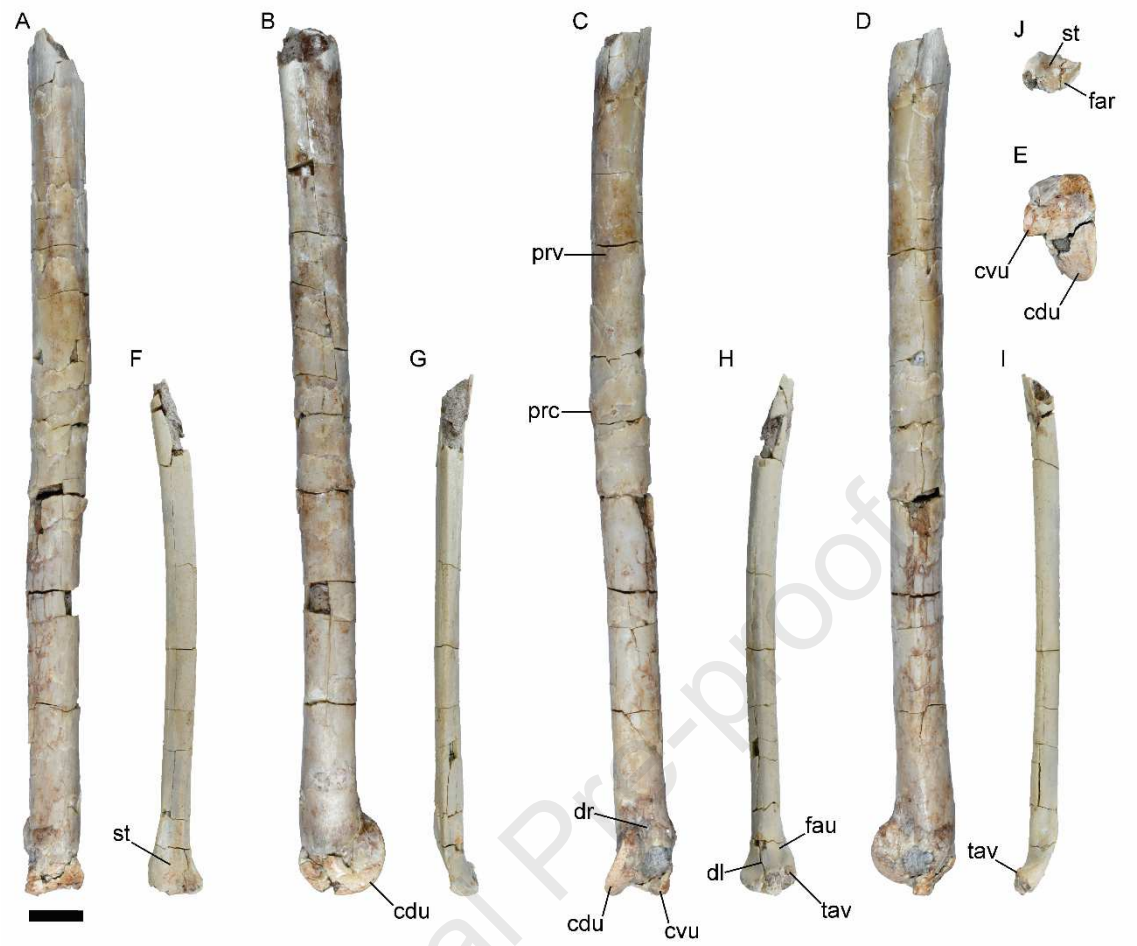

Fig. 4. *Vinchinavis paka* nov. gen. et sp., PULR-V 13-1998, holotype, left ulna (A-E) and radius (F-J) in dorsal (A, F), lateral (B, G), ventral (C, H), medial (D, I), and distal (E, J) views. Abbreviations: cdu, condylus dorsalis ulnaris; cvu, condylus ventralis ulnaris; dl, depression ligamentosa; dr, depression radialis; far, facies articularis radiocarpalis; fau, facies articularis ulnaris; prc, papillae remigales caudales; prv, papillae remigales ventrales; st, sulcus tendinosus; tav, tuberculum aponeurosis ventralis. Scale bar equals 1 cm. (color only in the online version)

