

AMERICAN MUSEUM *Novitates*

PUBLISHED BY THE AMERICAN MUSEUM OF NATURAL HISTORY
CENTRAL PARK WEST AT 79TH STREET, NEW YORK, N.Y. 10024
Number 3098, 31 pp., 4 figures, 3 tables
May 20, 1994

Paleogene Mammals from the Andes of Central Chile: A Preliminary Taxonomic, Biostratigraphic, and Geochronologic Assessment

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ABSTRACT

Two highly unexpected and diverse fossil mammal assemblages have been discovered in the upper Río Tinguiririca valley in the Andes Main Range of central Chile. This work brings to light the first Paleogene mammal faunas from Chile, as well as the first fossil mammals from the central Andean Main Range. The younger fauna presently includes representatives of at least three higher-level groups of marsupials, five notoungulate families, two groups of edentates, a rodent, plus a probable litoptern, and represents the first well-known transitional Eocene-Oligocene fauna from South America. It documents the first or last

appearances of at least seven subfamilial or higher-level taxa. This co-occurrence of formerly temporally disjunct taxa identifies the fauna as representing a new interval of South American land mammal evolution. This fauna (here termed the Tinguiririca Fauna) represents the youngest diversely sampled pre-Deseadan fauna from South America, and records the earliest occurrence of rodents on the continent. Radioisotopic dates from volcanic units containing and associated with the Tinguiririca Fauna are the first available for the Eocene through early Oligocene South American mammal record, and thus represent a critical cal-

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ibration point for mammalian biogeochronology. The second fauna (here termed the Tapado Fauna) is presently less completely known than the first, but is clearly significantly older. Both faunas are of demonstrated importance to the interpretation of central Andean stratigraphy and tectonic his-

tory. Likewise they shed light on crucial and heretofore poorly understood phases of South American mammal evolution, and establish an important new source of geochronologic information for this Andean region.

INTRODUCTION

Prior to its Late Pliocene connection with North America, South America was isolated from other continents for a span of some 60 million years. This long period of insularity and the peculiar biota it engendered have captured the attention of evolutionary biologists and paleontologists for more than a century (Simpson, 1984). The best known, and perhaps most unusual, element of South America's endemic biotic history is its Cenozoic mammals, the succession of which is generally divided into a sequence of 13 distinct South American Land Mammal Ages (SALMAs). Some of these (particularly Paleogene) faunas remain very incompletely known, however, and decades of intensive investigation have failed to close several important gaps. Among these, an approximately 15 million year interval between post-Mustersan (?middle Eocene) and pre-Deseadan (late Oligocene-?early Miocene) horizons has previously represented the most poorly known span of the South American Cenozoic mammal record (Marshall, 1985). Apart from its length (encompassing up to a third of Cenozoic time), additional factors compound the difficulties posed by this faunal hiatus. First, the faunas generally accepted as bracketing this hiatus, the ?middle Eocene Mustersan and ?Eo-Oligocene Divisaderan SALMAs, (the latter sometimes being considered early Deseadan in age) are the two most poorly known of the entire South American Cenozoic mammal record. Second, this span coincides with a crucial faunal transition, from mammal communities dominated by archaic lineages to communities characterized by mammals of a markedly more "modern" stamp (Pascual et al., 1985). And third, this post-Mustersan pre-Deseadan hiatus encompasses the inadequately dated first appearance of primates and rodents in South America, two lineages of major importance in later Cenozoic and Recent faunas. Uncertainty over the timing of arrival of these two im-

migrant taxa stems from the length of the faunal hiatus preceding the Deseadan and lack of radioisotopic control for Mustersan and Casamayoran sediments.

We have recovered two new fossil mammal faunas of transitional Eo-Oligocene and probable early Eocene age from volcanoclastic sediments assigned to the Abanico (= Coya-Machali) Formation near the axis of the Andean Main Range in the valley of the Tinguiririca River in central Chile (fig. 1). The first discovered (Novacek et al., 1989) and younger of these faunas is from exposures near the town of Termas del Flaco (34°59'S, 70°26'W). This fauna, hereafter referred to as the Tinguiririca Fauna, represents South America's first diversely sampled pre-Deseadan, post-Mustersan mammal assemblage. In addition to illuminating a crucial phase of mammalian evolution, this fauna represents the first chronologically significant paleontological find for a major group of central Andean rock units, and is of broad significance for the interpretation of regional geologic history. Radioisotopic dates associated with the Tinguiririca Fauna are key calibration points for early Cenozoic South American biochronology, they aid in constraining the timing of the immigration of rodents to South America, and they help to date an important middle Cenozoic faunal turnover event. The bulk of the present contribution represents a preliminary description of the Tinguiririca Fauna.

A second fauna, here designated the Tapado Fauna (after Quebrada El Tapado which is near the principal locality), has been recovered from exposures approximately 12 km NW of Termas del Flaco (Flynn et al., 1991; Wyss et al., 1992a, 1992b). As material from this area is in preliminary preparation stages, we make only cursory reference to the Tapado Fauna in this report. To clear up possible confusion stemming from our expressed earlier views (ibid.), it is necessary to mention

that the Tapado Fauna is assuredly not younger than the Tinguiririca Fauna. Accepted stratigraphic interpretations of the region, which place sediments producing the former fauna some 2000 m higher in the local stratigraphic section than those producing the latter, had led us to expect a younger Tapado. Rather, the few specimens that have been prepared to date suggest that the Tapado Fauna is substantially older than the Tinguiririca Fauna; subject to revision by ongoing preparation, preliminary comparisons indicate a Casamayoran age. This establishes that the much older Tapado Fauna has been tectonically superposed over the Tinguiririca Fauna via post-Oligo-Miocene thrust faulting, demonstrating much greater tectonic complexity than had been previously appreciated for this region of the Andes.

In sum, the new faunas and associated geochronometric data are of demonstrated importance in elucidating the tectonic history of the rock units hosting them, the ages and history of several related formations in the region, and the ages of several related South American faunas and faunal events.

ABBREVIATIONS

AMNH	American Museum of Natural History
BRCU	Brownish Red Clastic Unit
LBLC	Lomas Blancas (or La Curandera)
MLP	Museo de La Plata
PU	Princeton University
SGOPV	Museo Nacional de Historia Natural, Santiago, vertebrate paleontology collections

GEOLOGICAL OVERVIEW AND PREVIOUS INVESTIGATIONS

The work of Charles Darwin provides the first systematic geological and paleontological accounts of the Andean Cordillera of central Chile and neighboring Argentina. Darwin characterized and formally named the rock unit forming the bulk of the central Andean Main Range in the technical account (1846) of his traverse of the Cordillera approximately 100 km north of the Tinguiririca drainage (Darwin, 1845), terming it the Porfirítica Formation. Over the next century there followed a series of more detailed works in the region, some touching on the valley of the Río Tinguiririca specifically (site of our

new mammal faunas) (Domeyko, 1862; Burckhardt, 1897, 1900; Philippi, 1899; Gerth, 1931; Groeber, 1947a, 1947b). These led ultimately to the abandonment of Darwin's Porfirítica designation in favor of Klohn's (1957, 1960) finer stratigraphic subdivisions, which are still employed (table 1). Important, more recent, refinements of this sequence include: Arcos (1987); Charrier (1973, 1981b); Davidson and Vicente (1973); González and Vergara (1962); and Charrier et al. (submitted).

The Porfirítica sequence is exposed over a 400 km north-south long, 50 km east-west wide, swath along this segment of the Andean Main Range and measures roughly 10,000 meters in stratigraphic thickness. Its lower half (the Nacientes del Teno, Rio Damas, Baños del Flaco, and Colimapu Formations) (table 1) consists of interbedded, sedimentary, marine and terrestrial formations recording a series of transgressive and regressive phases of detrital back arc deposition. Marine levels contain abundant invertebrate fossils, firmly establishing these lower deposits to be medial Jurassic through Late Cretaceous in age (Klohn, 1960; González and Vergara, 1962; Charrier, 1981a, 1981b).

Such clarity does not extend, unfortunately, to age determinations for the upper units of the Porfirítica assemblage (approximately 5 km thick), of which the Abanico Formation forms an important component. These formations (none of which had yielded chronologically useful fossils prior to our work) consist of continental, mainly volcanic, and volcanoclastic arc deposits. Stemming partly from this lack of paleontologic control, there has been considerable uncertainty about the age of most of these upper units, including the Abanico [= Coya-Machali (Klohn, 1960)] Formation. Adding to these difficulties, pervasive low-temperature recrystallization has hampered the use of conventional "whole rock" $^{40}\text{K}/^{40}\text{Ar}$ radioisotopic dating techniques for these units (Charrier, 1981a; Vergara et al., 1988). The Abanico Formation, traditionally assigned a late Cretaceous age (Klohn, 1960), has yielded a highly variable range of $^{40}\text{K}/^{40}\text{Ar}$ age estimates, some as old as early Paleocene but most being Miocene-late Oligocene (Charrier and Munizaga, 1979; Drake et al., 1982; Vergara, 1978; Vergara and Drake, 1978, 1979). Because of alter-

TABLE 1

Stratigraphy of Andes Main Range, Central Chile

[(after Klohn, 1960; González and Vergara, 1962; Charrier, 1973, 1981a, 1981b; Charrier et al., submitted), showing currently accepted subdivision of Darwin's Porfirítica Formation. Ages of post-Neocomian units are relatively uncertain, being based for the most part on suspect $^{40}\text{K}/^{40}\text{Ar}$ determinations (see text).]

Unit/formation	Lithology	Thickness	Age
Young Andean volcanics	Andesitic & dacitic lavas & pyroclastics	Stratovolcanoes & isolated flows, variable thickness	Late Pliocene-Recent
UNCONFORMITY			
Farellones	Continental, dacitic pyroclastics	2000–3000 m	Miocene (25–7 Ma)
UNCONFORMITY			
Abanico (=Coya-Machali)	Continental volcanic, pyroclastic & detrital deposits	1000–2000 m	?Paleogene-early Neogene (62.3–16.4 Ma)
UNCONFORMITY			
Colimapu	Continental sandstones & volcanic deposits	2000–3000 m	Late Early Cretaceous
Baños del Flaco (=Lo Valdés)	Marine fossiliferous limestones	2000 m	Tithonian-Neocomian
Leñas-Espinoza	Pyroclastic turbidites	>1200 m	Kimmeridgian
Río Damas	Continental sandstones, conglomerates and lavas	3000–4000 m	Kimmeridgian
Nacientes del Teno	Marine sandstones and limestones and 100–200 m thick gypsum upper member	800–1000 m	Bajocian-early Kimmeridgian
UNCONFORMITY			
Paleozoic Andean Basement			

ation, these dates are generally discounted as anomalously young (Charrier, 1981a; Vergara et al., 1988). Discovery of fossil mammals and single-crystal laser fusion analyses suggesting Paleogene ages for portions of the Abanico Formation (Charrier et al., submitted), dictate, therefore, considerable age revision of upper Porfirítica units.

Prior to the present series of investigations, reports of fossil vertebrates within the Porfirítica units had been limited to dinosaur footprints from the upper part of the Baños del Flaco Formation at its type locality near Termas del Flaco (Casamiquela and Fasola, 1968), ichthyosaur remains from the same area and undoubtedly from the same formation (Philippi, 1895), and fragmentary di-

nosaur remains from the Viñita Formation, approximately 200 km further north (Casamiquela et al., 1969). The ichnofossils and the accessibility afforded by the road serving the summer resort town of Termas del Flaco prompted our initial exploration in the Tinguiririca region.

JJF, MAN, MJN, and ARW spent one day in February 1988 prospecting in exposures immediately surrounding Termas del Flaco. As all pre-Quaternary rocks in the vicinity had been consistently mapped as Mesozoic, the discovery of fragmentary yet indisputably Cenozoic mammals was completely unforeseen. A field party from the AMNH (New York), Field Museum of Natural History (Chicago), Universidad de Chile Santiago,

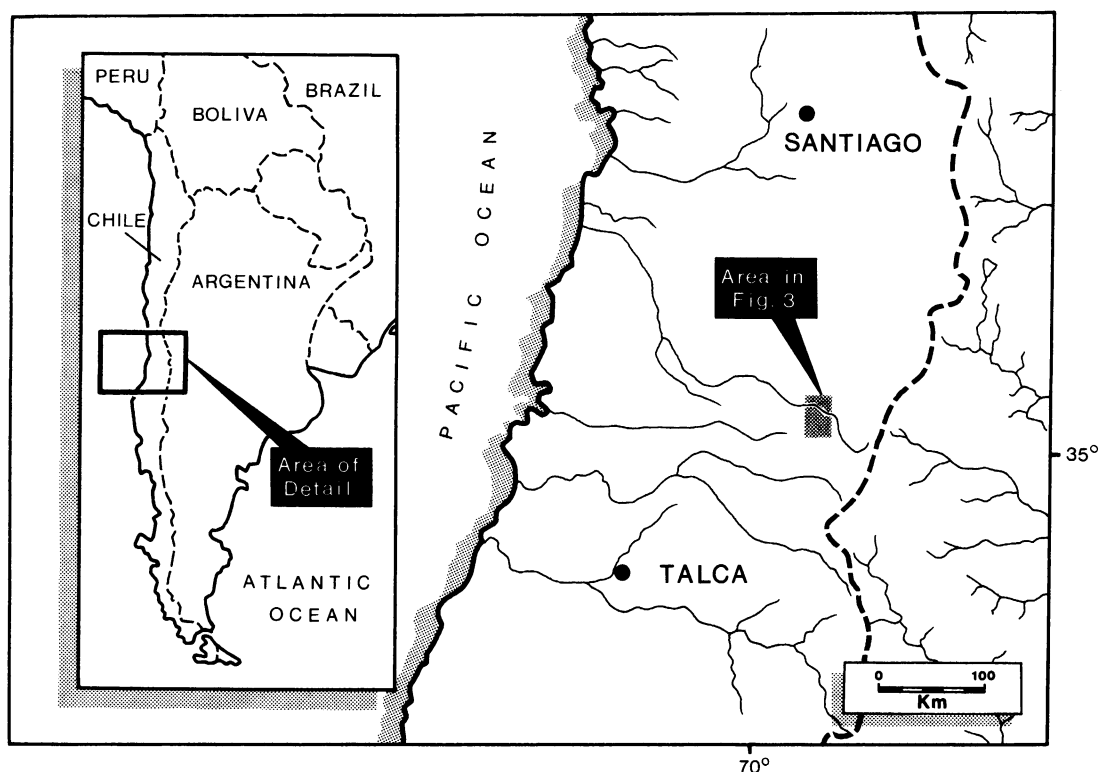


Fig. 1. Location of Termas del Flaco. Shaded rectangle corresponds to area shown in figure 3.

Museo Nacional de Historia Natural Santiago, and the University of California Santa Barbara, returned to the site in January-February 1989, at which point the paleontological importance and geological implications of the discovery became apparent.

GEOGRAPHIC SETTING

The main part of the horizon producing the Tinguiririca Fauna occurs high within the northwest-southeast trending valley of the Río Tinguiririca near the town of Termas del Flaco, Chile (figs. 2a, b, 3). The area of exposure is in rugged mountainous terrain, slightly off-axis of the Main Andean Cordillera, approximately 7 km west of the Argentine border. The north-south extent of the fossiliferous unit is presently uncertain. Exposures of the mammal-bearing unit may be rather extensive south of the Río Teno (the next major drainage to the south), but road closures have hampered access to that region. Exposures are likely equally widely distributed to the north as well, but again access is difficult.

Tinguiririca-Fauna-producing localities are concentrated in three main areas, all in the vicinity of Termas del Flaco, and all representing apparently the same restricted stratigraphic unit. The most important set of localities occurs south of the Río Tinguiririca in steep badlandlike exposures near an unnamed pass [identified simply by its elevation 2738 m on the topographic sheet (Anonymous, 1985); known locally as the "Portezuelo El Fierro" and will be referred to as the El Fierro localities] located 3 km nearly due south of town (fig. 4). Fossiliferous exposures extend from approximately 1 km north of this pass, through the pass itself, and 1 km south into the upper drainage of the Río Teno. A second, much less extensive set of exposures occurs approximately 1 km west of the Fierro Pass on the steep eastern slope of Cerro Alto del Padre. These localities are referred to as the Cerro Alto del Padre localities. The third set of Tinguiririca Fauna-producing localities is north of the Río Tinguiririca, some 4 km northwest of Termas del Flaco. Al-



Fig. 2a. View south-southeast across the Tinguiririca River Valley, with the "Portezuelo El Fierro" appearing just left of center, and the eastern flank of Cerro Alto del Padre to the right. Elevation difference between the river and the "Portezuelo" is approximately 1030 m.

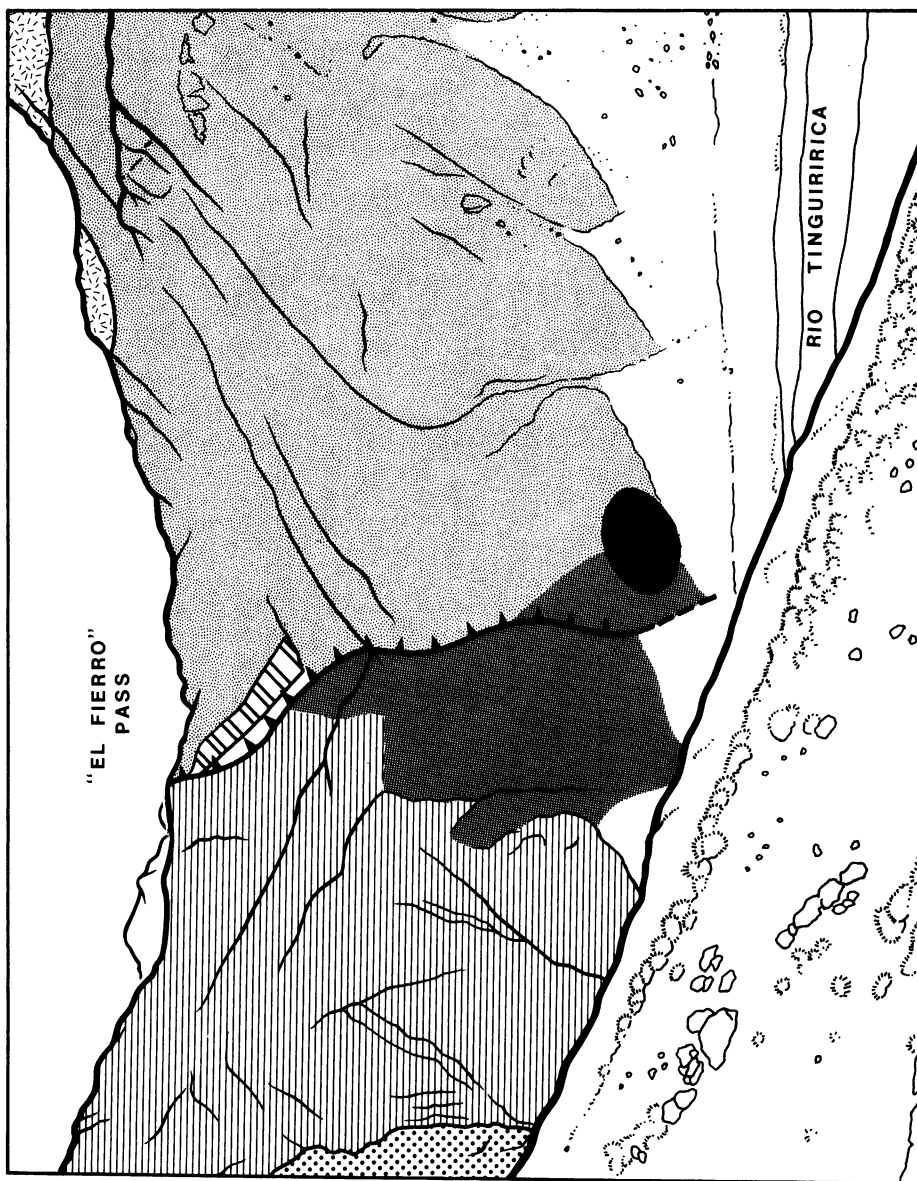


Fig. 2b. Geologic interpretation of figure 2a (after Charrier et al., submitted). Fill patterns designating rock units correspond with those used in figure 3 except that units 5 and 7 of figure 3 are undifferentiated here. Unit 3 of figure 3 is not shown for sake of clarity; it is visible as a small light-colored patch immediately below the base of the easternmost (topographically highest) portion of unit 6 in figure 2a.

though none of these three sets of localities are laterally continuous directly, lithostratigraphic and biostratigraphic evidence suggests that they probably represent the same restricted stratigraphic unit. We have discerned no significant differences in fossil content between the locality sets and therefore presume them to be approximately contemporaneous. Similarly, we have observed no changes in faunal composition with differences in stratigraphic position within the <100 m thick Tinguiririca-Fauna-producing horizon.

STRATIGRAPHIC CONTEXT

The Tinguiririca Fauna occurs in 35–50° westward dipping volcanoclastic sediments, ranging in color from brownish-red to violet, to greenish-gray and buff, interbedded with flows and tuffs. The fossiliferous strata are assigned to the Abanico Formation (Charrier et al., submitted), a unit broadly distributed in this region of the Andes. Although the fossil localities occur in deposits identified as the medial to Late Cretaceous age Colimapu Formation on earlier large-scale maps of this region (Klohn 1960; González and Vergara, 1962; Vergara, 1965; Charrier, 1973; Arcos, 1987), new results from detailed mapping and sedimentology show this identification to be in error (Charrier et al., submitted). The Colimapu Formation, in fact, appears to be entirely absent in the Termas del Flaco region; a small wedge of Cretaceous, coarse, red, detrital sediments—informally termed the Brownish Red Clastic Unit [BRCU] (Charrier et al., submitted) probably represents a new formation. In contrast to the fossiliferous Paleogene unit, the BRCU is nonvolcanoclastic, coarser grained, much redder in color, more steeply dipping, and lacks extrusives. The abrupt nature of the contact between the BRCU and underlying Baños del Flaco Formation, as well as several sedimentological features argue against referral of the BRCU to the Colimapu Formation (Charrier et al., submitted).

In connection with our referral of the Tinguiririca-Fauna-producing horizon to the Abanico Formation, it should be mentioned that the lithology of this horizon also resembles that reported for portions of other post-

Colimapu units (Farellones, Plan de los Yeuques, and Corona del Fraile Formations) that have been mapped in the central Andes (González and Vergara, 1962; Klohn, 1960). Thus we cannot entirely exclude the possibility that the fossiliferous strata correlate with one of these latter units or that they represent a new, unnamed unit. Even if future work were to show the fossiliferous unit to pertain to something other than the Abanico Formation, however, the fossiliferous sediments unquestionably occur within the upper (post-Neocomian) half of the Porfírica sequence. Irrespective of their formational allocation, mammals from the Termas del Flaco region represent the first chronologically informative fossils from a stratigraphically important and geographically widespread set of rock units in this region of the Andes.

The contact of the Tinguiririca-Fauna-producing unit with underlying formations is most clearly observed for the series of localities straddling the El Fierro Pass (see above). In the northern part of this area, the fossil-bearing unit is approximately 50 m thick and rests in slight angular unconformable contact on the underlying BRCU. The BRCU thins to the south, disappearing altogether near the pass. South of the pass, the Cenozoic deposits rest in disconformable contact on the Jurassic, marine Baños del Flaco Formation. The latter formation appears to bend subtly along strike; north of the pass the Cenozoic deposits and the Baños del Flaco Formation diverge by some 40° in strike, but south of the pass they are indistinguishable in this regard.

Two basaltic flow units in the region are relevant to the present discussion. An eastern flow unit occurs conformably beneath the El Fierro Pass set of localities, and above the BRCU and the Baños del Flaco Formation. This flow is somewhat heterogeneous in composition, up to approximately 40 m thick, shows a baked lower contact, and its upper surface bears a puddingstone conglomerate. To the west, at the set of localities on the eastern slope of Cerro Alto del Padre, at least one flow is intercalated within the fossil-bearing unit.

Fossils occur in brownish-red to violet volcanoclastic sediments that may be the product of a lahar; internally, the relatively fine-grained fossiliferous horizon is uniform in

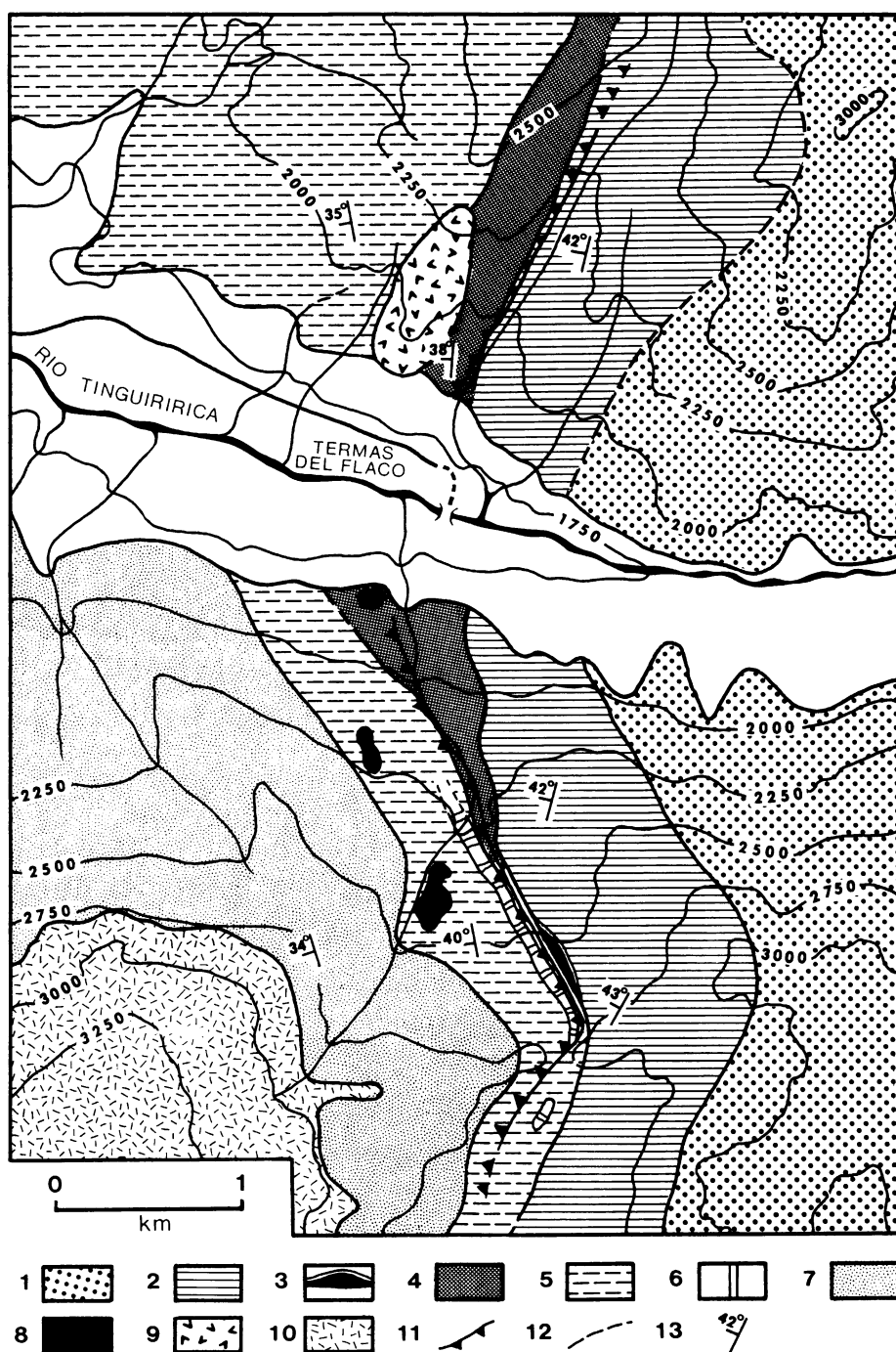


Fig. 3. Geology of the study region (after Charrier et al., submitted): 1, Río Damas Formation; 2, Baños del Flaco Formation; 3, 104 Ma White Tuff Unit; 4, brownish-red Clastic Unit; 5, volcaniclastic part of the Abanico Formation; 6, lower basalt flow of the volcaniclastic part of the Abanico; 7, sedimentary and volcanic upper part of the Abanico Formation; 8, fluidal felsic intrusives; 9, Andesitic dike; 10, Alto del Padre Volcanic Unit; 11, El Fierro Fault; 12, inferred contact; 13, strike and dip.



Fig. 4. View south of the northern part of the "Portezuelo El Fierro" set of localities. Fossil vertebrates occur in the purplish unit seen immediately below the pass.

lithology and is structureless. Roughly spherical nodules, ranging between approximately 5 and 40 cm in diameter, are a characteristic weathering feature of this horizon. In general, we have found these nodules to be more highly fossiliferous and to yield better quality specimens than surrounding non-nodular but lithologically identical sediments. These nodules are broken with hand sledges in the field and most specimens are first observed in cross section. Fragmented nodules are reassembled in the laboratory and are then prepared mechanically.

Fossils are invariably found isolated, generally consisting of fragmentary dentitions or partial skulls, isolated teeth or postcranial remains, less frequently articulated limbs, and, in a few instances, complete skeletons. Fossils appear rather evenly dispersed throughout the fossiliferous horizon; although we have taken to harvesting nodules, we have found no single locality with concentrations of bone warranting quarrying.

TAXONOMIC ANALYSIS

Preparation has been sufficient to reveal wide taxic diversity, including representatives of five mammalian ordinal or superordinal groups (table 2). The most abundant element of the fauna is a suite of notoungulates, numbering approximately 15 taxa. Marsupials, edentates, a rodent, and a probable litoptern are also represented. Nonmammalian tetrapods are not presently known from the fauna.

Of the nearly 400 specimens collected in the Termas del Flaco region to date, an unusually large fraction consists of jaws, skulls, and partial skeletons. Induration of the encasing volcanoclastic matrix makes preparation of these specimens difficult and time intensive; consequently nearly half of our collection currently remains unavailable for detailed study. Offsetting this disadvantage is the preservation and completeness of the material, which is often excellent. Specimens of exceptional quality include crania and partial skeletons of two families of edentates, crania and partial skeletons of members of at least three notoungulate families (Archaeohyracidae, Notostylopidae, and Interatheriidae), and nearly complete jaws of at least three higher-

TABLE 2

Taxonomic List for the Tinguiririca Fauna
(Identifications are based on direct comparison with relevant collections in North and South American museums.)

Marsupialia
?Groeberiidae
new genus and species
?Argyrolagidae
new genus and species
Polydolopidae
<i>Polydolops</i> , new species
Didelphimorphia incertae sedis
new genus and species
Eutheria
Edentata
?Dasypodidae incertae sedis
Phyllophaga
<i>Pseudoglyptodon</i> , new species
Litopterna
Indaleciinae
new genus and species
Rodentia
?Dasyproctidae
new genus and species
Notoungulata
Notostylopidae
new genus and species
Interatheriidae
"Notopithecinae"
new genus and species
Interatheriinae
new genus and species A
new genus and species B
Archaeohyracidae
<i>Pseudhyrax</i> cf. <i>eutracytheroides</i>
cf. " <i>Bryanpattersonia sulcidens</i> "
new taxon A
new taxon B
new taxon C
new taxon D
Homalodotheriidae
<i>Trigonolophodon</i> cf. <i>elegans</i>
Notohippidae
"Rhynchippinae"
<i>Eomorphippus</i> , new species
" <i>Eomorphippus</i> " cf. <i>pascuali</i>
new taxon A
new taxon B
Isotemnidae incertae sedis

level marsupial groups (Didelphimorphia inc. sed., Polydolopidae, ?Argyrolagidae, and ?Groeberiidae).

The faunal description provided below is necessarily incomplete and provisional, with

a more comprehensive analysis awaiting preparation of a greater percentage of available material. Nevertheless, the fauna is sufficiently important to warrant a brief discussion of its major components, updating and elaborating upon a preliminary faunal list published previously (Wyss et al., 1990).

In the following discussion taxa are identified to the degree of specificity allowed by existing nomenclature. Although the majority can be diagnosed as new with specimens presently in hand, because ongoing preparation will improve representation of many of them, we postpone their formal recognition. Our use of traditional family endings for many of the higher-level taxa discussed is only for convenience, and is not intended to imply equivalence of cladistic rank.

MARSUPIALIA

?Groeberiidae, new genus and species. A highly distinctive new taxon represented by several partial mandibles (e.g., SGOPV 2993, 2997), this find probably marks only the second occurrence of this enigmatic group of marsupials. The type and previously only known taxon *Groeberia minoprioi* (Patterson, 1952), now represented by excellent cranial remains (Goin, 1988–89; Pascual et al., in press), is restricted to the Divisadero Largo Formation of west-central Argentina. Although the two forms show numerous morphological differences, among adequately known South American marsupials the Tinguiririca form appears to show closest affinities to *G. minoprioi*. Synapomorphic resemblances include the medial (relative to the cheek tooth row) position of the posterior end of the greatly enlarged lower incisor, plus a distinctive bilobate molar crown pattern with well-developed lingual and buccal flexids and similar paraconid development, and it is on this basis that we provisionally refer the Chilean form to the Groeberiidae. In contrast to *G. minoprioi*, the Tinguiririca groeberiid has a relatively shallow mandibular ramus, only three lower molars, and a distinctive peglike last premolar.

One upper dentition (SGOPV 2952) consisting of three molars and a pair of incompletely preserved, high crowned, posteriorly curved incisors is perplexing. This dentition

matches in size, and is of the correct general morphology, to suggest association with the mandibles just described. The preserved portions of its incisors (basically the labial faces of an enlarged anterior tooth, followed by a smaller tooth of essentially similar form) are reminiscent of *G. minoprioi*. The occlusal pattern and shape of the molars of this specimen, however, are unlike those of any marsupial known to us. In sharp distinction to triangular-shaped upper molars of *G. minoprioi*, those of the Tinguiririca form are rectangular in outline, the long axis aligned parallel to the tooth row. This unusual upper dentition either: 1) belongs to the taxon represented by the groeberiid lowers and is simply highly autapomorphic; 2) represents uppers of the argyrolagid recognized tentatively below; or 3) represents neither an argyrolagid nor a groeberiid, but a patagoniid (Pascual and Carlini, 1987), or a new gliriform marsupial.

?Argyrolagidae, new genus and species. Argyrolagids represent another poorly known endemic clade of South American marsupials, the earliest previously known occurrence of which is incomplete mandibular material from the Deseadan of Bolivia (Wolff, 1984). We provisionally refer one laterally crushed mandible (SGOPV 2860) from the Tinguiririca Fauna to the family. Although its present state of preparation and poor preservation do not permit us to rule out its reference to the new groeberiid discussed above, there appear to be subtle differences. If an argyrolagid identification is substantiated by additional preparation and/or enamel microstructural analysis, this would represent the oldest known occurrence for the group. Also, as discussed with reference to the probable groeberiid above, an upper dentition (SGOPV 2952) possibly pertains to this family.

Polydolopidae: *Polydolops*, new species. A new species of *Polydolops* is represented by a mandible (SGOPV 2941) preserving a complete dentition (see Wyss et al., 1990: fig. 4a). An enlarged procumbent ?canine and a "plagiulacoid" blade immediately identify this specimen as a polydolopid. The lack of incisors, a strong labial rib on p3, and retention of p1 permit assignment of this new species to *Polydolops*, indicating closest affinities to *P. mayoi* and *P. thomasi*. Of these two spe-

cies, the Tinguiririca form appears to be most similar to, but is differentiable from, the former (Flynn and Wyss, 1990).

Recognizing that its fragmentary nature precluded definitive assignment, Patterson and Marshall (1978) tentatively identified a large, edentulous, anterior mandibular fragment (PU 21998) from the Deseadan of Bolivia as a polydolopid, the only then recorded post-Mustersan record for the family. Marshall (1982) tentatively referred this specimen to *Polydolops* itself, a decision reversed with the description of a large, fragmentary paleothentine from Salla, and referral of PU 21998 to it (Villarroel and Marshall, 1982). Hence there is no positive evidence for a Deseadan occurrence of polydolopids, and the new Tinguiririca taxon represents (with one doubtful exception, see below) the last appearance of the family.

Discussion of an important fossil mammal collection made early this century by Santiago Roth from Cañadón Blanco (Chubut, Argentina) will be taken up in a subsequent section. It is relevant to note here that Roth's collection includes one polydolopid mandibular fragment (MLP 52-XI-4-176), referred by Marshall (1982), thinking it was Mustersan in age, to *P. mayoi*, an otherwise restricted Mustersan taxon. MLP 52-XI-4-176 is clearly referable to *P. thomasi*, however, typically a Casamayoran taxon (we are grateful to M. Bond for pointing this out). The Cañadón Blanco polydolopid is probably not associated stratigraphically with the bulk of the specimens known from this locale (see below), making this the last known appearance for this family.

Didelphimorphia incertae sedis, new genus and species. An enigmatic didelphimorphian is represented by a small mandibular mold (SGOPV 2944) containing only minor enamel fragments but good impressions of much of the dentition. We have cast an epoxy resin "positive" of this mold, making it possible to discern crown morphology in considerable detail. The preserved tooth row base of p2-m4 is approximately 11 mm in length. The last molar is the smallest in the molar series; its lingual face is aligned with the lingual edge of the remainder of the cheek tooth series. The talonids are notably broad, and the trigonids relatively low with paraconids and

metaconids closely spaced; cingulae are essentially absent. Exclusive of borhyaenids and polydolopids, the Eocene through early Miocene record of South American marsupials is virtually nonexistent, thereby precluding extensive comparison of this specimen with roughly contemporaneous taxa. The specimen exhibits a mixture of features (some of which cannot be determined with certainty from the cast) allying it with any number of higher level marsupial taxa. We have examined casts of most of the marsupials from the Paleocene of São José de Itaboraí, Brazil, and illustrations of specimens from the Tiu-pampa Fauna of Bolivia (Muizon, 1991), and the Tinguiririca form agrees closely with none of them. Likewise, the Tinguiririca form shows no close similarities with any of the Neogene taxa we have had available for comparison. For the moment, therefore, we can identify this specimen with no greater specificity than *Didelphimorphia incertae sedis*.

EUTHERIA

Edentata: Dasypodidae incertae sedis. Dasypodids are a fairly common element of the Tinguiririca Fauna. We have recovered several articulated carapace fragments; a few of these are greater than 50% complete and contain large portions of the remainder of the postcranial skeleton. A relatively poorly preserved partial cranium (SGOPV 2848) with at least one articulated mandible is known from the collection. As little of the scute surface detail is presently visible, we can only state that the material is clearly not glyptodontid.

Phyllophaga: Pseudoglyptodon, new species. One specimen consisting of a partial cranium (SGOPV 2995) with articulating mandibles of this enigmatic taxon has been recovered; it preserves a complete dentition and partial auditory regions (see Wyss et al., 1990: fig. 4b). *Pseudoglyptodon* is known from a partial mandible (PU 20552) from the Deseadan of Bolivia (Engelmann, 1987). A very similar mandibular fragment bearing one and a third teeth from the Mustersan of Patagonia (AMNH 29483) was figured by Simpson (1948: 93) who assigned it to the Glyptodontidae, doubtfully to *Glyptatelus*. Engelmann did not make comparisons to this latter spec-

imen, but it is clear that it and PU 20552 are very closely related. *Glyptatelus* Ameghino, 1897, is based on isolated (glyptodontid) scutes, justifying Simpson's hesitance to refer dental material to it, and Engelmann's recognition of a new taxon *Pseudoglyptodon* (to which the Mustersan AMNH 29483 is referable). In addition, the Tinguiririca specimen confirms Engelmann's allocation of PU 20552 to the Phyllophaga, and clarifies the familial placement of AMNH 29483. The Tinguiririca specimen is distinct (at least at the species level) from the Salla form (McKenna et al., in prep.); more importantly, it adds greatly to morphological knowledge of the early diversification of sloths.

Litopterna: Indaleciinae, new genus and species. Although its ordinal placement is still open to question, a small, well-preserved mandibular fragment containing p4-m3 (SGOPV 3072) represents the only possible litoptern presently known from the Tinguiririca Fauna. Among recognized litopterns and didolodontoids, this specimen clearly pertains to the Indaleciinae, a relatively poorly known group which until recently has been considered one of two major subdivisions of the adianthid litopterns (Cifelli and Soria, 1983). Among members of the Indaleciinae, the Tinguiririca form most resembles *Indalecia grandensis* from the Casamayoran of northwestern Argentina (Bond and Vucetich, 1983), although much of this similarity reflects shared plesiomorphy. In light of its age, it is interesting to note that the Tinguiririca form shares no apparent apomorphies with the youngest previously known indaleciine *Adianthoides leali* from the Divisaderan of west-central Argentina, nor does it share apparent apomorphies with the other known member of this genus, *A. magnus* from the Casamayoran of Patagonia (Cifelli and Soria, 1983). If the Tinguiririca form shares special affinities with any other known indaleciine, it is instead with the more northerly *Indalecia*.

A recently proposed phylogeny of archaic South American ungulates and litopterns (Cifelli, 1993) bears on the ordinal allocation of SGOPV 3072 and therefore requires brief comment. As noted, indaleciines have traditionally been allocated to the Litopterna, usually to the family Adianthidae.

In a study proposing assignment of disassociated proximal tarsal bones from Riochican fissure fills of Itaboraí to dental species from the same locality, Cifelli (1983) has convincingly shown that some dentally "primitive" (i.e., didolodontoid-like) taxa possessed diagnostic litoptern ankle specializations. More central to the question addressed here, Cifelli concluded also (although with less confidence) that one dentally "advanced" (i.e., litoptern-like) taxon, *Victorlemoinia*, was associated with a distinctive didolodontoid ankle. As pointed out by Cifelli, however, several Itaboraí taxa represented by teeth are unknown pedally, suggesting that the converse might also be true; some taxa known from pedal remains might not be represented by teeth. Although this poses a problem particularly for taxa known from relatively few specimens such as *Victorlemoinia*, the proposed association was nevertheless favored, with *Victorlemoinia* being excluded from the Litopterna on that basis (Cifelli, 1983).

In an extensive recent numerical cladistic analysis of these groups, therefore, *Victorlemoinia* was scored assuming its filiation with a didolodontoid ankle (Cifelli, 1993). Maximally parsimonious trees placed *Victorlemoinia* within a dentally plesiomorphic grouping termed the Didolodontoidea, along with *Adianthoides* and *Indalecia* (neither of which is known postcranially), which are placed as the most immediate outgroups to *Victorlemoinia* itself. To determine to what degree this unexpected exclusion of *Adianthoides* and *Indalecia* from not only the Adianthidae, but also from the Litopterna, is based on the assumed *Victorlemoinia* dental/ankle association, we reanalyzed Cifelli's (1993) data matrix using PAUP (Swofford, 1990), scoring *Victorlemoinia* as unknown for postcranial features. This resulted in grouping of the *Victorlemoinia*, *Adianthoides*, *Indalecia* triad with litopterns (but, interestingly, not near adianthines). *Adianthoides* and *Indalecia* were placed in a similar position within the Litopterna when *Victorlemoinia* was simply deleted from the analysis. Pending a more detailed review of the evidence originally used in referring didolodontoid tarsals from Itaboraí to *Victorlemoinia*, we believe there is sufficient uncertainty about whether these elements might be ascribed to

a didelodontoid unrepresented by teeth, to warrant continued placement of this taxon, *Adianthoides*, *Indalecia*, and the new *Tinguiririca* form in the Litopterna. Although we differ on the question of ordinal placement, we share Cifelli's (1993; Cifelli and Soria, 1983) doubts that these taxa (Indaleciinae), are closely related to adianthines, therefore leaving familial allocation of the new taxon unspecified.

Rodentia: ?Dasyproctidae, new genus and species. Undoubtedly the most unexpected, as well as one of the scarcest, elements of the Tinguiririca Fauna is its rodent. Our first extensive season of collecting produced several specimens identified from cross-sectional views in the field as possible members of this order. As a few of these specimens were prepared it became evident that they represented the gliriform marsupials described above. Meanwhile, other elements of the fauna began to point to its pre-Deseadan age (see below), and the remaining "presumptive rodents" slipped in preparation priority due to increasing duplication of material of the marsupial taxa. Our earlier claim (Wyss et al., 1990) that the Tinguiririca Fauna predates the immigration of rodents to South America was overturned when a mandible (SGOPV 2933) indisputably pertaining to this order was revealed by subsequent preparation (Wyss et al., 1993).

Aside from the anterior end of the incisor and most of p4, the mandible is essentially complete. The cheek teeth are worn, but moderate hypsodonty allows a considerable amount to be inferred about their original morphology. The combined length of m1-3 is approximately 13 mm. In its development during wear of three medially placed, isolated, enamel lakes on m2-3, the Tinguiririca rodent, although approximately 20% smaller, most closely resembles *Branisamys* from the Deseadan of Bolivia. Otherwise, the Tinguiririca rodent does not invite close comparison to any described Deseadan forms from either Patagonia or Bolivia. *Branisamys* is variously allocated to the Dinomyidae (Wood and Patterson, 1959; Patterson and Wood, 1982) and to the Dasyproctidae (Lavocat, 1976), a discrepancy owing principally to differing interpretations of ancestral caviomorph dental morphology. Although we re-

serve more detailed comment on this well-known controversy for a future paper, initial analysis leads us tentatively to favor the latter assignment.

Biostratigraphic and radioisotopic evidence (see below) clearly indicates that the Tinguiririca rodent represents the earliest record for the order in South America (Wyss et al., 1993). In addition to substantially increasing the minimum age of arrival of rodents on the continent, the Tinguiririca rodent offers important new information regarding the dental morphology of an early representative of the South American endemic rodent radiation.

NOTOUNGULATA

Notostylopidae, new genus and species. A partial palate (SGOPV 2906) preserving complete and unworn P4-M2, nearly complete M3, and additional tooth fragments, records the presence of this family. In size and morphology the Tinguiririca notostylopoid is most closely comparable to *Otronia muehlbergi* from the Mustersan of Chubut Province, and *Boreostylops lumbrerensis* (Vucetich, 1980) from the Casamayoran of Salta Province Argentina. These two taxa plus the Tinguiririca form are unique among notostylopoids in the presence of a papillate mass derived from the ectoloph, which occupies the crochet region. The Tinguiririca form is distinctive, however, in its more strongly developed metacone, more salient paracone and parastyle, better developed cingula, and its rugose cuspidate protocone base.

With one possible but unlikely exception (see below, and under Faunal Comparisons) notostylopoids are restricted elsewhere to Mustersan and older deposits; given its post-Mustersan age, the Tinguiririca occurrence is probably the latest known for the family. In this context, attention is called to a mandible (MLP 12-1511) from Cañadón Blanco described as a notostylopoid, *Orthogenium ameghinoi*, by Roth (1901), amended (due to preoccupation) to *Orthogeniops ameghinoi* (Ameghino, 1902). In discussing this taxon, Simpson (1948: 171), indicated that "*Orthogenium* is probably of Deseado age and is not a notostylopoid," a statement apparently based on unpublished correspondence from Patter-

son (on file at MLP). Indeed, among the specimens from Cañadón Blanco available to Patterson, the one most closely matching Roth's description, MLP 12-1516 (not numbered in Roth's time, but apparently cataloged as *Orthogenium* when examined by Patterson), is an archaeohyracid. MLP 12-1511 clearly pertains to a notostylopid, although it appears that *Orthogeniops* does not represent a valid taxon (Bond and Reguero, personal commun.). Because the Cañadón Blanco notostylopid is known only from a partial lower dentition, it cannot be compared directly with the Tinguiririca form (presently known only from uppers). The approximate length of p4-m3 of MLP 12-1511 (32 mm) is equal to the length of M1-3 in the Tinguiririca form. The latter therefore seems slightly too large to pertain to "*Orthogeniops*." Because the anterior-posterior dimensions of the upper teeth in the Tinguiririca form would have decreased significantly with wear, however, we caution that referral to the taxon represented at Cañadón Blanco is not certainly excluded.

