1 Notes toward a history of vertebrate paleontology at Gran Barranca

Richard H. Madden and Alejo Scarano

Abstract

The turn of the twentieth century began an intense period of paleontological exploration of Patagonia. The field work of Carlos Ameghino in Patagonia, including Gran Barranca, documented in correspondence with his brother Florentino, was central to the discovery of the biostratigraphic sequence of pre-Santacrucian mammalian faunas. The work of the Ameghinos was stimulated by rivalry and benefitted from substantive contributions from contemporaries, notably Andrés Tournouër.

The early field study at Gran Barranca was sustained during the early twentieth century by geologists working in mineral and petroleum exploration in Patagonia, including a noteworthy contribution by Egidio Feruglio. The contributions of paleontologists working for museums of natural history in the United States, Elmer Riggs, Bryan Patterson, and George Simpson, represent another mid-century phase of activity at Gran Barranca. This work yielded exquisite specimens and set a new standard of utility for documentation and stratigraphic resolution. The Second World War and immediate post-war period also saw collecting activity at Gran Barranca by paleontologists associated with Argentine museums, Alejandro Bordas, Alfredo Castellanos, and Galileo Scaglia, work that continued to yield novelty from the exposure.

Rejuvenated by contemporary revolutions in tectonics and geochronology, Rosendo Pascual and his many students and collaborators at the National University and Museum of La Plata initiated multidisciplinary work at Gran Barranca, two noteworthy components of which were the stratigraphy and sedimentology of Luis Spalletti and Mario M. Mazzoni and the geochronology mediated by Larry G. Marshall of the abundant basalts of central Patagonia and Gran Barranca. This work enabled the first refined interpretations of the Patagonian fossil record in light of broader scientific questions about middle Cenozoic earth history.

Continuing this tradition, scientists from the Facultad de Ciencias Naturales y Museo de La Plata, Duke University, the Museo Argentino de Ciencias Naturales, and the Universidad de Buenos Aires, and numerous other institutions, using technical advances in radioisotopic dating and magnetostratigraphy and an intensification and diversification of collecting effort, bring much that is new to an increasingly sophisticated understanding of faunal and floral response to environmental change through the middle Cenozoic.

The Paleontology of Gran Barranca: Evolution and Environmental Change through the Middle Cenozoic of Patagonia, eds. R. H. Madden, A. A. Carlini, M. G. Vucetich, and R. F. Kay. Published by Cambridge University Press.

Resumen

Con el comienzo del siglo XX, arrancó un período de intensiva exploración paleontológica en Patagonia. El trabajo de campo de Carlos Ameghino en Patagonia, y en Gran Barranca, documentada en correspondencia con su hermano Florentino, es punto clave en el descubrimiento de la secuencia bioestratigráfica de las faunas paleomastozoológicas pre-Santacrucenses. El trabajo de los Ameghino vino estimulado por rivales y aprovechó de contribuciones sustantivas de contemporáneos, notablemente Andrés Tournouër.

Trabajos de campo en Gran Barranca fueron sostenidos durante la primera parte del siglo por geólogos involucrados en la exploración minera y petrolera en Patagonia, con una notable contribución de Egidio Feruglio. Las contribuciones de paleontólogos pertenecientes a museos de historia natural en los Estados Unidos, Elmer Riggs, Bryan Patterson, y George Simpson, significan otro período de actividad en Gran Barranca. Este trabajo rindió especímenes exquisitas y sirvió establecer unó nuevo estándar para la documentación de resolución estratigráfica. Durante la Segunda Guerra Mundial y el período inmediatamente posterior continuó la actividad de colección de paleontólogos trabajando para museos argentinos, Alejandro Bordas, Alfredo Castellanos y Galileo Scaglia, trabajo que continuamente rindió novedades del afloramiento.

Junto con las revoluciones en geotectónica y geocronología, Rosendo Pascual y sus estudiantes y colaboradores de la Universidad Nacional y Museo de La Plata comenzaron las primeras investigaciones multidisciplinarias en Gran Barranca, entre las cuales dos componentes notables fueron la estratigrafía y sedimentología de Luis Spalletti y Mario M. Mazzoni y la geocronología de los abundantes basaltos de Patagonia central y Gran Barranca conjugada por Larry G. Marshall. Este trabajo sirvió fundamentar interpretaciones sintéticas acerca del registro paleontológico patagónico en el contexto de preguntas mayores acerca de la historia terrestre en el Cenozoico medio.

Siguiendo esta tradición, científicos de la Facultad de Ciencias Naturales y Museo de La Plata, la Universidad de Duke, el Museo Argentino de Ciencias Naturales, la

Universidad de Buenos Aires y otras instituciones, empleando avances tecnológicas en datación radiométrica y magnetoestratigrafía, junto con una intensificación y diversificación del esfuerzo de colecta, han podido aportar muchas novedades a la comprensión cada vez más sofisticada de la respuesta de la flora y fauna a los cámbios ambientales del Cenozoico medio.

