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NOTE

RAMPHASTOSULA (AVES, SULIDAE): A NEW GENUS FROM THE EARLY PLIOCENE OF THE PISCO FORMATION, PERU

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ABSTRACT—Cranial material from a new genus (*Ramphastosula*) of Sulidae is described. The material comes from the Early–Lower Pliocene of the Pisco Formation of the central-southern coast of Peru. The skulls are characterized by (1) remarkable convex curvature of the dorsal surface and straight ventral surface of the rostrum, only with a curvature on the third anterior part and the tip of the bill; (2) well developed occipital and temporal regions; (3) broad opisthotic process projecting to the level of postorbital processes; (4) broad temporal fossa, and (5) flat braincase and robust frontal region.

RESUMEN-*RAMPHASTOSULA* (AVES, SULIDAE): UN NUEVO GÉNERO DEL PLIOCENO TEMPRANO DE LA FORMACIÓN PISCO, PERÚ.

Se describe material craneal de un nuevo género (*Ramphastosula*) para la familia Sulidae, proveniente del Plioceno temprano de la Formación Pisco (costa centro-sur del Perú). El material se caracteriza por presentar (1) un rostrum marcadamente curvo dorsalmente y recto en su superficie ventral, curvándose sólo en la tercera parte anterior y la punta; (2) regiones occipital y temporal muy desarrolladas; (3) procesos opistóticos anchos proyectados más alla del nivel de los procesos postorbitales; (4) fosa temporal ancha, y (5) techo craneano plano y región frontal robusta.

INTRODUCTION

The oldest records of the Sulidae come from the late Eocene of Europe: *Masillastega rectirostris* Mayr, 2002, from Messel (Germany) and *Eostega lebedinskyi* Lambrecht, 1929, from Cluj-Manastur (Romania). *M. rectirostris* was described as a possible member of the Sulidae. Mayr was also uncertain about the classification and dating of *E. lebedinskyi* (Mayr, 2002:507). However, Mlíkovský (2002) indicated that the classification and dating are correct.

Later, younger discoveries are unquestionably sulids: *Sula ronzoni* (Milne-Edwards, 1867) and *Empheresula arvernensis* (Milne-Edwards, 1867) from the Oligocene of France. Thereafter, the Sulidae expanded, and by the Pleistocene the family was present in North Europe, South Africa, Oceania and America (Warheit, 2002).

In South America, fossils of Sulidae have been reported from: the Chilcatay Formation (Middle Miocene) of Peru, with the genus *Sula* (Stucchi and DeVries, 2003), the Pisco Formation (middle Miocene–early lower Pliocene) (Fig. 1) in Peru, including the genera *Sula* and *Morus* (Stucchi, 2003), and the Bahía Inglesa Formation (late Miocene) of Chile, which includes the same genera (Walsh and Hume, 2001; Walsh, pers. comm. 2003). The fossils studied here come from the Pisco Formation.

The Pisco Formation (Fig. 1) is a sedimentary sequence that extends for 50 km along the central-southern coast of Peru. Six vertebrate-bearing levels have been identified: Sacaco (3–3.9 Ma), Sud Sacaco (4–5 Ma), Montemar (4.5–6 Ma), Aguada de Lomas (7–8.8 Ma), El Jahuay (9–9.5 Ma) and Cerro La Bruja (12–14 Ma) (Muizon and DeVries, 1985; Marocco and Muizon, 1988; DeVries, pers. comm. December 2003).

The present research describes two skulls, two braincases and one rostrum. Based on their morphological characteristics, all of them are ascribed to a new genus of the Sulidae.

All fossils described here are housed at the Departamento de Paleontología de Vertebrados, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos (MUSM), Lima, Peru, and are catalogued with MUSM numbers.

SYSTEMATIC PALEONTOLOGY

Order PELECANIFORMES Sharpe, 1891
Family SULIDAE (Reichenbach, 1849)
RAMPHASTOSULA gen. nov.

Type Species—*Ramphastosula ramirezi*, gen. et sp. nov. (Fig. 2).

Etymology—The generic name is derived from *Ramphastos* (generic name of the toucan, a bird from the Peruvian rainforest) and *Sula*, the generic name of the boobies, in reference to the similar shape of its beak to that of the toucans, and the shape of its neurocranium, which is similar to boobies.

Remarks—The specimen described in here is assigned to family Sulidae (sensu Cracraft, 1985) based on the following characters of superfamily Suloidea: (1) lateral wall of presphenoid sinus reduced in size; (2) greatly reduced maxillopalatines, and (3) temporal fossa extending to midline. But, unlike Phalacrocoracidae and Anhingidae, the Peruvian specimen exhibits: (1) upper tympanic recess greatly enlarged; (2) mediopalatine processes enlarged toward pterygo-palatine joint; (3) braincase moderately compressed dorsoventrally; (4) braincase expansion relatively foreshortened anteroposteriorly; (5) postorbital processes present and well developed, (6) opisthotic process directed downward, and (7) presence of interorbital septum.

Furthermore, the Peruvian specimen also presents the following characters of Sulidae: (1) longitudinal nasal groove; (2) hook present in pit of bill; (3) absence of supraorbital depression for salt glands; (4) palatines fused throughout their length; (5) bony nostrils greatly reduced, and (6) nostrils lateral and not tubular in external nares.

Diagnosis—*Ramphastosula* is characterized by: (1) remarkable convex curvature of dorsal surface and straight ventral surface of rostrum, only with curvature on third anterior part and tip of bill; (2) well-developed occipital and temporal regions; (3) broad opisthotic process projecting to level of postorbital processes; (4) broad temporal fossa, and (5) flat braincase and robust frontal region.

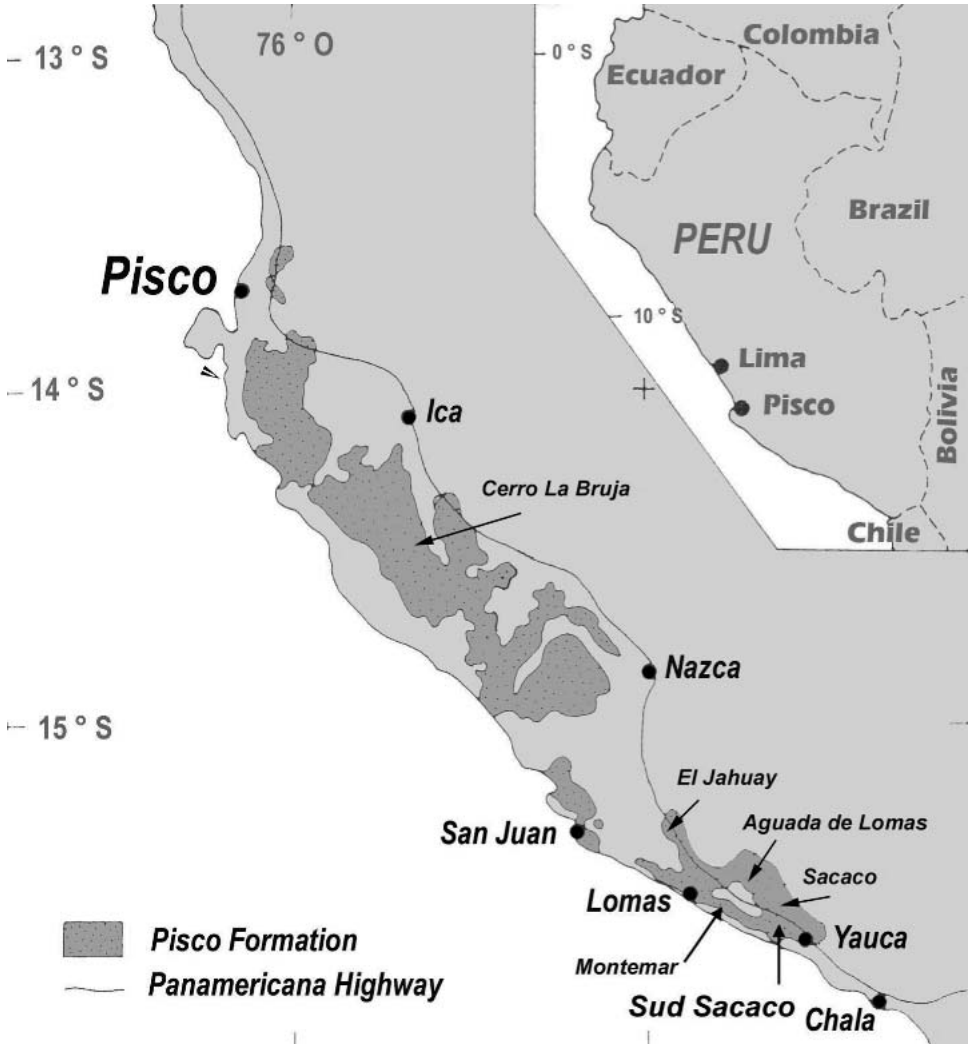

FIGURE 1. Pisco Formation Map, indicating the six vertebrate-bearing levels with the arrows (Muizon and DeVries, 1985)

RAMPHASTOSULA RAMIREZI sp. nov.
(Fig. 2)

Holotype—MUSM 264: skull missing pterygoids, quadrates, lacrimals, and jugal bars; collected by M. Urbina in 1995 (Fig. 2A, B).

Type Locality and Horizon—Sud-Sacaco level, Pisco Formation (central-southern coast, Peru); early lower Pliocene.

Etymology—Named for Mr. Gregorio Ramirez, in recognition of his valuable contribution to Peruvian vertebrate paleontology.

Paratypes—MUSM 266: braincase; MUSM 410: rostrum (Fig. 2C); MUSM 267: braincase, with proximal portion of rostrum, without occipital region (Fig. 2D); MUSM 411: braincase and rostrum (Fig. 2E). All were collected from the same locality as the holotype by M. Urbina in the same year.

Diagnosis—As for genus.

Measurements—MUSM 264: total length of rostrum: 98.4 mm; total length of neurocranium: 69.1 mm; breadth at naso-frontal hinge: 29.5 mm; height of neurocranium: 35.1 mm; breadth of opisthotic processes: approx. 48 mm; MUSM 267: breadth at naso-frontal hinge: 27.1 mm; MUSM 411: total length of rostrum: 117.9 mm; breadth at naso-frontal hinge: 29.3 mm.

Description

Premaxilla and Maxilla—The premaxillae and maxillae exhibit a wrinkled surface formed by diminutive grooves on the lateral surfaces. The cranium is almost three quarters (70%) of the total length of the rostrum. In lateral view (Fig. 2B), the dorsal margin is convex. Ventrally, it is straighter, curving at the anterior part to form a hook-like end, more pronounced than in other Sulidae (see also MUSM 411, Fig. 2E). Like all members of the family, it possesses a secondary nasal aperture and a longitudinal groove in the rostrum. In extant species this groove is formed by the primary nasal aperture in pre-adult forms and closes on maturing. In dorsal (Fig. 2A) and ventral views, *R. ramirezi* is similar to other specimens of Sulidae and longitudinally fused palatines can be observed.

Neurocranium—In lateral view (Fig. 2B), the braincase is dorsoventrally compressed from the posterior medial orbits to the sagittal crest, resembling a platform inclined at almost 45° to the basal plane, rising posteriorly. In this part of the braincase there is an enlargement of the frontals, which are robust. In other Sulidae, this portion of the braincase is generally flat, following the projection of the rostrum. There are certain exceptions such as *Sula variegata*, where it is slightly convex and has comparatively robust frontals (see Fig. 3). The opisthotic processes are well developed, more so than in other Sulidae (Fig. 3).

In dorsal view (Fig. 2A), broad temporal fossae and well-developed opisthotic processes are observed. Unlike any other Sulidae, maximun width occurs in this area. As in most sulids, the sagittal crest is thin and narrow. The postorbital processes are of average size, bifurcated with high orientation as in the genera *Sula* and *Morus*. *Papasula* retains the primitive long, pointed, ventrally oriented condition (Olson and Warheit, 1988:10; see also van Tets et al., 1988:37).

In ventral view, the neurocranium exhibits fusion of the otic bones.