Interatheriidae: Three interatheriids, including members of both currently recognized subfamilies, "*Notopithecinae*" and *Interatheriinae*, are currently known from the Tinguiririca Fauna.

"Notopithecinae," new genus and species. A new, diminutive taxon is represented by several nearly complete jaws and at least one partial cranium preserving an auditory region. As the "*Notopithecinae*" is typically regarded as a group of "early [pre-Deseadan] and primitive" interatheriids (Simpson, 1967: 74) and lacks an apomorphy-based diagnosis, we employ its subfamilial designation in quotes to highlight its likely paraphyletic status.

Perhaps the most notable characteristic of the Tinguiririca "notopithecine" is its mere presence in what is clearly a post-Mustersan fauna (see discussion below). In addition to its late occurrence, the Tinguiririca "notopithecine" is remarkable for its small size; in most dental dimensions it is approximately half the size of *Guiliemoscottia* from the Mustersan of Patagonia, for example, previously the youngest known representative of the subfamily. The only smaller "notopithecine" is an undescribed form from Catamarca Province, northwest Argentina, of uncer-

tain early Tertiary (post-early Casamayoran) age (Pascual, 1983; Alonso et al., 1988), which is approximately 20% smaller than the Tinguiririca taxon. In addition to their size, the Catamarca and Tinguiririca forms share the distinctive resemblance of marked simplification of the internal crown pattern. All cristae and fossettes disappear from the cheek teeth in these two forms, leaving behind a featureless occlusal surface after even only moderate wear.

Interatheriinae, new genus and species, A, B. Two interatheriines are known from the Tinguiririca Fauna, one from exquisite material. We are aware of no published diagnoses of this subfamily, cladistic or otherwise, but generally it is construed as including "advanced" (i.e., Deseadan and younger) interatheres. Pending complete formal description of these taxa, which will necessitate a rigorous analysis and diagnosis, we regard this assemblage as provisionally monophyletic.

The larger and more abundant of the two interatheriines (indeed, the most abundantly preserved taxon in the Tinguiririca Fauna), new genus and species A, is represented by several skulls (e.g., SGOPV 2821), complete dentitions, as well as multiple nearly complete postcranial skeletons (see Wyss et al., 1990: fig. 4c). There is considerable variation in size and details of morphology in the specimens now assigned to new taxon A, making it possible that two species are represented. The skull is approximately 95 mm in length and its general shape is highly reminiscent of *Notopithecus* (see fig. 23 in Simpson, 1967). It displays the hallmark interathere synapomorphy, a splintlike jugal sandwiched between maxillary and squamosal contributions to the zygomatic arch (Riggs and Patterson, 1935). Establishing the interatheriine affinities of this taxon are its large size and reduction of external ribbing on the upper cheek teeth. In previously known early interatheriines, a deep, vertically oriented lingual cleft separates the protoloph and metaloph of the upper molars and posterior premolars, persisting even after extensive wear. By contrast, in new taxon A a narrow lingual groove is lost after only moderate wear, resulting in an undivided internal surface of these teeth; this condition is doubtless primitive for the *Interatheriidae* (if not for a more

general group of notoungulates). Overall, interatheriine, new genus and species A appears to present a morphology intriguingly transitional between "notopithecine" and interatheriine interatheres.

At lower taxonomic levels, new taxon A does not closely resemble previously described members of the Interatheriinae. It is most similar to a number of specimens from a pre-Deseadan, post-Mustersan faunule known as Lomas Blancas (or La Curandera) [LBLC] from Patagonia, currently being described by Marcelo Reguero of MLP. Agreement between the Tinguiririca interatheriine new taxon A and the LBLC material is closest in the lower dentition; a maxilla (MLP 61-VIII-3-27) from LBLC appears to be considerably advanced relative to the Tinguiririca taxon.

The second, substantially smaller, Tinguiririca interatheriine, new taxon B, is currently represented by a single pair of partial mandibles (SGOPV 3065). As with the larger form, new taxon B does not invite close comparison with published forms. Disregarding small differences in size and crown height, new taxon B closely resembles only an undescribed form, known from a single specimen (MLP 12-1529) from Cañadón Blanco currently being described by M. Reguero. The Tinguiririca Fauna is the first known to record the co-occurrence of both traditionally recognized interathere subgroups, interatheriines making their first, and "notopithecines" their last, appearances.

Archaeohyracidae. Archaeohyracids constitute by far the most diverse element of the Tinguiririca Fauna. Indeed, containing no fewer than five and perhaps as many as nine distinct taxa, the Tinguiririca Fauna records an archaeohyracid diversity unprecedented among Cenozoic faunas of any age or location in South America. Uncertainty about the number of taxa represented owes primarily to the unknown association of upper and lower dentitions, and to similar size of most of the taxa. A few of these forms may, with varying degrees of confidence, be referred to previously known taxa. However, the majority appear to be new, most at supraspecific taxonomic levels. We consider below the taxa currently recognized; possible associations of upper and lower dentitions are discussed, but

generally we consider each form separately listed to be likely distinct.

Cf. "*Bryanpattersonia sulcidens*." The smallest archaeohyracid in the Tinguiririca Fauna is presently represented by a single prepared specimen, a mandible bearing p1-m3 (SGOPV 2954); additional material of this taxon (including an upper dentition) is suspected to be in the collection but remains encased in matrix. *Bryanpattersonia* was erected by Simpson (1967) to accommodate the presumed Mustersan taxa referred to *Archaeohyrax* by Ameghino. Of interest here is the smaller of Simpson's two recognized species, *B. sulcidens*, erected on the basis of specimens referred to *Archaeohyrax sulcidens* by Ameghino (1902) and to *A. gracilis* by Roth (1903), but considered conspecific by Simpson. SGOPV 2954 agrees very closely with a series of partial mandibles from Cañadón Blanco referred to *A. gracilis* by Roth. There are minor differences in tooth dimensions between the Tinguiririca and Cañadón Blanco material but these may be due to differences in wear. We postpone final decision on whether the Tinguiririca and Cañadón Blanco material is referable to the same species until additional Tinguiririca material becomes available for examination, and until completion of ongoing studies by M. Reguero clarifying the taxonomy of the Argentine taxa. For the moment, we simply note the close resemblance between the small Tinguiririca archaeohyracid and Roth's material from Cañadón Blanco. Using existing nomenclature, we therefore provisionally refer SGOPV 2954 to "*Bryanpattersonia sulcidens*," fully aware that the generic and perhaps specific designations of this material are likely to change in the near future. The Tinguiririca "*B. sulcidens*" is clearly distinct from the taxa listed below—i.e., none of the Tinguiririca archaeohyracids currently known from upper dentitions (new taxa A, B, D) matches this taxon in size.

Archaeohyracid new taxon A: A second Tinguiririca archaeohyracid is represented by a beautifully preserved rostrum (SGOPV 2823) with little worn teeth; other than its missing incisors and unerupted M3s, both sides of the upper dentition are complete. In general morphology, degree of hypsodonty, and molarization of posterior premolars this

taxon shows affinities to (but is probably distinct from) forms variously known as *Archaeohyrax propheticus* Ameghino 1897, *A. patagonicus* Ameghino 1897, *Archaeothyrotherium transitum* Roth 1902, *Bryanpattersonia nesodontoides* (Ameghino 1901) (genus erected by Simpson 1967), and *Archaeohyrax* sp. (MacFadden et al., 1985). As post-Mustersan archaeohyracids have not been revised for nearly a century, their nomenclature is in a considerable state of confusion; some of the names listed above doubtless represent synonyms. Whatever the resolution of these nomenclatural uncertainties, SGOPV 2823 appears not to pertain to any previously recognized species. Although the shape and dimensions of individual upper cheek-teeth vary considerably with wear in these taxa, comparisons of lengths of contiguous sections of the tooth row are probably more reliable indicators of true size differences among taxa. In comparison to the taxa listed above known from relatively complete material, such measures indicate SGOPV 2823 to be slightly (circa 5%) smaller than *A. patagonicus*, and 20% smaller than *A. propheticus*, but slightly larger than an unnamed species from Salla (MacFadden et al., 1985; personal obs.). No lowers are known to be certainly associated with this taxon but several unprepared specimens are likely candidates for referral.

In addition, we have recovered at least one skull (SGOPV 2900) which is possibly referable to this taxon. Although the dentition of this specimen is imperfectly preserved because of postmortem deformation, in general it appears similar but slightly smaller than SGOPV 2823 (in fact, in terms of size, SGOPV 2900 seems to agree closely with the Salla form). Either archaeohyracid new taxon A is characterized by strong dimorphism and/or variation, or this skull represents a distinct taxon. In view of the number of certainly distinctive archaeohyracids already known from the Tinguiririca Fauna, we conservatively consider SGOPV 2900 a small morph of new taxon A.

Archaeohyracid new taxon B: This highly distinctive taxon is currently represented by a single palate (SGOPV 2877). It is one of two possible (but probably the only) low-crowned archaeohyracids presently known

from the Tinguiririca Fauna (see new taxon D, below). I1 is greatly enlarged and strongly curved posteriorly. The tips of the opposite incisors meet but their roots are widely separated. It is unclear whether the posterior incisors, canines, and anterior premolars were absent or simply reduced; in either case a substantial diastema is indicated. From I1-M3 the tooth row measures approximately 66 mm. We defer more detailed analysis and description until the right side of this specimen has been prepared. For present purposes it suffices to note that its enlarged incisor and low-crowned cheek-teeth, particularly in the premolar region, sharply differentiate this taxon from all previously known Mustersan and Deseadan members of the Archaeohyracidae.

Archaeohyracid new taxon C: This archaeohyracid is represented by a fragmentary mandible (SGOPV 2901) bearing parts of four teeth, including (with minor damage lingually) most of m1-3. It is approximately the same size as specimens discussed below under *Pseudhyrax*, and shares some morphological similarities with that taxon. Setting SGOPV 2901 apart from all previously known archaeohyracids, however, is a bizarre anteroposteriorly shortened talonid on m2. The talonid of this tooth is roughly rectangular in outline, but its longest axis lies perpendicular to the tooth row, resulting in a structure roughly twice as wide as long. Adding to the tooth's peculiarity is its posteroexternal termination which forms a tight, nearly 90°, corner, in contrast with the smoothly curving form of this region of the talonid typical of other archaeohyracids. Although currently incompletely represented, archaeohyracid new taxon C is unmistakably distinct from any archaeohyracid known. Based on its overall morphology and complimentary size, SGOPV 2901 may represent the lowers to Archaeohyracid new taxon B, but this is presently speculative.

Archaeohyracid new taxon D: A largely complete palate (SGOPV 2851) may represent a second low-crowned archaeohyracid, but more likely is an extremely worn example of a high-crowned taxon represented by a maxilla (SGOPV 2918). SGOPV 2851 preserves a dentition complete except for both canines and the right incisor series; the entire

tooththrow measures approximately 63 mm. I1 is small relative to the condition seen in *Archaeohyrax patagonicus*, *A. propheticus*, new taxon B, and the skull tentatively referred to new taxon A. I2 and 3 are similar in shape to I1 but are only about one-half and one-third of the latter's size respectively; the three incisors are separated by short diastemata. A 10 mm wide gap separates the premolar and incisor series; it is not known whether this was interrupted by a canine, but even if it was, a significant diastema would have been present. The premolars are worn nearly to the roots; the molars retain 5–10 mm of crown thickness (measured on the external face).