Introduction

In light of our direct experience at Gran Barranca, we present here some perspectives about the history of discovery of the faunal succession at Gran Barranca, especially as illuminated by our exploration for the intermediate fossil-bearing stratigraphic levels not intensively collected hitherto and developments in field methods. We concentrate here on the establishment of the pre-Santacrucian faunal sequence in Patagonia, a 23-million-year interval of Earth history between about 41 and about 18 Ma, revealed by the exposures at Gran Barranca. The dates of important publications suggest that the overall sequence of evolution of Patagonian mammalian faunas may well have been established on the basis of fossils collected at disparate and geographically isolated localities, ordered into a sequence of evolutionary stages based on ideas about unidirectional progress in evolutionary morphology. Indeed, the clearest and most explicit expression of unidirectional progress in herbivore dental evolution is found in Ameghino (1904), and was published before the stratigraphic superposition at Gran Barranca was depicted in 1906. This order of publication suggests that stage of evolution was the evidence by which the faunal sequence was established before it was confirmed by superposition at Gran Barranca.

Experience leads us to believe otherwise. It seems likely that Gran Barranca was more central to Ameghino's developing ideas about superposition. Nevertheless, one must acknowledge the special problems Gran Barranca presents for the history of Patagonian paleontology. These problems arise from the nature of the fossil record there. Gran Barranca is a cliff and its sediments are poorly consolidated. Weathering by episodic rain and rapid drying by wind of the glass-rich pyroclastic sediments is hard on fossils. Piecing together a faunal sequence based on such fragmentary remains requires sustained collecting over many years. Unless detailed and accurate field notes and sections are kept up to date, and stratigraphic position marked by metal labels affixed by metal wire to steel rebar driven deep into the sediment by sledgehammer, memory is lost and posterity will struggle to build on past work. Notes and even sandwiches blow away in the gusty westerlies. The steep slopes are difficult to prospect, and only the young and intrepid are truly comfortable on Gran Barranca. The energy and fortitude required to stay on the outcrop is considerable, ascent is strenuous and descent, facilitated by rodados, may be faster but more painful. Gran Barranca is long and high, and the Sarmiento Formation appears monotonous, or not, depending on sunlight. Color is a deceptive guide to the stratigraphy as volcanic glass is subject to subtle changes in tone, varying from pale gray, to greenish, to pinkish, to yellowish, and white with the angle of sunlight and cloud cover. Then too, Gran Barranca, despite its size, is mostly hidden from view. These practical difficulties appear evident throughout the history of exploration and work at Gran Barranca.

Gran Baranca's best-exposed, most accessible, and richest fossil levels are the *Colpodon* and *Notostylops* beds, the highest and lowest beds. The intermediate *Astraponotus* and *Pyrotherium* levels are not nearly as fossil-rich and occur on the steepest slopes. While the *Pyrotherium* beds at Gran Barranca are of limited areal extent, the *Astraponotus* beds and levels between the *Notostylops* and *Pyrotherium* beds present a different problem altogether. These exposures are among the most difficult of all to prospect, occur sporadically between the east and west end of the barranca, have variable lithology that is laterally discontinuous and difficult to characterize, and until recently were not known to be very fossiliferous. Even competent professional collectors have mistaken them for younger and older levels. For these reasons, the history of the discovery of the *Astraponotus* beds at Gran Barranca is most difficult to reconstruct (see Bond and Deschamps this book).

Historical overview

The Ameghinos

In his first contribution to our understanding of the fossil mammals from the "*Pyrotherium*" beds (currently Deseadan), Ameghino (1895) describes numerous new genera and species from the nominal type Deseadan at La Flecha. Judging from the systematic paleontology in that publication, there is no evidence that the faunal sequence at Gran Barranca had been discovered prior to 1895. Soon afterwards, Ameghino (1897a) published a review of his views about the "*Pyrotherium*" beds, and likewise provides no hint of the discovery of either older fossil levels or morphologically more primitive taxa.

Carlos Ameghino is thought to have discovered the first fossil mammals from the barranca south of Lake Colhue-Huapi, during his expedition of 1895–96 (Simpson 1967a), but the supporting evidence for this assertion is problematical. The fossils described by Florentino Ameghino in 1897, and thought by Simpson to have been collected at Gran Barranca, include the type material of 11 taxa typical of the Casamayoran, including *Notostylops murinus*. In the geological appendix to his publication, Florentino states that the formation including *Notopithecus*, *Pyrotherium*,

Archaeohyrax, and *Didolodus* comprises several levels whose differences have yet to be resolved, alluding to a suspicion that more than one level may have been represented in the collection he described.

Reconstructing the geographic provenance of the fossils discovered by Carlos Ameghino and described by Florentino in 1897 is difficult and establishing stratigraphic provenience is only somewhat easier. More importantly, reconstructing the travel itinerary of Carlos during his many expeditions along the coast of the Gulf of San Jorge and into the interior of Patagonia is especially difficult.

On 6 October 1897, Ameghino (1897a) described fossils collected by Carlos between October 1893 and August 1896, including taxa that in retrospect are of obviously more primitive and of greater antiquity than taxa in the "*Pyrotherium*" fauna. Among other things he proposes the new family "Notopithecidae," including the new genus and species, *Notopithecus adapinus*. While this publication includes numerous descriptions of taxa of Casamayoran age, Ameghino makes no distinction between them as a group from the other more numerous and more derived taxa that are also described. This suggests that his analysis of this fauna had not yet benefitted from the clarity of observed direct stratigraphic superposition.

In that same year, Ameghino (1897b) outlined the broad succession of mammal evolution in Argentina, illustrated with many of the fossils described in 1897a, but the geologic succession does not extend down to resolve levels below the "*Pyrotherium*" beds. Thus, again, the stratigraphic succession had not yet been resolved, although fossils from what we now know are older levels were becoming known to Florentino at this time.

Establishing a sequence between Notostylops *and* Pyrotherium

The first published notice of the existence of a sequence among pre-Santacrucian faunas in Patagonia was by Florentino Ameghino in 1899 (Ameghino 1899). The *Pyrotherium* fauna was well known at the time, based on collections made by Carlos at La Flecha in 1893–94 and at Cabeza Blanca in 1894–95 (Ameghino 1895). Where before he had lumped several groups of fossils of different age, Ameghino (1899) now distinguished the *Pyrotherium* (Deseadan) from the older (Casamayoran) *Notostylops* faunas by taxonomic composition, relative abundances, and some evolutionary differences between primitive and more advanced representatives of Isotemnidae, Notohippidae, and Pyrotheria. Among the contrasts, there are two notable examples of evolutionary change: (1) three derived groups in the *Pyrotherium* fauna (Toxodontia, Leontiniidae, Homalodotheriidae) were claimed to have their ancestry among more primitive isotemnids, and (2) the evolutionary trend to higher tooth crowns (hypsodonty) was first noted among Notohippidae.

Although for the first time the faunas are distinguished by their relative age, there is nothing in this revelation that indicates unequivocally that Carlos had observed the stratigraphic succession at Gran Barranca, as there is more than one place in Patagonia where this particular two-fauna sequence can be observed in superposition or near superposition with a conspicuous discontinuity between them (e.g. Valle Hermoso and the immediate vicinity of Cabeza Blanca).

Sometime between October 1899 (Ameghino 1899) and July 1901 (Ameghino 1901) Ameghino resolved the full sequence of middle Cenozoic faunas in Patagonia to a level of resolution that is essentially modern. (The resolved succession was published in the *Boletín de la Academia Nacional de Ciencias en Córdoba* in 1899, but the date of publication is debated; Simpson [1967b, p. 251] gives it as July 1901.) The faunal sequence included five of the six faunal levels we now recognize at Gran Barranca. Especially important is the intercalation of the beds with *Astraponotus* (Mustersan) between the *Pyrotherium* and *Notostylops* beds and the distinction between the beds with *Astrapothericulus* (early Santacrucian or "Pinturan") and those with *Colpodon* (Colhuehuapian).

The question remains whether this sequence could have been established in any way other than by collecting in direct stratigraphic superposition at Gran Barranca. Could it have been constructed, for example, by inference from evolutionary morphology observed in taxa from assemblages collected at different localities, each with a single fossil-bearing level or at most two superposed horizons? Specifically, with the distinction between the *Notostylops* and *Pyrotherium* faunas resolved (Ameghino 1899), how was the intermediate position of the *Astraponotus* beds (Mustersan) established? And if it required direct superposition, was this sequence established at Gran Barranca?

Carlos' first collection from the Mustersan at Gran Barranca

Bond and Deschamps (this book) review in length the history of the recognition of the Mustersan, and show how the question can only be answered indirectly. Carlos may have collected in the Mustersan at Gran Barranca sometime before 1901 when Ameghino (1901) first mentioned the existence of (1) fossil-bearing beds above the *Notostylops*, (2) the Astraponotéen, and (3) a level immediately above the Astraponotéen but below the *Pyrotherium* beds in 1901. Also, specimen labels and preservation indicate that Carlos Ameghino may well have discovered the locality we call GBV-4 "La Cancha" (the Tinguiririan at Gran Barranca) sometime just prior to the description of its fossils in 1901 (Reguero *et al*. 2003). This sort of evidence bearing on the intermediate levels provides some constraints on the time and activity of Carlos Ameghino at Gran Barranca.

Carlos' first collection from the Colhuehuapian at Gran Barranca

According to Ameghino (1902), Carlos discovered the "fauna mammalogique des couches à *Colpodon*" in 1898, during his tenth paleontological expedition between October 1898 and June 1899. Was this discovery made at Gran Barranca? In correspondence dated 15 February 1899, Carlos wrote that his 1898–99 expedition was limited to the vicinity of the Gulf of San Jorge and it is not clear that his explorations extended as far north as Gaiman/Trelew or as far west as Gran Barranca, the nearest localities with "*Colpodon*" faunas. Prior to the discovery of Gran Barranca by Andrés Tournouër (see below), Florentino (in a letter dated 18 April 1899) mentions that Carlos had discovered very similar fossils "en el interior del Deseado," but not at Gran Barranca. It wasn't until six months later when Carlos wrote Florentino the important letter of 9 October 1899 describing the sequence of faunas he observed at Gran Barranca, that we know he had collected the "Colhueapense" fauna at Gran Barranca. These were fossils corresponding perfectly with those collected by Tournouër. This evidence suggests that Carlos did not collect in the Colhuehuapian until after Tournouër, and provides yet another constraint on the time of his activity at Gran Barranca.

The influence of French paleontology

Albert Gaudry and Henri Gervais

Florentino Ameghino lived in Paris between 1878 and 1881 when he was 24–27 years old, and worked and studied at the Laboratoire de Paléontologie in Paris with Henri Gervais. The influence of French paleontology on Ameghino was significant and sustained over many years. Gaudry's *Les Enchainements du monde animal dans les temps géologiques: mammifères tertiaires*, the first of a comprehensive three-volume work, was published in the first year of Ameghino's residence in Paris. At least five subject areas of Gaudry's inquiry seem to have been particularly influential on Ameghino's intellectual development and professional activities: (1) ungulate tooth morphology and homology, (2) phylogenetic trees, (3) fossil succession, (4) the age of fossil deposits, and (5) human evolution.

Did the influence and inspiration of Gaudry and Gervais on Ameghino extend to include field methods for recording fossil provenance and stratigraphy? Podgorny (2005) claims that Ameghino "also trained in the observation of fossils, prehistoric remains, and geological strata." Stratigraphic profiles had been part of scientific publication in paleontology since the time of Brogniart and Cuvier ("Coupe général et idéale") as early as 1808 and 1811 (Rudwick 2005) and these published stratigraphic sections are very much in the style of those made by Ameghino (1906).

Andrés Tournouër

Andrés Tournouër was engaged by Gaudry to collect fossils from older strata in Argentina, inspired by the scientific discoveries of Ameghino and the description of new fossil mammals from Patagonia. Simpson (1984) claimed that Tournouër made five collecting trips to Patagonia; Podgorny (2005) claims six, including the last in 1904. Whatever the total count, two of these are important to the history of Gran Barranca: (1) Tournouër's first expedition from November 1898 to April 1899 which overlapped chronologically with Carlos Ameghino's tenth expedition between October 1898 and June 1899, and (2) a trip in February 1903 when Tournouër met the Ameghino brothers at Cabo Blanco and explored with them along the South Atlantic coast to the vicinity of Punta Casamayor.

The discoverer of Gran Barranca: Tournouër or Carlos Ameghino?

On 15 February 1899 Carlos Ameghino wrote a letter to Florentino from Bahía Camarones describing some of the results from his previous three-month exploration around the Gulf of San Jorge. These explorations were of mediocre yield from the standpoint of paleontology but from the standpoint of geology were important because they revealed that heretofore he had confused two distinct faunas as the *Pyrotherium* fauna.

Two months later, on 18 April 1899, Florentino wrote to Carlos from La Plata to the effect that Tournouër had recently returned to Buenos Aires from an exploration to the interior of Chubut bringing a collection of fossils that while not very large, was interesting. Florentino conveyed that Tournouër mentioned having encountered Carlos at one point during that expedition, and that the fossils in question were collected at an outcrop about one hour's horseback ride from where Carlos and Tournouër had met. Tournouër mistakenly thought he discovered the *Pyrotherium* fauna south of Lake Musters, but to Florentino this collection represented a younger fauna. Among the remains, material of *Astrapotherium* were abundant, along with a small astrapothere similar to one Carlos had discovered previously in the interior of Deseado, together with another new astrapothere of gigantic proportions. In addition to these, there was a notohippid with a diastema between the incisors and cheek teeth. In these characteristics, this collection appeared to represent a level older than the Santacrucian. This fauna would eventually become known as the Colhuehuapian and Tournouër's 1899 collection was the first made from the type Colhuehuapian at Gran Barranca.

Sometime thereafter, between 18 April and 9 October 1899 Carlos returned to prospect at this locality. After returning from this trip, Carlos wrote Florentino from Santa Cruz in which he describes Gran Barranca. In his words (translated from the original Spanish):

> The disentanglement of the *Pyrotherium* fauna, of which I wrote in my letter from Camarones, has been confirmed . . . [by] having later discovered an exposure near Colhue-Huapi where the beds are concordant stratigraphically but not paleontologically, as the beds between are nearly devoid of fossils, and between one fauna and another there is a profound difference, always recognizable at first glance. This cliff is the same one where Tournouër collected the fossils he took and that I effectively indicated to him in order to get him off my back, as he asked me to show him a place where he could collect some fossils, as in all his wanderings he had not found anything; but I never imagined that after me he would find what you say he collected there.

Carlos continues his description of Gran Barranca:

> The cliff at this place comprises three horizons that correspond to three different faunas: 1) the *Notostylops* fauna, 2) the *Pyrotherum* fauna, very poor and scarce, but typical, as there occurs the pyrothere and astrapotheres with five lower molars, and 3) a fauna that could well be called Colhueapense, and that corresponds perfectly to the Patagonian, as you already discerned from the few fossils that Tournouër took.

By this letter, Carlos admits having returned to the locality Tournouër collected and whose location Florentino had transmitted to him by letter in April, and to have discovered there a sequence of three faunas in stratigraphic superposition, conformable one on the other. In the third of these faunas, which he called "Colhueapense," Carlos claimed to have collected an assemblage that contained all the same taxa collected by Tournouër, and many new ones. Thus, by his own words, Carlos recognized that Tournouër was the first to collect fossil mammals there, and thus to have discovered Gran Barranca.

Of course, it is possible to read Carlos' letter of 9 October 1899 in a different way. First, one could interpret the statement "I never imagined that after me he would find what you say he collected there" to mean that Carlos was surprised Tournouër had managed to find anything at all at Gran Barranca after Carlos had already worked the exposure and high-graded all its fossils, except for the novelty of Tournouër's collection as expressed by Florentino in his letter. Also, the comparison Florentino makes between Tournouër's collection and material collected by Carlos from near the source of the Rio Deseado implies that the only assemblage of similar composition and aspect previously seen by Florentino was the material Carlos collected from the "interior of Deseado," and not at Gran Barranca.

From the description of Tournouër's collection given by Florentino in his letter of 18 April 1899, it appears that Tournouër only collected in the Colhuehuapian at Gran Barranca, and not in lower levels. After Tournouër's discovery of fossils at Gran Barranca, Carlos returned there and discovered a sequence of three faunas.

What supporting material evidence is there to the claim of Tournouër's discovery? The Tournouër Collection from Gran Barranca in Paris appears to be exclusively material belonging to the Colhuehuapian level(s) and was collected before the middle of April 1899. Three documents in the archives of the Laboratoire in Paris describe Tournouër's activities at Gran Barranca in 1899.

(1) The "Compte rendu succinct de voyage de Monsieur A. Tournouër en Patagonie" describes the itinerary of Tournouër's 1899 expedition to Patagonia. This brief narrative on five handwritten pages includes a description of the stratigraphy in the vicinity of Lake Colhue-Huapi. This document is undated and unsigned, but in the handwriting of Tournouër.
(2) A transmittal letter from Tournouër in Buenos Aires to Gaudry of four handwritten pages dated 19 April 1899 that accompanied the shipment of fossils collected at Gran Barranca and conveys what was learned from Florentino Ameghino as to their significance.
(3) An undated and unsigned sketch of a stratigraphic profile of Gran Barranca in the handwriting of Tournouër (Fig. 1.1). On this sketch, there is an annotation "niveau du Colihuapi" above a dashed line that indicates lake base level, analogous to the manner in which sea level is indicated on other published profiles by Tournouër (1903). The profile indicates three fossil levels, with an intervening sterile(?) section. At the top are "gris gris avec couches friables avec astrapotherides." This is how the Colhuehuapian at Gran Barranca was described and characterized by Tournouër in correspondence. Immediately below these stratigraphically are the "argiles rouge a *Pyrotherium*" or red clays with *Pyrotherium*. Below a sterile(?) zone is the "Guaranien