Remarks. The fossils assigned to Accipitridae in Argentina are few. The first and single record of a skull element of this family was recovered from the late Miocene of Península Valdés, Chubut Province (Picasso *et al*. 2009). Ungual phalanges assigned to Buteoninae were reported for the late Miocene of the Arroyo Chasicó Formation (Mosto

et al. 2007). Many of the remains previously assigned to Accipitridae are of dubious allocation or must be reconsidered. For example, *Cruschedula revola* and *Climacarthrus incompletus* described for the Deseadan of Patagonia, are *incerti ordinis* and *nomen dubium* respectively (Tambussi & Degrange 2013). Some ungual phalanges were erroneously assigned to Accipitridae by Agnolín (2006): a phalanx (MPEF-PV 1050) of the Eocene of the Gran Hondonada that presents strongly marked lateral grooves; the same occurs in a Miocene phalanx from the Río Negro Province (MLP 74-II-1-21). Phalanx MPEF-PV 1387 considered as an Accipitride indet. by Agnolín (2006), corresponds to the Falconidae *Thegornis*, recovered from Anfiteatro del Guanaco locality (Santacrucian) in the province of Santa Cruz, in the surroundings of Lake Belgrano (not Chubut as Agnolín 2006 indicates). In this way, *Vinchinavis paka* begins to complete an important hiatus on the history of the group.

PALAEOENVIRONMENTAL INTERPRETATION AND FINAL COMMENTS

The Toro Negro Formation contains a varied fauna of fossil vertebrates, consisting mainly of mammals such as glyptodontids, dasypodids, abrocomid rodents and birds (Arcucci *et al.* 1999; De Iullis *et al.* 2004; Rodríguez Brizuela 2004; Rodríguez Brizuela & Tauber 2006). Ichnofossils also suggest the presence of macraucheniid litopterns, shorebirds, perching birds and large cursorial birds, some which may correspond to some of the body fossils that have been recovered (Krapovickas *et al.* 2009).

Fossil birds studied herein were exhumed only from Facies association II and III (Ciccioli *et al.* 2018) of the lower levels of the lower member of the Toro Negro Formation (~7–6 Ma, U-Pb), exposed in Quebrada de la Troya between Vinchina and

Jagüé towns in La Rioja Province. They include rheids, condors and a new taxon of a large eagle, *Vinchinavis paka*.

Fossil remains of rheids are not rare in Argentinian fossil sites. These medium to large cursorial birds are excellent indicators of open environments. Given the inferred environmental conditions for Toro Negro Formation, it is not striking that they are recorded here. In general lines, the different species have wide ranges of geographical distribution so, if the assignment to *Opistodactylus kirchneri* is confirmed, the distribution would be consistent for a Rheidae.

The presence of eagles indirectly allows us to suppose that the area was also occupied by multiple possible small-medium-sized prey. So far, such components of the ecosystem have not been recorded. Scavenging is a well-documented tactic for food acquisition in diverse terrestrial animals (Varland *et al.* 2018). The quintessential example of scavengers are condors and vultures. They are true obligate scavengers, so they are dependent carrion. Carrion may refer to many animal carcasses, but one can afford to imagine scenarios with high frequency of vertebrates of small to large size. The Toro Negro fossil avifauna (Fig. 5) reveals an assemblage with a substantial open and arid-semiarid component. In general, the fauna recovered suggests temperate to warm conditions, with open areas of grasslands and more or less closed arboreal formations.

The biochronology of the mammal fossil assemblage recovered in the Toro Negro Formation is poorly studied, but the dates of the bearing levels temporarily correspond to the Huayquerian faunal stage (Cione & Tonni 2005), one of whose most classic exposures are those of the Cerro Azul Formation. The birds described for the latter include representatives of Rheidae, Tinamidae, Falconidae, Tyraniidae and the extinct Phorusrhacidae and Teratornithidae (Cenizo *et al.*, 2012). The Toro Negro and

Cerro Azul bird assemblages only share the first of these taxa, reliable indicators of the existence of open environments. As far as we know so far, both environments were possibly contemporaneous but environmentally dissimilar. In this sense, we emphasize the usefulness of fossil birds as sensitive environmental indicators, and their potential contribution to palaeoenvironmental reconstruction.

Fig. 5. Life restoration of the birds from Toro Negro Formation. Original artwork by H. Santiago Druetta. (color only in the online version)

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Highlights

Avian remains from the late Miocene of Northwestern Argentina are described extensively.

A new genus and species of a large eagle is proposed.

Herbivorous rheids, scavengers condors and zoophagous eagles are represented in the Toro Negro Formation at La Rioja Province.

Palaeoenvironmental considerations from the Toro Negro Formation are made

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: