

NOTA PALEONTOLÓGICA

# Bird tracks preserved in fluvial channel facies of the Río Negro Formation (Neogene), La Pampa Province, Argentina



Ricardo Néstor MELCHOR<sup>1</sup>

## Introduction

The vertebrate ichnofauna of the Neogene Río Negro Formation is composed of abundant mammal footprints and rare bird footprints. This ichnofauna has been extensively recorded from sea cliff exposures located south of the mouth, and also on the margin of the Negro river downstream of Carmen de Patagones city (figure 1). One of the remarkable aspects of this ichnofauna is the presence of trackways of large mammals, including those named as *Megatherichnium oportoi* Casamiquela, 1974, which provides evidence for bipedal locomotion in Megatherioidea (Casamiquela, 1974, Leonardi, 1994; Casinos, 1996). The tracks of other large mammals display a lower quality of preservation and have been recognized as *Macrauchenichnus rector* Casamiquela in Angulo and Casamiquela, 1982 and cf. *Mylodontidichnum* Aramayo and Manera de Bianco, 1987 (Angulo and Casamiquela, 1982; Aramayo, 1999; Aramayo *et al.*, 2004). The materials used to erect other ichnotaxa of possible large mammals are poorly preserved tracks or undertracks and the status of those ichnotaxa is uncertain. This is the case of *Falsatorichnium calceocannabius* and *Caballichnus impersonalis*, which were tentatively assigned to Megatherioidea and Equidae by Casamiquela (in Angulo and Casamiquela, 1982). The remaining mammal trace fossils are *Porcellusignum conculcator* Casamiquela, in Angulo and Casamiquela, 1982 (purported Hydrochoeridae tracks); large meniscated burrows (compared by Casamiquela with Octodontidae burrows), and a digitigrade trackway assigned to a carnivorous marsupial (Angulo and Casamiquela, 1982; Leonardi, 1994; Aramayo *et al.*, 2004). The record of bird tracks are restricted to one undertrack assigned

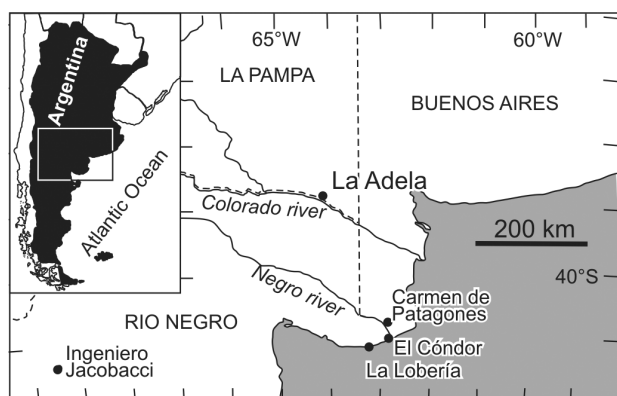
to a phororhacid from the vicinity of El Cóndor town (Aramayo *et al.*, 2004) and undetermined tracks of small birds found near Ingeniero Jacobacci (Casamiquela, 1969, p. 308; Leonardi, 1994, p. 35), both from Río Negro Province. Despite that the outcrops of the Río Negro Formation cover a large area in Buenos Aires, Río Negro and La Pampa provinces, no findings of continental trace fossils have been reported for other localities.

The purpose of this communication is to describe, to assign ichnotaxonomically, and to infer the paleoenvironmental significance of small bird tracks from outcrops of the Río Negro Formation at La Adela town, La Pampa Province.

## Geological setting

The Río Negro Formation was proposed to include typically cross-bedded and laminated gray volcanoclastic sandstones of Neogene age that crop out at the lower track of the Negro river, northern Patagonia (Andreis, 1965). At its type area, the formation was considered by its author as fluvial or fluvial associated with eolian deposits. In the exposures located south of the Negro river mouth (mostly between El Cóndor and La Lobería, figure 1) the unit was divided in a lower member of continental origin, an intermediate member of marine origin, and an upper member of continental origin (Angulo and Casamiquela, 1982; Zavala and Freije, 2001). Most of the vertebrate tracks have been recorded from the upper member, which was interpreted as representing dominantly eolian deposition, including dune, dry interdune, wet interdune, fluvial ephemeral, and arid paleosol facies associations (Zavala and Freije, 2001). Most of the specimens of the vertebrate ichnofauna of the formation have been found in fine grained wet interdune facies and are commonly cast by overlying sandy dry dune facies (Zavala and Freije, 2001). In these exposures at the Atlantic coast, there is a gradual upward increase in the participation of light brown, massive, very fine grained sand-

<sup>1</sup>CONICET-Universidad Nacional de La Pampa, Av. Uruguay 151, 6300 Santa Rosa, La Pampa, Argentina.  
rmelchor@exactas.unlpam.edu.ar



**Figure 1.** Location map of the studied area and localities mentioned in the text / *mapa de localización del área de trabajo y de las localidades mencionadas en el texto.*

stones and siltstones showing paleosols with carbonate nodules (the arid paleosol facies association of Zavala and Freije, 2001). The age of the formation is currently assigned to the interval late Miocene-early Pliocene, on the basis of radiogenic dates and fossil mammal remains (Zinsmeister *et al.*, 1981; Aramayo, 1987; Alberdi *et al.*, 1997).

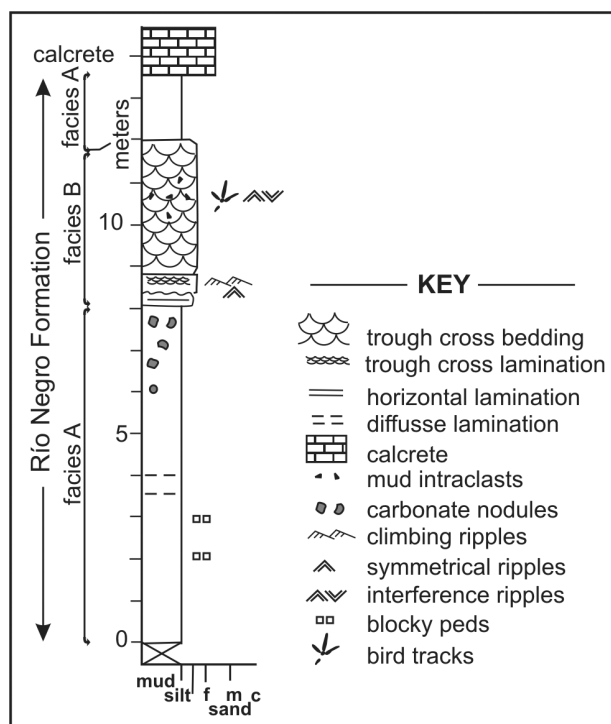
The Río Negro Formation (or lateral equivalents) is exposed in terraces fringing the Colorado river valley at the boundary between La Pampa and Río Negro provinces (Franchi *et al.*, 1984). Toward the north, within La Pampa Province, the unit is overlain and probably laterally replaced by the late Miocene Cerro Azul Formation (Visconti, 2007). The bird tracks described herein were collected near the top of the northern terrace of the Colorado river valley, immediately northeast of the town of La Adela. The fossil traces were found in the unpaved access road to a sanctuary locally known as "La Hermita". There is no direct age constraint for these outcrops, although the sedimentary facies are more akin to the upper member of the Río Negro Formation at the Atlantic coast. In consequence, it is likely that the age of these tracks is closer to the younger age estimate for the unit.

**Facies and paleoenvironment**

The local section of the formation (13.5 m thick) includes two sedimentary facies and is capped by a massive to pisolithic calcrete profile, which is not considered part of the unit (figure 2). Facies A is composed of carbonate cemented light brown siltstone, which is structureless or show rare diffuse horizontal lamination. Fine angular blocky pedes (Retallack, 1988) are recognized in a 1.3 m thick interval from the lower part of the section and 1 to 4 cm in diameter carbonate nodules are common toward the contact

with facies B. Less than 1 cm wide, slightly darker siltstone intraclasts are common in this facies. Facies A is similar to the "arid paleosol facies association" by Zavala and Freije (2001). Facies B is typified by bluish-gray fine to medium grained sandstones with trough cross-bedding and mudstone intraclasts. Other minor sedimentary structures are climbing and symmetrical ripples, and parallel and trough cross-lamination. The bird tracks are preserved in fine grained sandstone on the top of a trough along with interference ripples. Facies B is comparable with the ephemeral fluvial facies association by Zavala and Freije (2001).

Facies A is interpreted as fine grained sediment of eolian origin (loess) and associated paleosols. The identification of loess deposits is based on the silt-grade grain size, massive appearance and association with paleosols. Paleosols are identified on the basis of presence of peds (soil aggregates) and vertical increase in the abundance of carbonate nodules, although no detailed comparisons with modern soils can be drawn. The lower, 8 m thick, occurrence of this facies (figure 2) would represent stacked compound paleosols, which are suggestive of rapid and unsteady sedimentation with minor erosion (*e.g.* Kraus, 1999). The presence of carbonate nodules and common carbonate cementation indicate hydrologi-



**Figure 2.** Sedimentologic log of the outcrop of the Río Negro Formation at La Adela town / *perfil sedimentológico del afloramiento de la Formación Río Negro en el poblado de La Adela.*

**Table 1.** Summary of measurements on the best preserved footprints. Lengths are expressed in millimeters and angles in degrees. Track designation is those of figure 3.1. L\*: total footprint length, distance between the distal tips of digit III and the point of intersection between the projection of the hallux to the prolongation of digit III axis; L: footprint length, distance between the distal tip of digit III, and the more proximal boundary of the sole; W: footprint width, distance between the distal tip of digits II and IV measured perpendicular to the footprint axis; I, II, III, IV: length of digits I to IV; II-III: angle formed by the axis of digits II and III; III-IV: angle formed by the axis of digits III and IV; I-III: angle formed by the axis of digits I and III clockwise; II-IV: angle formed by the axis of digits II and IV; L/W: footprint length/width ratio. / *Resumen de las mediciones realizadas en las huellas mejor preservadas. Las longitudes están expresadas en milímetros y los ángulos en grados. Los números de las huellas corresponden con aquellos de la figura 3.1. L\*: longitud total de la huella, distancia entre el extremo de la impresión del dígito III y el punto de intersección entre la proyección del dígito I y la prolongación del dígito III; L: largo de la huella, distancia entre el extremo del dígito III y el límite más proximal de la planta; W: ancho de la huella, distancia entre el extremo de los dígitos II y IV medida perpendicular al eje de la huella; I, II, III, IV: longitud de los dígitos I a IV; II-III: ángulo formado por los ejes de los dígitos II y III; III-IV: ángulo formado por los ejes de los dígitos III y IV; I-III: ángulo formado por los ejes de los dígitos I y III, en el sentido de las agujas del reloj; II-IV: ángulo formado por los ejes de los dígitos II y IV; L/W: razón entre el largo y ancho de la huella.*

track #	L*	L	W	I	II	III	IV	II-III	III-IV	I-III	II-IV	L/W
a	33	25	26	8	14	21	15	31	46	149	77	0.98
b		22	22		9	16	12	50	52		92	1.00
c		23	25		13	15	15	33	42		71	0.92
d	33	27	24	7	13	21	16	28	42	146	65	1.13
e		24	25		13	16	15	34	42		76	0.96
f		21	23		11	15	13	25	45		70	0.91
g		29	28		15	15	17	23	37		60	1.04
average		24.5	24.7		12.6	17.0	14.7	32	43		73.0	0.99

cal deficiency in the soil profile, probably under semi-arid climatic conditions.

The common presence of trough cross-bedding with mud intraclasts suggests that facies B was transported by water flows and that they represent fluvial channel deposits. The reduced lateral exposure does not allow distinguishing between channel-fill and channel-bar facies. The lower part of the channel deposits contains rippled sandstones, which suggest lower flow regime transport, probably representing tail bar deposits. The presence of bird tracks and interference ripples within the channel deposits imply discontinuous water discharge.

The paleoenvironmental scenario for this section is envisaged as a low relief landscape with dominant fine-grained eolian sedimentation and fluvial channel that suffered repeated (seasonal?) changes in water discharge.

## Systematic ichnology

Ichnogenus *Gruipeda* Panin and Avram, 1962

**Type ichnospecies.** *Gruipeda maxima* Panin and Avram, 1962:465, pl. 7, fig. 25.

**Comments.** The recent revisions of the ichnogenus *Gruipeda* by Sarjeant and Langston (1994) and the proposal of ichnotaxobases for avian footprints by de Valais and Melchor (2008) are followed.