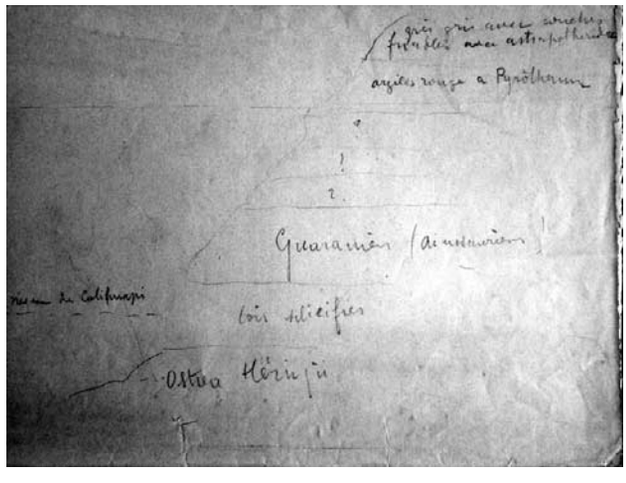

Fig. 1.1. Profile of Gran Barranca sketched by Andrés Tournouër (undated). (Courtesy of the Muséum National d'Histoire Naturelle, Paris.)

(Dinosaurien)" corresponding to Ameghino's *Notostylops* beds. The sketch is reminiscent in orientation and proportions to Ameghino's more detailed profile of 1906. Tournouër sketched the profile in 1899 according to his letter to Gaudry of 19 April 1899.

However, Simpson claims that Carlos Ameghino discovered Gran Barranca. The basis for Simpson's claim (1967a, 1984) is the evidence cited to show that Carlos collected the *Notostylops* fauna at Gran Barranca in 1895–96. Simpson (1967a) wrote that Carlos Ameghino "positively affirmed to me, and collection data and all other evidence are in accordance, that pre-Deseadan mammals were first found in 1895–1896 in this barranca." Furthermore, "[a]ll the pre-Deseadan forms described in 1897 were from there. Both the '*Notostylops* fauna' and the '*Astraponotus* fauna,' our Casamayoran and Mustersan faunas, were first found and (although later) recognized there, and a majority of all Ameghino specimens of both ages are from there ... [i]t is the most imposing and important single known fossil mammal locality in South America, and one of the most important in the world. It must also be considered the greatest single discovery of Carlos Ameghino's extraordinary career" (Simpson 1967, p. 64).

The evidence Simpson (1967a) proffers to support his claim comprises the following: (1) all pre-Deseadan taxa described in Ameghino (1897a) were from Gran Barranca and labels on many Casamayoran and Mustersan specimens indicate "Colhue-Huapi" and a few indicate "Colhue-Huapi Sud," (2) that the mixed nature of the *Pyrotherium* fauna described by Ameghino (1895) and resolved in (Ameghino 1897a) was first revealed to Carlos Ameghino in the field by stratigraphic superposition at Gran Barranca, and (3) in interview Carlos claimed to have discovered the barranca in 1895–96.

The claim that Carlos collected the first fossil mammals from the *Notostylops* level at Gran Barranca in 1895–96 is the basis for the claim that Carlos was the first to discover Gran Barranca. But, there is nothing in Carlos' correspondence to Florentino at that time that describes Gran Barranca or the complete sequence there, nor anything that establishes that Carlos revealed the sequence there until October 1899, after Tournouër.

With respect to the 11 Casamayoran taxa described by Ameghino in 1897 and assumed by Simpson to have been collected at Gran Barranca, Simpson found only eight in 1930 (Cifelli 1985). The 93 Ameghino types labeled from "Colhue-Huapi" (Simpson 1967a) represent roughly 46 valid Casamayoran taxa (Cifelli 1985). Of these 46 taxa, Simpson found only 20 at Gran Barranca, despite having prospected and collected over the entire exposure for a month. With respect to labels on specimens in the Ameghino collection Simpson (1967a) claimed that 93 types are labeled from Colhue-Huapi, and that Carlos assured him that most types not labeled were also from Gran Barranca. While this may be true, most types for valid Casamayoran taxa were described after 1901, after news about Tournouër's discovery was transmitted by letter from Florentino to Carlos, and after Carlos returned to collect there, and after Carlos described Gran Barranca in his letter.

Carlos' claim to have discovered Gran Barranca in 1895–96 was based on recollections made in 1931, 28 years after he was last in Patagonia in 1903.

Reconciliation about who discovered Gran Barranca may be further resolved by recalling that for Simpson, Gran Barranca included exposures and localities extending over 22 kilometers, from near Km 170 of the old Comodoro–Sarmiento railway, all the way to Profile 12 (today known as "Las Flores"). In addition, Simpson extended Gran Barranca to include the exposures at Km 145, the area of Valle Hermoso, and noted that "this is essentially a unit although the exposures are not completely continuous" (Simpson 1948, pp. 212 and 193). Using an expansive definition, it is easy to imagine how Simpson could claim that Carlos discovered Gran Barranca.