We tentatively refer an unusual, extremely highly crowned, and only moderately worn maxilla (SGOPV 2918) bearing P2–M3 to new taxon D. Apart from being within about 30% of the same size, SGOPV 2918 and SGOPV 2851 appear utterly dissimilar at first glance. The molars of SGOPV 2918 are particularly notable for their extreme hypsodonty and highly bowed form. The crown height of M3, measured from the center of the ectoloph at the wear surface to the base of the roots along the tooth's curved external face, is approximately 27 mm. Although this contrasts sharply with the condition seen in the palate SGOPV 2851, the "low-crowned" morphology of the latter specimen is plausibly derived from the hypsodont morphology represented by SGOPV 2918 through extreme wear. The strongest indicators of such a relationship are the concave form and texture of the external face of the base of the molars, and general cheek-tooth outlines. SGOPV 2918 is substantially larger than SGOPV 2851, regardless of how much wear is envisioned. Nevertheless, we conservatively allocate these two specimens to the same taxon pending recovery of material in an intermediate wear state or preserving the anterior dentition of a less worn individual. Several lower jaws (e.g., SGOPV 2917) correspond closely in size and degree of hypsodonty to the less worn of the two upper dentitions just described.

Pseudhyrax sp.: Two poorly known but nonetheless distinct morphs are, to all appearances, assignable to *Pseudhyrax*. Both are represented by single mandibular fragments bearing m2–3. The smaller form, SGOPV 2887, is a slightly bigger than average *P.*

strangulatus (compared to numerous specimens referred to this taxon housed at the MLP), a smaller than average *P. euthrachytheroides*, or a new species of *Pseudhyrax*. Choice between these alternatives must await revision of *P. strangulatus* and *P. euthrachytheroides* in progress by M. Bond, and the establishment of ranges of variation for the large single-locality samples now available for these taxa.

The larger morph, represented by SGOPV 2985, agrees almost exactly in size and morphology with typical sized specimens of *P. euthrachytheroides* from the Mustersan of Patagonia (Bond, in prep.), and the Chilean form is therefore reasonably referred to this species. No upper dentitions obviously referable to *Pseudhyrax* occur in the Tinguiririca Fauna. Given the generally conservative morphology of archaeohyracid lower dentitions, however, it is conceivable that the lowers of the taxa represented by SGOPV 2887 and 2985, although indistinguishable from *Pseudhyrax*, are actually the counterparts of other taxa discussed in this section currently known only from uppers.

The Tinguiririca archaeohyracid collection is by far the most important known. It greatly extends knowledge of the family, both in terms of taxonomic diversity and morphological completeness. The skulls (in addition to SGOPV 2900 we have at least two more unprepared archaeohyracid crania) are the earliest known. Prior to discovery of the Tinguiririca Fauna only a single archaeohyracid cranium was known (Ameghino's holotypic material for *Archaeohyrax patagonicus*). Unprepared cranial material promises to clarify possible associations of upper and lower dentitions discussed above, permitting a more accurate appraisal of the unprecedented diversity represented. In addition, the Tinguiririca Fauna provides the first associated postcranial material for the family.

Homalodotheriidae. *Trigonolophodon* cf. *elegans*: The posterior ends of a pair of large mandibles (SGOPV 2820) record the occurrence of a homalodothere in the Tinguiririca Fauna. In size and morphology SGOPV 2820 is virtually identical, in the few elements comparable, to the syntype of *Trigonolophodon elegans* (MLP 12-1727), an excellent mandible including symphysis from Caña-

dón Blanco (Roth, 1903). We have been unable to examine the other species of this taxon named by Roth from the same locality in the same publication (*T. modicus*, *T. inflatus*), but dimensions presented by Roth would seem to rule out the former—we provisionally refer SGOPV 2820 to *T. elegans* because of their close resemblance. *Trigonolophodon* species have never been revised and seem to have been nearly universally ignored. Several specimens of homalodotheri upper molars (which we previously attributed to *Periphragnis*, Wyss et al., 1990) are represented in the Tinguiririca Fauna; it seems reasonable to refer them to the same taxon. Unfortunately we have not yet been able to compare these upper molars with the specimens collected by Roth.

Notohippidae. Four notohippids are presently known in the Tinguiririca Fauna, all members of the undoubtedly paraphyletic “Rhynchippinae.” The Chilean specimens sort into two size classes, each including an “advanced” and a “primitive” form. Our discussion begins with the currently best known form, the large “advanced” type, and proceeds in order of decreasing size.

Eomorphippus, new species. A relatively large notohippid is represented by a rostrum preserving a complete upper dentition (SGOPV 3046), at least one nearly complete lower dentition, as well as some additional mandibular fragments. This taxon is similar (and undoubtedly closely related to) but distinct from MLP 12-1508, the type of *Eurystomus stehlini* Roth, 1901, referred (on Patterson’s recommendation) by Simpson (1967) to *Eomorphippus obscurus* Ameghino, 1901. The Tinguiririca form differs from MLP 12-1508 principally in being approximately 20% larger, in having a slightly more reduced upper canine, and in minor differences in upper incisor widths. Otherwise, the two forms are extremely similar in tooth crown morphology and high degree of hypsodonty (including the incisors).

For several reasons, *E. obscurus* is probably latest Mustersan or younger in age, rather than a typical Mustersan taxon as it is usually considered. *E. obscurus* is best known from the post-Mustersan, pre-Deseadan (at least in part) Cañadón Blanco fauna (see below), but also occurs elsewhere in the Mustersan of

Patagonia. It is significant to note that some (if not all) of these other occurrences are likely from “late” rather than typical Mustersan horizons (Bond, personal commun.). Some Ameghino specimens, for example, are labeled as coming from “Partie la plus supérieure de couches à *Astraponotus*” (latest Mustersan in current terminology), and Simpson (1967: 185) made special mention that his specimen likely referable to this taxon (AMNH 29462) was collected from high within his Mustersan section. Moreover, *E. obscurus* is not known from typical Mustersan deposits that have been well sampled and collected intensively by Rosendo Pascual, his students and colleagues, during the past three decades in Patagonia. Again, we are indebted to M. Bond for this information.

Notohippid new taxon A. A second relatively large, but far more poorly known notohippid occurs in the Tinguiririca Fauna. It is currently represented by a distinctive partial upper incisor battery (SGOPV 3004); the closed incisor arcade indicates its notohippid affinities. A maxillary fragment with two teeth (P4-M1) roughly three-quarters complete (SGOPV 2883) may represent the same taxon. Little may presently be said about this taxon, but it clearly does not pertain to *Eomorphippus*, new species, described above (although it is approximately the same size), nor does it closely resemble any known notohippid. In contrast to *E. obscurus* and *E.*, new species, the incisors are low-crowned (enamel is restricted to the tips and does not extend to the roots), and the canine is similar in size and shape to the incisors. Similarly, the cheek-teeth of this taxon are much less hypsodont than their counterparts in *E. obscurus* and *E.*, new species.

“*Eomorphippus* cf. *pascuali*.” A fragmentary maxilla preserving P2 through the anterior half of M1 and an erupting M3 (SGOPV 2991), plus an isolated m3 (SGOPV 3096) represent a taxon provisionally referable to “*Eomorphippus pascuali*.” The taxonomy of “rhynchippine” notohippids is badly in need of revision and is plagued with inadequate types, greatly complicating proper designation of the Tinguiririca material. *E. pascuali* was erected by Simpson (1967) on the basis of a maxilla (AMNH 29405) selected as its type, and a mandible (AMNH 29474) doubt-

fully referred, collected from the same locality (high in the Mustersan section) that produced AMNH 29462 (see above). It is clear, however, that *E. pascuali* (whether or not AMNH 29474 is correctly referred) is only relatively distantly related to the only other recognized species of *Eomorphippus*, and therefore warrants a different generic designation. M. Bond has identified the distinctiveness of a taxon previously placed in synonymy with *Eomorphippus* (Simpson, 1967), and its similarity to specimens currently referred to *E. pascuali*; pending his formal resurrection of that name (which has priority over *E. pascuali*), we employ current nomenclature, inadequate as it is. Thus, while SGOPV 2991 is referable (or is very closely related) to specimens currently identified as *Eomorphippus pascuali*, both halves of this binomial are subject to change in the near future.

Notohippid new taxon B. A fourth notohippid from the Tinguiririca Fauna is presently known from a pair of mandibles (SGOPV 2855) preserving at least one representative of each tooth position except the canine and p1. Notohippid new taxon B is strikingly similar in most comparable morphological details to the taxon described above as *Eomorphippus*, new species, but is only slightly greater than one-half its size. Otherwise it is quite unlike any other known notohippid. This taxon may therefore represent a second new species of *Eomorphippus*, or a distinct generic-level taxon; choice between these alternatives awaits recovery of referable upper dental remains and a systematic analysis of the taxa involved.

Isotemnidae, incertae sedis. Several mandibular fragments, a partial mandibular mold, and other fragmentary dental remains referable to this family have been recovered from the Tinguiririca deposits. These specimens are generally too incomplete to allow confident identification, but one appears to agree rather closely with *Rhyphodon*. More precise taxonomic assignment of the Tinguiririca isotemnid(s) must await collection and preparation of additional material.

FAUNAL COMPARISONS

South American mammal faunas bracketing the Eocene-Oligocene transition in-

clude the relatively poorly known ?middle Eocene Mustersan (known almost exclusively from Argentine Patagonia), the very incompletely known and peculiar ?Eocene-Oligocene Divisaderan (west-central Argentina—the age of neither of these SALMAs is constrained by independent dating), and the presumably slightly younger and much better represented Deseadan (known also primarily from Argentine Patagonia and the Salla beds of Bolivia) (Simpson et al., 1962; Hoffstetter, 1976, MacFadden et al., 1985). Whether the Divisaderan is in fact distinct from the Deseadan has recently been questioned (MacFadden et al., 1985; Marshall et al., 1986—but see Bond, 1991 for contrary view). Moreover, there remains considerable disagreement about temporal calibration of the Deseadan (ibid.). Nonetheless, a growing body of radioisotopic and paleomagnetic data suggest most or all of the Deseadan SALMA to be significantly younger than early Oligocene (MacFadden et al., 1985; Sempere et al., 1990; Flynn and Swisher, in prep.), its traditional placement, a view consistent with results presented here. The enormous length of time encompassing the poorly known interval between the Mustersan and Deseadan SALMAs (likely 15–25 m.y., depending on which calibration of the Deseadan is accepted), is relevant to the comparisons presented below.

Biostratigraphic evidence indicates the Tinguiririca Fauna to be neither Mustersan nor Deseadan in age, but to represent some intermediate interval not corresponding to the Divisaderan either (Wyss et al., 1993). Ruling out assignment of the Tinguiririca Fauna to the Mustersan (or older SALMAs) is the occurrence of numerous higher-level taxa known elsewhere only from Deseadan and younger faunas. These include interatheriine interatheres, Rodentia, members or close allies of the genus *Archaeohyrax*, and perhaps argyrolagids. Arguing against assignment of the Tinguiririca Fauna to the Deseadan or younger faunas is the occurrence of taxa not certainly known elsewhere from post-Mustersan faunas including notostylopids, “notopithecids,” polydolopids, and *Pseudhyrax*. With the caveat necessary for all cases of negative evidence, it is important to point out a few characteristically commonly preserved Deseadan taxa absent from the

Tinguiririca Fauna. Hegetotheres, *Pyrotherium*, advanced members of the Interatheriinae (including for example *Plagiarthrus*), notohippine notohippids, mesotheres, nesodontine toxodonts, caenolestids, and glyptodontids are all unrecorded in the Tinguiririca Fauna.

Aside from their containing markedly different groeberiids and indaleciines, the Tinguiririca and Divisaderan faunas share few taxonomic resemblances. Oldfieldthomasiid notoungulates, the dominant element of the Divisaderan fauna, are unknown in the Tinguiririca Fauna. Beyond stating that the Tinguiririca Fauna and the Divisaderan are obviously distinct, significant difficulties and contradictions are encountered in attempting to place the two faunas in any temporal sequence. These problems will be taken up after further consideration of the Tinguiririca Fauna relative to the much better known Deseadan SALMA.