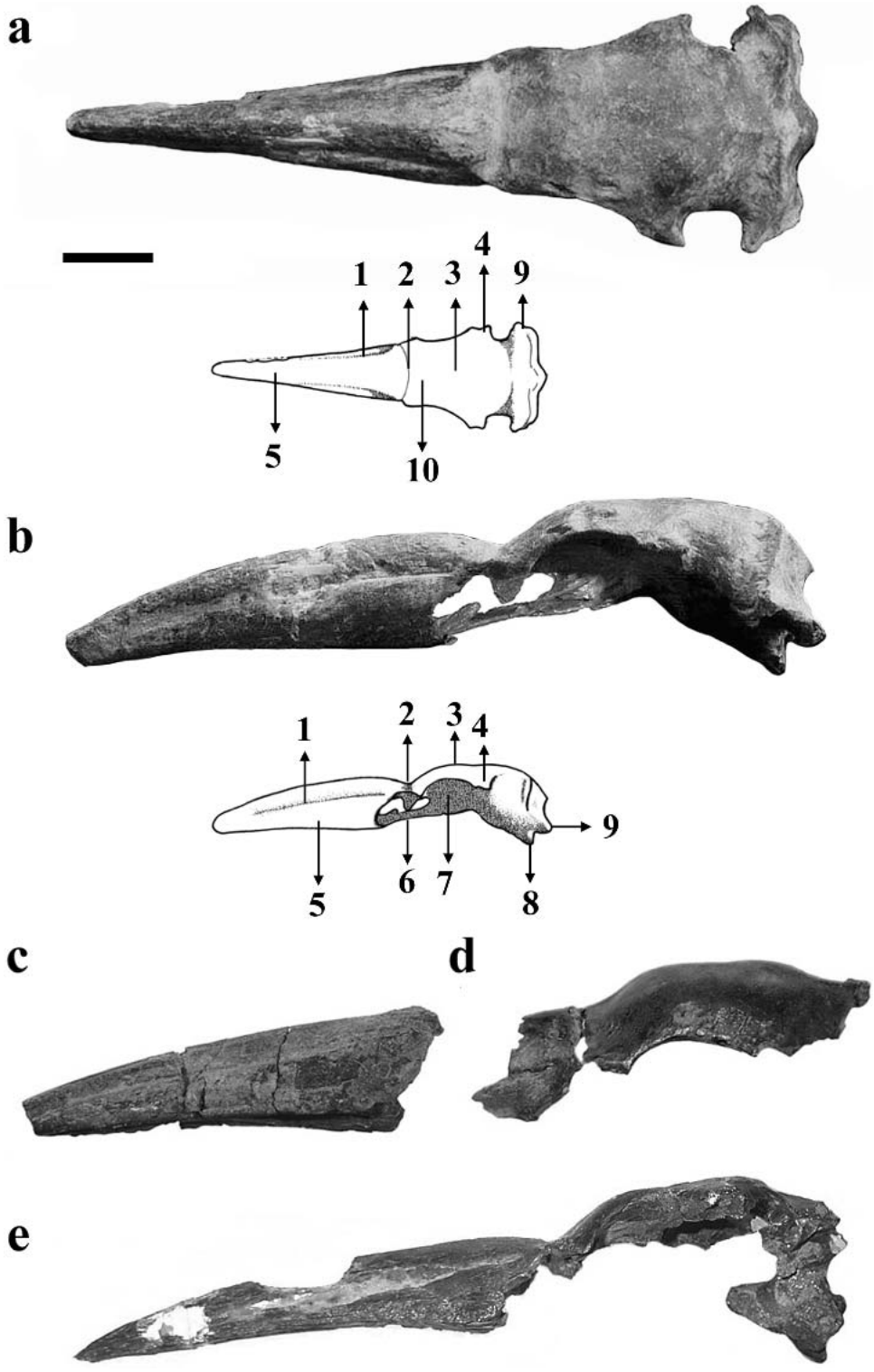

FIGURE 2. **A**, dorsal view of *Ramphastosula ramirezi* holotype MUSM 264; **B**, lateral view of *R. ramirezi* holotype MUSM 264; **C**, lateral view of *R. ramirezi* paratype MUSM 410; **D**, lateral view of *R. ramirezi* paratype MUSM 267; **E**, lateral view of *R. ramirezi* paratype MUSM 411. Scale bar equals 20 mm. Photos by M. Stucchi. **Numbers**: **1**, longitudinal groove; **2**, naso-frontal hinge; **3**, braincase dorsoventrally compressed; **4**, postorbital process; **5**, rostrum; **6**, palatines; **7,** interorbital septum; **8**, lateral process of basitemporal plate; **9**, opisthotic process; and **10**, frontal region of braincase.