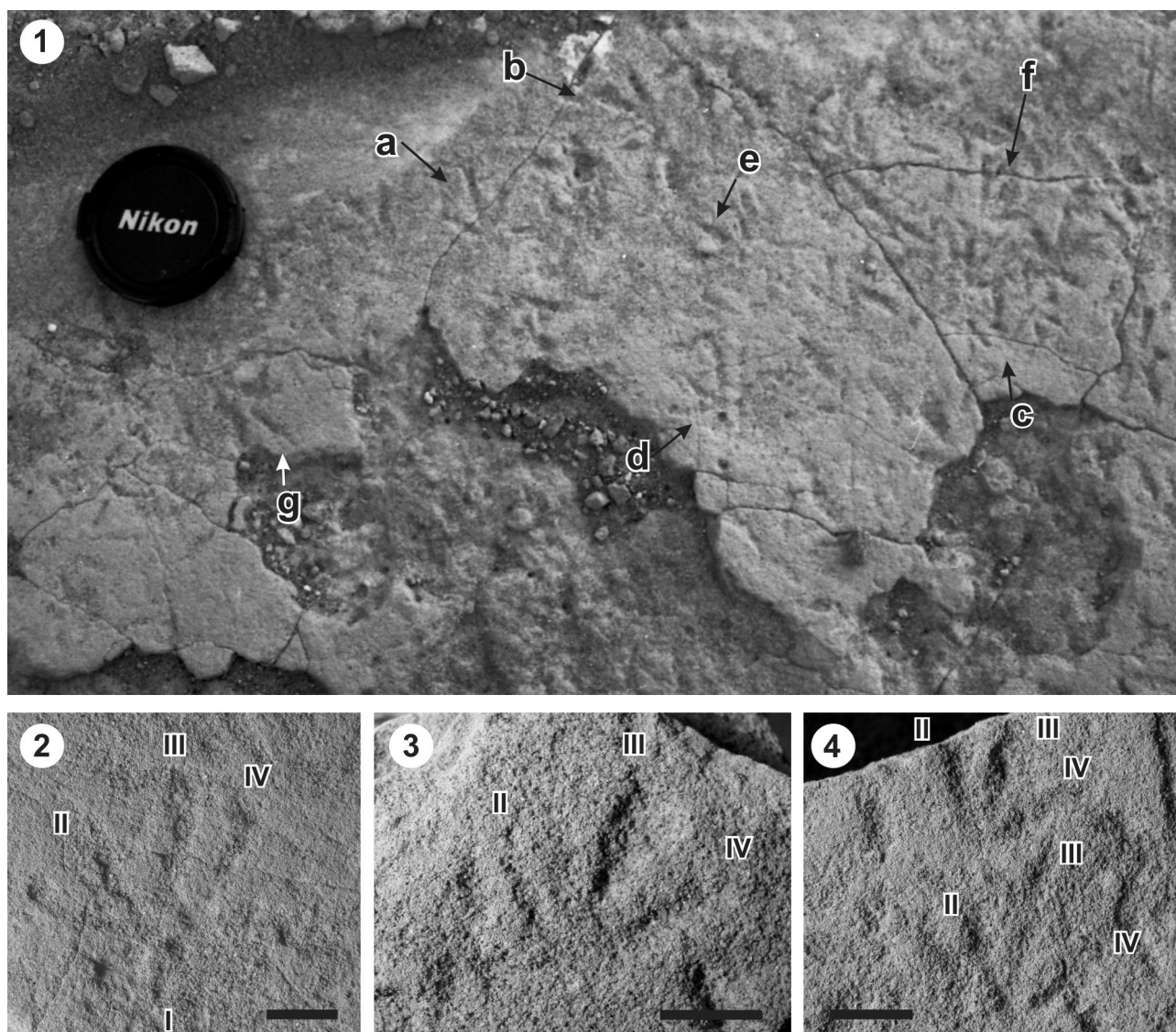
Ichnospecies *Gruipeda dominguensis* de Valais and Melchor, 2008  
Figure 3

**Examined material.** Bedding surface with, at least, 16 moderately preserved footprints and numerous incomplete footprints (figure 3.1). Part of the material has been collected and is now housed at the Paleontology Collection of the Facultad de Ciencias Exactas y Naturales. These include GHUNLPam 27114 a sandstone slab with three complete footprints, GHUNLPam 27115 with three footprints, and GHUNLPam 27116 and 27117 with a single footprint (figures 3.2, 3.3, 3.4).

**Locality.** La Adela town ("La Hermita" sanctuary; 38° 58' 56" S, 64° 05' 05" W), La Pampa, Argentina.

**Age and horizon.** Cross-bedded sandstones (Facies B) of Río Negro Formation (figure 2), late Miocene - early Pliocene.

**Description.** Tridactyl or tetradactyl footprints showing no preferred orientation preserved as cast (negative epirelief) in a bedding plane composed of siltstone or very fine-grained sandstone. Tetradactyl



**Figure 3.** *Gruipeda dominguensis* de Valais and Melchor, 2008. 1, Field photograph of the track-bearing surface. Letters belong to measured tracks (see table 1). Lens cap is 52 mm wide / fotografía de campo de la superficie con huellas. Las letras corresponden a las huellas medidas (véase tabla 1). La tapa del lente es de 52 mm de ancho. 2, Tetradactyl track corresponding to track "d" in figure 3.1. GHUNLPam 27114 / huella tetradáctila que corresponde a la impronta "d" en la figura 3.1. 3, 4, Tridactyl footprints that correspond with tracks "b" (GHUNLPam 27115), and "c" plus "f" (GHUNLPam 27117), respectively in figure 3.1. / huellas tridáctilas que corresponden con las huellas designadas como "b", y "c" mas "f", respectivamente, en la figura 3.1. I to IV: impression of digits I to IV / impresión de dígitos I a IV. Scale bar is 1 cm long / barra de escala de 1 cm de longitud.