The Tinguiririca Fauna shares two important resemblances with the Deseadan, neither of which necessarily indicates, however, an assignment of the fauna to that SALMA. It is remarkable that a rodent is known from the Tinguiririca Fauna—this marks the first known co-occurrence of the gliriform marsupials Polydolopidae and Groeberiidae, with true members of the superorder Glires, for example (Wyss et al., 1993). By itself, the biostratigraphic evidence set forth above strongly indicates the Tinguiririca Fauna to predate the Deseadan, implying that the Tinguiririca form is the earliest known rodent on the continent.

Because of their high diversity in known Deseadan faunas (with more than a dozen taxa from as many as six families currently recognized), rodents are generally believed to have arrived in South America substantially earlier than strict reading of their fossil record would suggest. This is indicated both by their high diversity at first appearance in Deseadan strata, and by recognition that this debut follows a lengthy hiatus, which has led to a longstanding expectation that pre-Deseadan rodents would eventually be found. In agreement with biostratigraphic evidence, it is of interest that the Tinguiririca form is not clearly assignable to, or obviously closely allied with, any previously known Deseadan

rodents (Wyss et al., 1993). Geochronologic evidence further substantiates a pre-Deseadan age for the Tinguiririca rodent (ibid.). In sum, several independent lines of evidence suggest that the Tinguiririca rodent is pre-Deseadan in age.

Similarly, the joint occurrence of *Pseudoglyptodon* in the Tinguiririca Fauna and the Deseadan of Bolivia cannot be used to argue for a Deseadan age assignment for the former. It may be recalled that in addition to the occurrence of *Pseudoglyptodon* at Salla, a very similar Mustersan mandibular fragment (AMNH 29483), doubtfully referred to *Glyptatelus* by Simpson (1948), almost certainly pertains to *Pseudoglyptodon* (McKenna et al., in prep.). Hence *Pseudoglyptodon* is not restricted to the Deseadan, and its presence in the Tinguiririca Fauna does not require reference to that interval.

Although primates are not presently known from the Tinguiririca Fauna, the group's rarity in the South American fossil record gives cause for optimism that they may yet be found. If, as is often assumed, rodents and primates arrived in South America roughly simultaneously, these hiatus-filling deposits from the Tinguiririca valley of Chile afford what is perhaps the most promising opportunity for discovery of platyrrhine primates significantly older than those presently known.

As repeated references to close morphological similarities in many of the taxonomic descriptions above suggest, the Tinguiririca Fauna appears most closely related temporally to a collection of specimens described by Santiago Roth between 1901 and 1903 from a locale currently referred to as Cañadón Blanco (but as "Terciario inferior de Cañadón Blanco" by him). Because this fauna has largely been ignored since then, a brief account of its history is warranted.

Several factors have contributed to obscure the significance of Roth's relatively small collection from Cañadón Blanco. First, most of Roth's taxonomic descriptions for this fauna were intended only as brief, preliminary notes, consisting of no more than a few sentences, providing only rudimentary anatomical and mensural information, and lacking illustrations. Second, Roth, a rival of the Ameghinos, kept the location of many of his most

productive localities secret, and to this day Cañadón Blanco has not been relocated (it is known only to be within Chubut Province). And third, the taxonomic assemblage attributed to Cañadón Blanco was unlike any known until nearly a century later. This led to Patterson's suggestion (unpublished notes on file MLP, in—and adopted by—Simpson, 1967, e.g., pp. 13, 114) that contrary to Roth's affirmations, the Cañadón Blanco fauna was not derived from a single stratigraphic horizon, but represented a mixture of specimens from Casamayoran, Mustersan, and Deseadan age faunas. In subsequent descriptions, therefore, Cañadón Blanco specimens were variously allocated (on the basis of unstated but presumably "stage of evolution" criteria) Casamayoran, Mustersan, or Deseadan ages, and Roth's collection ceased to exist as a recognized fauna. We have studied Roth's collection at the Museo de La Plata firsthand and have found the bulk of it to be uncannily similar to the Tinguiririca Fauna, with several taxa identical at the species level (or nearly so) being shared. Discovery of the Tinguiririca Fauna has demonstrated rather conclusively, therefore, that most of Roth's Cañadón Blanco collection does indeed constitute a fauna.

Ongoing, more detailed description of the Tinguiririca Fauna by ourselves, and revision of the Cañadón Blanco fauna by M. Reguero of MLP, will define more precisely the degree of congruence between the two faunas. For now we wish merely to emphasize again the close similarity between *Eomorphippus obscurus* from Cañadón Blanco and *Eomorphippus*, new species, from Tinguiririca, the close correspondence between the taxon described above as *Interatheriinae*, new genus and new species B with an undescribed form from Cañadón Blanco, and the close similarity of the homalodother and "*Bryanpattersonia sulcidens*" from the two faunas. Apparent even from these preliminary comparisons is that a long sought fauna intermediate in age between the Deseadan and Mustersan was found by Santiago Roth—it simply took nearly a century to be recognized as such. Discovery of the Tinguiririca Fauna thus lends impetus to a renewed search for Cañadón Blanco.

Finally, it should be added that a small

residuum of specimens from Cañadón Blanco (including the notostyloid and polydoloid—see above) are suggestive of a Casamayoran age (Bond and Reguero, personal commun.). Unless similar forms are eventually identified in the Tinguiririca Fauna, caution dictates that we assume a small number of Casamayoran specimens "contaminates" the otherwise pre-Deseadan post-Mustersan Cañadón Blanco collection.

Pending the results of ongoing taxonomic analysis, we comment only briefly on the relative age of the Tinguiririca and Cañadón Blanco faunas. Age comparisons are complicated by incomplete knowledge of the Cañadón Blanco Fauna (in terms of numbers of specimens—small bodied taxa especially—and taxic diversity) relative to that from Tinguiririca, and the uncertain stratigraphic association of the Argentine specimens, raising the issue of which faunal differences are sampling artifacts and which are real. Thus it is difficult to judge the significance of the apparent absence from Cañadón Blanco of such "archaic" Tinguiririca forms as "notopithecids" and "*Eomorphippus pascuali*," and the apparent absence of such "progressive" Tinguirirican forms as the rodent and *Interatheriinae* new taxon A. Given these limitations, and instances of apparently conflicting data (a rodent in the Tinguiririca Fauna but apparent absence of the group at Cañadón Blanco, presence of an hegethere at Cañadón Blanco but not in Chile), all that can presently be stated with confidence is that the two faunas are very similar in age.

Temporal placement of the Divisaderan relative to other better known Eocene-Oligocene SALMAs is also not satisfactorily resolved and discovery of the Tinguiririca Fauna only increases this uncertainty. Since its recognition as a distinct SALMA (Pascual et al., 1965, 1966) the Divisaderan has been typically regarded as latest pre-Deseadan or earliest Deseadan in age, a view called into question by identification of the Tinguiririca Fauna as pre-Deseadan.

If "advanced" faunal elements from Divisadero Largo are emphasized for correlation, then at least partial equivalence with the Deseadan might be indicated. This has come to be the accepted view in some recent treatments of the problem (MacFadden et al.,

1985; Marshall et al., 1986), with *Trachytherus*, *Acamana*, and *Ethegetotherium* serving as proposed "taxonomic ties" between the Deseadan and Divisaderan [we recognize that at least some of these identifications are open to question (Bond, 1991), but accept them here for the sake of simplifying the discussion]. Alternatively, but not usually emphasized, if more "primitive" aspects of the Divisaderan fauna are considered, a closer correlation of it to older faunas is suggested (Bond, 1991). This would be indicated, for example, by the occurrence of oldfieldthomasiids and indaleciines in Divisaderan and Casamayoran SALMAs, and their absence in the Deseadan.

Discovery of the Tinguiririca Fauna (and acceptance of its pre-Deseadan age) introduces a new wrinkle to the Divisaderan problem. The Tinguiririca Fauna is not presently known to contain hegetotheres, mesotheres, or *Acamana*, all of which imply that it is older than the Divisaderan. Unlike the Divisaderan, however, the Tinguiririca Fauna lacks oldfieldthomasiids, it has a groeberiid that is "advanced" in certain respects relative to the Divisaderan *Groeberia*, and it contains such Deseadan elements as rodents and interatheriines not known from the Divisaderan. All possible temporal sequences of these faunas present certain inconsistencies which are being explored in ongoing work. On balance, we cannot discount the possibility that the Tinguiririca Fauna is younger than the Divisaderan, which would imply in turn that the Divisaderan is considerably older than generally believed (Bond, 1991).

FAUNAL DISCUSSION

A striking feature of the Tinguiririca Fauna is its domination by extremely high-crowned notoungulates, including several species of notohippids, interatheres, and archaeohyracids. Conspicuous in their absence are such low-crowned forms as oldfieldthomasiids, other "archaic" lineages such as archaeopithecids, and low-crowned representatives of the Archaeohyracidae, which characterize pre-Deseadan faunas elsewhere in South America (Pascual et al., 1985). The Tinguiririca Fauna thus represents the first South American mammalian community dominated by high-

crowned herbivores, a changeover likely related to climatic shifts and establishment of seasonally drier and more open habitats (e.g., grasslands and/or savanna woodlands; *ibid.*; Janis, 1989). From geochronologic data presented below, the Tinguiririca herbivore fauna appears to indicate that a shift to this type of dentition, accommodating an abrasive diet, occurred significantly earlier in South America than in various taxa on the northern continents.

Another intriguing feature of the Tinguiririca Fauna is that it documents a mixture of northern and southern South American faunal elements, reflecting early Cenozoic latitudinal biogeographical zonation, long advocated by Rosendo Pascual (see Pascual and Ortiz Jaureguizar, 1990, and references therein). In that contemporaneous deposits are unknown outside of Patagonia (i.e., in northern South America), and given its greater proximity to that southern region, it is not surprising that the bulk of the Tinguiririca Fauna is "Patagonian" in character. Less expected, perhaps, is the occurrence of a "notopithecoid," an indaleciine, and a groeberiid, all of which are either unknown in Patagonia or show closest affinities to northern representatives of these groups. Hence the peculiar mixture of taxa present in the Tinguiririca Fauna is probably attributable to temporal as well as geographic factors, its novel composition reflecting the sampling of previously poorly known time and latitudinal intervals.

GEOCHRONOLOGY

High levels of endemism preclude correlation of most of the South American Land Mammal Age succession to the global geologic timescale by traditional biostratigraphic methods. Aside from rare marine intercalations, magnetostratigraphy and radioisotopic dating provide the two most powerful means of global correlation for Cenozoic South American terrestrial deposits. Single crystal $^{40}\text{Ar}/^{39}\text{Ar}$ dates for horizons within, above, and below the fossil-bearing sequence at the Cerro Alto del Padre and El Fierro Pass localities (see Geographic Setting) are presented in table 3. Special significance attaches to these results because the Abanico Formation represents the single known post-Riochican,

pre-Deseadan mammal-producing unit containing datable volcanic horizons from anywhere on the South American continent. As such, these dates are particularly relevant to current disagreement about the lower temporal boundary of the Deseadan SALMA (see above). Multiple dates from within and immediately beneath the fossiliferous horizon indicate that the fauna is at least as young as about 31.5 Ma, meaning that the beginning of the Deseadan must be somewhat younger. Dates from basalts and sediments underlying, but within the same stratigraphic unit as, the fossiliferous horizon indicate that the faunal assemblage may be as old as late Eocene (circa 37.5 Ma), and might therefore span the Eocene-Oligocene boundary.

Recognition of a new interval of land mammal evolution: The Tinguiririca Fauna would appear to have several characteristics warranting its recognition as a distinct and biochronologically informative land mammal age. First, in its mixture of first and last appearances of several higher-level taxa, the Tinguiririca Fauna agrees almost exactly with what would have been predicted for an interval of this age. Second, the Tinguiririca Fauna is known from many exceptionally complete specimens and is taxonomically diverse, increasing its usefulness as a tool for correlation. Third, there already appears to be one known geographically distant locality (Cañadón Blanco) characterized by a very similar suite of taxa. And fourth, the fauna occurs in sediments that have been radioisotopically dated. We delay formal recognition of a new SALMA, however, pending completion of a more detailed taxonomic characterization of the Tinguiririca Fauna, and more complete publication of the fauna from Cañadón Blanco and LBLC by our colleagues at the Museo de La Plata.