The Gran Barranca at the beginning of the twentieth century

In 1903, Tournouër published stratigraphic profiles made at points along the Gulf of San Jorge as far south as the mouth of the Rio Deseado. The five profiles include (1) Casamayor, (2) Punta Nava, (3) the "rive droite du Deseado," (4) the "rive gauche du Deseado," and (5) Florida Negra. Rather surprisingly, Tournouër never published a section for Gran Barranca, although he had made a sketch of it (Fig. 1.1).

The meeting of Tournouër with the Ameghinos in Patagonia in February 1903 is described in a long footnote (Ameghino 1906, p. 135) which provides a brief description of the activities of Florentino, Carlos, and Tournouër around the Gulf of San Jorge in February 1903 when they may have sketched some of the stratigraphic profiles of coastal exposures that were later published by Ameghino (1906, pp. 134–135).

Stylistic similarities between stratigraphic profiles of Tournouër (1903a) and those published by Ameghino (1906) are numerous and include (1) language, (2) depiction of the slope in profile, (3) telegraphic descriptions of lithostratigraphy, (4) special attention to fossil content, (5) strata numbered from base to top using arabic numbers with subordinate lower-case letters, (6) an indication of base level (either sea level or the level of a nearby body of water), and (7) texture infilling to designate lithology. The similarities of convention are so numerous that it seems plausible that the Ameghinos and Tournouër worked on them together.

Tournouër prepared a sketch map showing the location of Gran Barranca and a definitive map of all the localities he visited in Patagonia prior to mid-1903 (before he collected at Cerro Negro). He also prepared a catalog or list of the

fossils that served to record the basic succession of three pre-Santacrucian faunas, Casamayoran, Deseadan, and Colhuehuapian. These last items must have been prepared sometime in mid-1903, after almost all Tournouër's fieldwork was completed, after the fact of superposition at Gran Barranca had been revealed, and after Tournouër and the Ameghino brothers met together on the coast of Patagonia where they confirmed the stratigraphic sequence.

With this basic information about the fossil succession and geologic age, Gaudry reconstructed the broad evolutionary patterns of the Patagonian middle Cenozoic fossil record. Gaudry and Tournouër began to publish the results of their research activities in 1902 and Gaudry began serious study of the South American fossils after he retired the chair of paleontology in 1903. Gaudry's contributions to the evolutionary history of the fossils Tournouër collected were considerable, and include recognition of the geographic isolation of Patagonia and strong homoplastic resemblances in the dentitions of southern ungulates compared with those of the northern continents (Gaudry 1904, 1908).

Working at the same time, Ameghino (1904) established a truly remarkable threefold parallelism among ontogenetic development, phylogenetic descent, and geological succession in the evolutionary history of the upper cheek teeth in the toxodonts, an extinct group of southern ungulates. This example of a threefold parallelism is the first detailed reconstruction of the evolutionary history of hypsodonty among South American Cenozoic mammals. It is difficult to imagine how this threefold parallelism could have been completed without a sequence of fossil taxa in stratigraphic superposition.

Elmer Riggs and the Field Museum

The First Captain Marshall Field Paleontological Expedition to Argentina and Bolivia between 1922 and 1925 yielded many fossil specimens from Gran Barranca. The fossils are important for their quality and completeness, crucial for the determination of more fragmentary material. Elmer S. Riggs and party worked at Gran Barranca between November and December of 1923, with a field crew that included John Bernard Abbott, George F. Sternberg, Jose Strucco, and C. Howard Riggs (see Fig. 15.1 in Kay this book). In a letter to George Gaylord Simpson dated 21 May 1932, Elmer Riggs clarifies how this collection was made: "It may be explained that, in order to hold up the standard of collecting our collectors were given to understand that nothing less than a maxilla or a mandible with a series of teeth was to be regarded as a specimen."

Five sorts of original information about Field Museum of Natural History (FMNH) work at Gran Barranca are available in archives at the FMNH: (1) specimen ticket labels for material collected by E. S. and C. H. Riggs, (2) the field notebooks of G. F. Sternberg and J. B. Abbott, (3) separate "Record of Collections" made by Sternberg and Abbott, (4) E. S. Riggs' "Private Journal," and (5) glass plate negatives. After their return to Chicago, maps of their travel itinerary, areas collected, and campsites, were drawn for exhibition based on a 1911 map by Alberto Lefrançois. The map indicates the "Horizons with *Colpodon*, *Pyrotherium*, *Astraponotus*, and *Notostylops*" as a single unit we recognize today as the Sarmiento Formation. Riggs and party collected from this unit at both Valle Hermoso and Gran Barranca. Later, a list of the fossils "from the Deseado Series (the *Notostylops* Beds and *Pyrotherium* Beds of Ameghino)" including the material from Gran Barranca with genus-level determinations was prepared (with annotations by Bryan Patterson). In the Simpson Archives at the American Philosophical Society is an undated revised list of specimens from the *Notostylops* and *Astraponotus* beds at Gran Barranca collected by the FMNH and temporarily loaned to the American Museum of Natural History (AMNH). This list includes annotations by Patterson and the signatures of Abbott and Patterson.