The basitemporal plate is slightly inclined posteriorly and presents the typical semicircular form. There is a broad upper tympanic aperture, similar to that observed in extant species.

In caudal view, the occipital region has a trapezoidal form, with lateral and superior borders formed by post-temporal crests. These have the same orientation, but are slightly lower than in other Sulidae.

DISCUSSION

Ramphastosula ramirezi satisfies the diagnostic characters of the Sulidae, and there are substantial differences that justify its assignment to a new genus. The shape of the skull is clearly modified to support the size and weight of the beak. The frontals and the opisthotic processes are

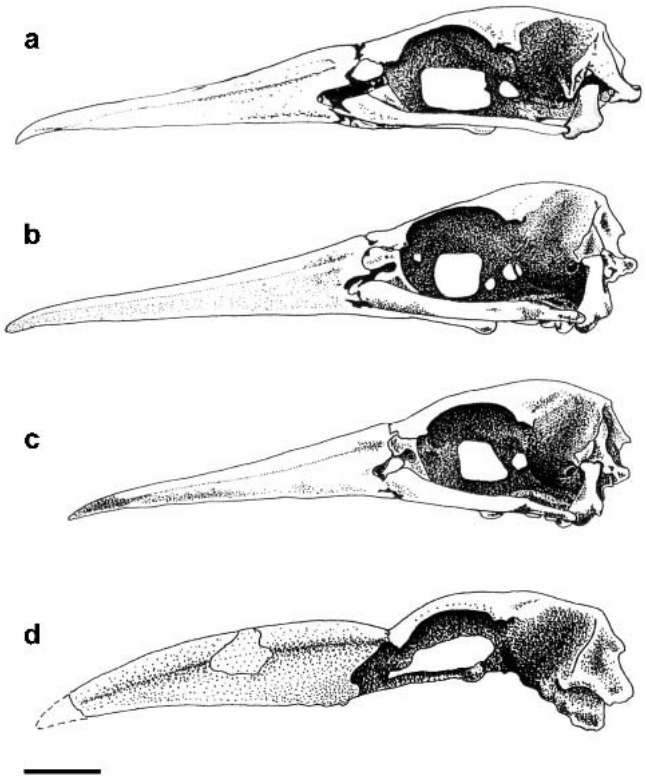

FIGURE 3. Comparison between **A**, *Sula dactylatra*; **B**, *S. nebouxii*; **C**, *S. variegata*; **D**, *R. ramirezi*. Scale bar equals 20 mm. A re-drawn from van Tets et al. (1988:fig. 2); B, C, D, originals. Drawn by M. Stucchi.

more robust, and the temporal fossae are bigger, due to the necessity of larger muscles in this area. The adductor mandibulae extends through the temporal fossa, facilitating the opening of the beak. The splenius capitis and rectus capitis lateralis insert in the opisthotic processes, where they raise, rotate, and extend the head.

The mandible and the postcrania of this bird remain unknown, limiting inferences regarding its feeding adaptations. Nevertheless, the form of the beak would have interfered with plunging dives from high altitude, and dives from lower altitudes or other kinds of feeding strategies are more likely (see reconstruction of the head: Fig. 4). The well-developed opisthotic probably indicates a better diving capability.

Due to its morphological similarity with other members of the Pisco Formation Sulidae, it is probable that *R. ramirezi* evolved from one of the larger forms of *Sula* present in older levels of the Pisco Formation such as the Montemar (4.5–6 Ma) and Aguada de Lomas (7–8.8 Ma) levels (Stucchi, 2003).

Notice in Figure 2A (and in fig. 1 of van Tets et al., 1988:36) that the anterior region of the rostrum is similar to that of *Sula* but not to that of *Morus*; this is the only cranial difference between these two genera.

In the Montemar level, this family is represented by at least 5 different forms, including 3 new species: *Sula magna*, *Sula sulita*, and *Morus peruvianus*, one form close to *Sula variegata* and undetermined material (probably representing two different species), and in Aguada de Lomas level there was at least one of these, *S. magna* and material only recognized as *Sula sp.* (Stucchi, 2003).