SUMMARY OF SIGNIFICANCE OF TINGUIRIRICA FAUNA

The newly discovered Tinguiririca Fauna sheds light on an important phase of South American mammalian evolution and provides an important new source of geochronologic information for this region of the Andes. Following are the study's major conclusions:

1) Understanding of South American Ce-

nozoic mammal evolution has long been plagued by gaps in the paleontological record, the most significant of these being an approximately 15–25 million year hiatus preceding the Deseadan SALMA. The Tinguiririca Fauna clearly falls within this gap. The Tinguiririca Fauna represents the first Paleogene mammal fauna known from Chile, the only mammal fauna known from the central Andean Main Range (if not the entire Main Range), and the only well represented Eocene-Oligocene transitional fauna from the continent.

2) The Tinguiririca Fauna contains the oldest rodent from South America. The source area and age of arrival of this immigrant group (as well as primates) have long been vigorously debated. The new fauna significantly extends the minimum age of the first appearance of rodents (but not as yet primates) on the continent.

3) The span separating the Mustersan and Deseadan SALMAs coincides with an important mammalian faunal transition, a turnover from communities dominated by various "archaic" lineages, to communities of a much more "modern" aspect. The Tinguiririca Fauna provides the first detailed view of this transition.

4) Many early Cenozoic SALMAs remain poorly sampled radioisotopically (if sampled at all). Dates (table 3) from volcanic horizons associated with the Tinguiririca Fauna are the first reported from a 30 million year pre-Deseadan span, and help to constrain the currently debated lower temporal bound of the Deseadan SALMA.

5) The age of the Tinguiririca Fauna and its stratigraphic context significantly perturb currently accepted interpretations of the geotectonic history of the region. The Tinguiririca mammals represent the first chronologically significant paleontological find for a major sequence of central Andean rock units, and demonstrate the utility of fossil vertebrates for elucidating various geologic problems in this physiographic province.

ACKNOWLEDGMENTS

We thank D. Frassinetti and Director Luis Capurro, Museo Nacional de Historia Natural, Santiago for their sponsorship of our

TABLE 3
Age of the Tinguiririca Fauna (from Wyss et al., 1993)

Analysis number	³⁷ Ar/ ³⁹ Ar	³⁶ Ar/ ³⁹ Ar	⁴⁰ Ar*/ ³⁹ Ar	% ⁴⁰ Ar*	Age		
					Ma	±	SD
Sample 90CS-TDF20 (plagioclase)							
5259-01	5.6536	0.01943	53.0933	90.9	32.065		1.331
5259-02	5.6216	0.02251	52.8218	89.4	31.902		0.704
5259-03	3.3264	0.01558	50.2486	93.3	30.361		1.828
5259-04	4.7746	0.00786	52.9391	96.4	31.972		0.504
5259-05	5.1316	0.02409	51.3102	88.4	30.997		0.662
5259-06	4.8035	0.08048	51.9572	68.9	31.384		1.220
Weighted mean =					31.646		0.320
altered grain?							
5259-07	23.0828	1.04709	91.2434	22.6	54.757		11.634
Sample 90CS-TDF19 (plagioclase)							
5258-01	5.4000	0.00788	51.9069	96.4	31.354		0.468
5258-02	6.8320	0.21235	51.9136	45.4	31.358		1.514
5258-03	5.0410	0.03627	52.1694	83.4	31.511		0.539
5258-04	5.7482	0.04452	51.6674	80.2	31.211		0.580
5258-05	5.1570	0.01104	51.9845	94.7	31.401		0.365
5258-06	5.0637	0.01760	52.6603	91.6	31.805		0.665
5258-07	5.0960	0.00474	51.5102	98.1	31.117		0.446
5258-08	4.5901	0.01085	51.7061	94.7	31.234		0.358
Weighted mean =					31.335		0.171
Combined weighted mean of TDF19 and 20 =					31.404		0.151
Sample 90CS-TWHO (plagioclase)							
5241-02	1.9288	0.12751	61.2378	62.0	37.307		1.154
5241-05	0.3615	0.05299	60.9994	79.6	37.163		0.776
5241-06	0.4021	0.15814	61.8658	57.0	37.685		1.078
5241-07	0.4862	0.02445	62.0831	89.6	37.816		0.521
5241-08	0.3676	0.00909	62.0903	95.9	37.820		0.512
Weighted mean =					37.671		0.305
contaminant grains?							
5241-01	0.4813	0.16370	64.9995	57.3	39.573		1.911
5241-03	0.3814	0.03255	62.6420	86.7	38.153		0.896
Sample 90CS-TWHO (biotite)							
5242-01	0.0276	0.50394	61.3023	29.2	37.345		3.252
5242-03	0.0617	0.44815	60.8075	31.5	37.047		2.572
5242-04	0.0078	0.51079	61.2037	28.8	37.286		3.233
5242-05	0.0433	0.38783	61.6036	35.0	37.527		2.357
5242-06	0.0219	0.30230	60.9613	40.6	37.140		1.205
5242-07	0.1022	0.39658	61.1127	34.3	37.231		2.372
Weighted mean =					37.216		0.849
altered grain?							
5242-02	0.0232	0.49516	51.5898	26.1	31.480		3.973

* = radiogenic.

$$I_e + I_c = 0.581 \times 10^{-10} \text{ yr}^{-1}; I_b = 4.962 \times 10^{-10} \text{ yr}^{-1}; {}^{40}\text{K}/{}^{40}\text{K}_{\text{total}} = 1.167 \times 10^{-4}.$$

The age of the Tinguiririca Fauna was ascertained through ${}^{40}\text{Ar}/{}^{39}\text{Ar}$ laser total-fusion techniques applied to plagioclase and biotite separated from volcanoclastic horizons of the Abanico Formation. Mineral grains were treated

TABLE 3—(Continued)

in an ultrasonic cleaner with dilute ($\sim 0.7\%$) hydrofluoric acid for 5 min to remove any altered glass and adhering clays, then rinsed for 5 min in distilled water. They were irradiated together with a centrally located monitor mineral (Fish Canyon Tuff sanidine), for 30 min in the hydraulic rabbit core facility of the Omega West research reactor at Los Alamos National Laboratory following previously described procedures (Swisher et al., 1992). After irradiation, single crystals of the monitor mineral and Abanico samples were loaded into individual 2 mm diameter wells of a copper sample disk, placed within the sample chamber of the extraction system, and baked out at 200°C for 8 hours. Total fusion of the samples and monitor mineral was accomplished with a 6W Coherent Ar ion laser. Released gases were purified by two Zr-Fe-V getters operated at approximately 150°C , and condensable gases were collected on a -45°C cold-trap. Argon was measured in an on-line Mass Analyzer Product 215 noble-gas mass spectrometer operated in static mode. Laser heating, gas purification, and mass spectrometry were completely automated following computer programmed schedules (Swisher et al., 1992). The $^{40}\text{Ar}/^{39}\text{Ar}$ ages were calculated using a J value determined from replicate analyses of individual grains of the coirradiated monitor mineral Fish Canyon Tuff sanidine (FC) with a reference age of 27.84 Ma intercalibrated in-house with Minnesota hornblende MMhb-I with a published age of 520.4 Ma (Cebula et al., 1986; Samson and Alexander, 1987). The $^{40}\text{Ar}/^{39}\text{Ar}$ dating of single crystals of plagioclase and biotite separated from sample 90CS-TWHO, the stratigraphically lowest sample dated from the Abanico Formation, yielded weighted mean ages of 37.67 ± 0.31 Ma (SE) and 37.22 ± 0.85 Ma (SE), respectively. Samples 90CS-TDF20 and 90CS-TDF19 yielded concordant ages of 31.65 ± 0.32 Ma (SE) and 31.34 ± 0.17 Ma (SE). A combined weighted mean of both of these samples indicates an age of 31.40 ± 0.15 Ma (SE). The maximum output of the laser during this study was approximately 8 watts. Ca and K corrections were determined from laboratory salts: $(^{36}\text{Ar}/^{37}\text{Ar})\text{Ca} = 2.6 \times 10^{-4} \pm 5.0 \times 10^{-6}$, $(^{39}\text{Ar}/^{37}\text{Ar})\text{Ca} = 6.7 \times 10^{-4} \pm 3.0 \times 10^{-5}$ and $(^{40}\text{Ar}/^{39}\text{Ar})\text{K} = 2.03 \times 10^{-2} \pm 4.0 \times 10^{-4}$. J, the irradiation parameter, is based on replicate single-crystal analyses of the monitor mineral Fish Canyon Sanidine and is 0.0003412 ± 0.0000005 for sample 90CS-TWHO and 0.000338 ± 0.0000005 . Mass discrimination during this study, as determined by replicate air aliquots delivered from an on-line pipette system, was 1.006 ± 0.0002 . Decay constants are those recommended by Steiger and Jäger (1977) and Dalrymple (1979).

work in Chile. Financial support was provided by the National Geographic Society (3932-88), the National Science Foundation (DEB 9020213), the Eppley Foundation, the Frick Laboratory Endowment Fund, DTI (U. Chile), and a UCSB Junior Faculty Improvement Grant. Fossils were skillfully prepared by A. Davidson, R. Masek, S. McCarroll, and W. Simpson. The figures were prepared by E. Heck. J. Davis assisted in the editing. For generous assistance with identification of the fauna and/or helpful comments on the manu-

script we thank Mariano Bond, Alfredo Carlini, Francisco Goin, Guillermo López, Rosendo Pascual, Marcelo Reguero, and Guiomar Vucetich. For access to collections and the extension of numerous courtesies facilitating our work we are indebted to R. Pascual. Numerous people have helped with collecting in the field including J. D. Bryant, J. Christinet, G. Gould, R. Hitz, J. Meng, C. Veloso, and F. Zapatta; in this regard we would like to single out especially the talents and efforts of Gabriel Carrasco.

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NOTE ADDED IN PROOF

Despite recent suggestions to the contrary [L. G. Marshall and T. Sempere, 1993, Evolution of the neotropical Cenozoic land mammal fauna in its geochronologic, stratigraphic and tectonic context, *In* P. Goldblatt (ed.), *Biological relationships between Africa and South America*, pp. 329–392, New Haven, Yale Univ. Press; T. Sempere, L. G. Marshall, S. Rivano, and E. Godoy, 1994, Late Oligocene–Early Miocene compressional tectosedimentary episode and associated land-mammal faunas in the Andes of central Chile and adjacent Argentina (32–37°S), *Tectonophysics* 229: 251–264], we reiterate our earlier stated conclusion that the Tinguiririca Fauna is not assignable to the Divisaderan SALMA. Given the lack of specific biostratigraphic evidence offered in its substantiation, these authors' proposed assignment of the new Chilean fauna to the Divisaderan SALMA appears to have been influenced by "agreement" between radioisotopic dates associated with the Tinguiririca Fauna (this report and elsewhere) and a proposed 30–36 million year age for the Divisaderan (Marshall et al., 1986). In view, however, of biostratigraphic evidence strongly contradicting such an assignment (this report, and earlier publications), and the continuing lack of

geochronologic control for the type Divisaderan fauna from Argentina, this supposed temporal correspondence is of little consequence. Accordingly, several conclusions of a recent tectonic study of the central Andes (Sempere et al., 1994), are called into question. Among these is the proposed 35 million year maximum age of onset of foreland deposition in adjacent Argentina (based on the suspect biostratigraphic tie between the Divisadero Largo Formation and the Tinguiririca Fauna). Thus the supposed lower temporal bracket for an unconformity underlying Deseadan aged strata in neighboring Argentina is inadequate to rule out an early to middle Eocene age of onset of foreland basin formation and coeval Andean deformation. Timing of the termination of Cenozoic deformation in the central Andes is well understood; its commencement remains the problem. Critical is the age of initiation of deposition of the Abanico Formation, an issue still not adequately resolved.

It also merits note that the recently proposed subdivision of the Deseadan SALMA into pre- and post-arrival of caviomorph rodent portions (Marshall and Sempere, 1993), is now obviated by occurrence of a caviomorph in the pre-Deseadan Tinguiririca Fauna (Wyss et al., 1993).

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