footprints have three digits (digits II to IV) directed forward and the fourth (digit I) pointing posteromedially. Tridactyl footprints are more common and display a similar arrangement of digits. A summary of the measurements of the best preserved footprints is presented in table 1. Total footprint length (including the hallux) is 33 mm, whereas the footprint length without considering the hallux ranges from 21 to 29 mm and footprint width between 22 and 28 mm. The corresponding average footprint length / width ratio is about 1 (table 1). Digit impressions are slender and claw marks were occasionally observed. Digits II to IV radiate from the centre of the

sole, which is rounded although rarely impressed. Digit III is the longest and then follow, in decreasing order, digits IV, II and I. The divarication between digits II and IV is in the range 60°-92°, and the interdigital angle III-IV is always larger than the angle II-III. No trackway parameters were measured due to the small sample size and moderate preservation quality. The surface displays a high footprint density. Considering only complete footprints, a density of about 320 footprints / m<sup>2</sup> can be extrapolated (16 footprints in a 0.05 m<sup>2</sup> bedding plane)

**Remarks.** Tetradactyl footprints with three digits directed forward (II-IV) and the fourth directed back-

ward (I) and short, where the axis of digit I does not correspond with that of digit III, which lacks webbing marks contain the diagnostic features of the ichnogenus *Gruipeda* (Sarjeant and Langston, 1994; de Valais and Melchor, 2008). Although the specimens are moderately preserved and the trackway parameters are unknown, the footprints display most the attributes indicative of the ichnospecies *G. dominguensis* de Valais and Melchor, 2008. The trackway parameters are considered as accessory attributes in the diagnosis of this ichnospecies, however, the morphological affinity of the material examined is high enough to justify this assignation. The main features in common are the presence of tridactyl and tetradactyl tracks, a similar length/width ratio and size range, slightly asymmetrical footprints with the angle III-IV larger than II-III, the same relative size in digit imprints, and short posteromedially positioned hallux impression. For a comparison of the ichnospecies *G. dominguensis* with other similar ichnotaxa see the comments by de Valais and Melchor (2008:153). *Gruipeda* is commonly assigned to unwebbed shorebirds, mainly Charadriiformes.

## Discussion

Bird tracks are preferentially preserved in shallow lacustrine facies (e.g. Lockley *et al.*, 1994; Melchor *et al.*, 2006), although they also have been found more rarely in other environments like lagoons and inactive or abandoned channels. The known occurrences of bird tracks in abandoned fluvial channel deposits are from the Late Cretaceous Lance Formation and the overlying Paleocene Fort Union Formation, from Wyoming, USA (Johnson, 1986; Lockley *et al.*, 2003). In both cases the tracks were found in fine grained deposits interpreted as a channel-related pond after abandonment of the active channel. The example described herein from the Río Negro Formation is unusual because the bird tracks were preserved within the main channel deposits. These tracks indicate an important paleoenvironmental aspect that cannot be inferred from lithofacies attributes: the cessation in water discharge of the river, probably with a seasonal frequency (as suggested by associated facies A). This interruption allowed temporary ponding of water in the channel and settling of fine grained sediments, which was the focus of foraging activities by shorebirds. Neoichnological observations suggest that high bird track density, as that observed in the analyzed example, is typical of locations near the shoreline of a body of water (Genise *et al.*, 2009). After footprint formation, water flow resumed without eroding previously formed tracks, although fluvial processes were similar that those operating pre-

vious to footprint formation. In consequence, the presence of bird tracks within the cross-bedded channel facies of the Río Negro Formation are indicative of discharge variability and temporary cessation of the water flow.

## Conclusions

The birds tracks recovered from beds of the late Miocene-early Pliocene Río Negro Formation at southern La Pampa Province are assigned to *Gruipeda dominguensis* de Valais and Melchor, 2008. They are morphologically similar to modern unwebbed shorebirds.

The palaeoenvironmental analysis of the footprint-bearing succession suggests that these beds were deposited in a flat-lying landscape with dominance of fine grained eolian deposition (loess), development of incipient paleosols that accumulated carbonate (suggesting hydrological deficiency), and fluvial flows.

The presence of bird tracks within the coarse grained fluvial channel deposits is rarely reported in the literature and it suggests interruptions in fluvial water discharge. This evidence and the association of the fluvial deposits with loess and carbonate paleosols indicate that fluvial flows were likely temporary.

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