Paleoecology

R. ramirezi was found in the west side of Sud Sacaco Level (4–5 Ma) of the Pisco Formation (Fig. 1). This level represents a littoral environment with protected beaches, and reefs exposed to marine currents (Marocco and Muizon, 1988:111). Muizon and DeVries (1985: 558–560) explain that the west side of this level is characterized by elevated rocky platforms near the shoreline, suitable for an epibenthos composed of cirripedians and mollusks such as *Acanthina* spp., especially *A. obesa* and *A. triangularis*, *Herminespina spp*., and *Concholepas kieneri* (DeVries, 2003; DeVries and Vermeij, 1997). The eastern side of Sud Sacaco is characterized by the presence of broad sandy beaches and barrier lagoons with shallow depths and warm water, containing the remains of brachiopods, crabs, fishes, and bivalves of the genera *Anadara*, *Dosinia*, and *Amantis*.

In this paleoenvironment, *R. ramirezi* cohabited with other marine birds, such as: *Spheniscus urbinai* (Spheniscidae), about 25% bigger than extant *S. humboldti* with a disproportionately big skull and beak (Stucchi, 2002); *Phalacocorax sp*. (Phalacorocoracidae), an average-sized cormorant; *Fulmarus sp*. (Procellariidae); *Pelagornis sp*. (Pelagornithidae), very large, similar to *Pelagornis miocaenus* (Cheneval, 1993); a new genus and species of Vulturidae, similar in size to extant *Vultur gryphus* (Stucchi and Emslie, unpubl. data); and at least one indeterminate species of *Sula* (Sulidae), bigger than extant species (Stucchi, 2003).

Non-avian fauna included mammals: *Acrophoca longirostris* and *Piscophoca pacifica* (Phocidae), *Thalassocnus littoralis* (Nothrotheriidae), *Pliopontos littoralis* (Pontoporidae), *Piscolithax longirostris* (Phocoenidae), *Ninoziphius platyrostris* (Ziphidae), *Odobenocetops peruvianus* (Odobenocetopsidae), Physeteridae, Cetotheriidae, and Balaenopteridae (Muizon, 1993; Muizon and DeVries, 1985; Muizon et al., 2004); the gavial *Piscogavialis jugaliperforatus* (Gavialidae; Kraus, 1998); sharks: *Carcharodon carcharias*, *Carcharocles megalodon* and *Carcharinus* sp.; rays: *Myliobatis* sp.; and bony fishes: aff. *Psamoperca* (Centropomidae), Clupeidae-Alosinae, Xiphiidae, Sphyraenidae, Scombridae, Cybiidae, Siluriformes cf. Ariidae, and Tetraodontiformes (Muizon and DeVries 1985:554).

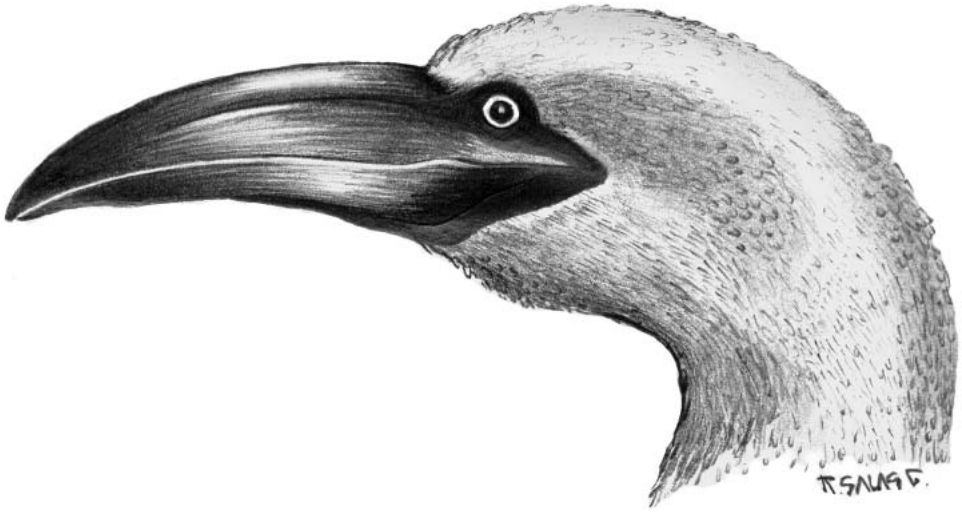

FIGURE 4. Reconstruction of *R. ramirezi* from the holotype MUSM 264. Drawn by Rodolfo Salas.

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