Riggs (1928) mentioned having made stratigraphic sections during the work in South America, but none were ever published for Patagonian localities. A composite stratigraphic column of the west end of Gran Barranca in the FMNH archives shows profiles of seven numbered stratigraphic units of the Sarmiento Formation in superposition. This section also shows the approximate levels where fossils were collected. Along the right-hand margin are specimen field numbers of Sternberg and along the left-hand margin are field numbers and "names as determined in the museum." As in Ameghino (1906) both Lower and Upper *Notostylops* beds are distinguished, as are the *Astraponotus* beds, the *Colpodon* beds, and the Tehuelche gravels at the top. It is difficult from this composite section to establish more precise stratigraphic or geographic provenance for the fossils collected at Gran Barranca and there is no indication from either the collection or FMNH archives that levels between the Casamayoran and Deseadan were collected.

For example, Riggs and party took around 1200 photographs between 1922 and 1927, and there are 15 black-and-white contact prints from $5' \times 7'$ glass plate negatives of Gran Barranca in a photo album conserved in the FMNH archives. Handwritten captions below the photographs describe each scene. With benefit of hindsight and experience, some of the captions should be amended and a few errors corrected, for example. The "*Astraponotus* beds, Deseado Series" in 71–48921, the "Astrapothere measures" in 72–48923, and the "*Parastrapotherium* Zone" of 73–48929 all correspond with the lower levels of the Colhue-Huapi Member at Profile A. Thus, Riggs used three different terms to describe the beds we consider to be the lower levels of the Colhuehuapian. However, Riggs also used the term

"*Parastrapotherium* Zone" in 74–48931 for the steeply eroding beds of the Upper Puesto Almendra Member at Profile MMZ.

Photographs 73–48928 and 79–48935 are noteworthy as they capture strata of the Vera Member at Profile K. The handwritten caption beneath 79–48935 reads "Upper Measures, Parastrap. Zone" and the photograph is a panoramic view of Profile K looking up from below the level of Simpson's Y Tuff. Photo 73–48928 appears to have been taken from the level of GBV-4 "La Cancha" or just below it. Assuming that Riggs explored along the base of Gran Barranca by vehicle, he had to climb on foot to take this panorama "Overlooking Lake Colhue-Huapi." There are no fossil mammals in the FMNH collection that display the preservation unique to fossils from GBV-4 "La Cancha."

There are 102 specimens in the FMNH collection from Gran Barranca or from localities south of Lake Colhue-Huapi, extending from between Km 143, 145, 163 to 170, and including Valle Hermoso and Gran Barranca. Only 16 are from intermediate levels between the Colhuehuapian and Casamayoran; all of these are said to have been collected in the Deseado Formation and at least half of these (eight, or as many as ten) are material assigned to *Parastrapotherium*.

In corresondence from Simpson to Riggs of 18 April 1932 Simpson admits "I had some tendency to confuse *Astraponotus* and *Pyrotherium* beds in the field at several localities and am still not sure as to which horizon is represented by one or two lots of specimens. In one case, for instance, we have only *Asmodeus* or *Proasmodeus* and these are extremely difficult to separate, although I suppose it can be done when I get down to it." Nevertheless, in another letter written the very next day, Simpson corrects the position of the *Astraponotus* beds on photographs of Gran Barranca that Riggs had labeled (see below).

Egidio Feruglio

The geologist Egidio Feruglio had a little more luck with the *Astraponotus* beds at Gran Barranca than Riggs, and made a small but noteworthy collection of fossils at one locality at Gran Barranca in 1927. A list of the fossils collected by Feruglio at his Locality 31 and now at the Geological and Palaeontological Museum of Padua University in Italy can be found in the Simpson Papers at the American Philosophical Society, along with an original drawing of a stratigraphic section at Gran Barranca stylistically similar to sections Feruglio published in *The Geology of Patagonia* (Feruglio 1949). On the profile where the fossils were found, Feruglio depicts remarkably little stratigraphic detail in the Sarmiento Formation. The lack of stratification at this profile is reminiscent of Profile K, and in particular, the stratigraphic position of the stratum labeled "banco fosilifero f with fósiles No. 31" on the slope leading to the top of the barranca closely resembles that of GBV-4 "La Cancha." Among Feruglio's material from this locality, Simpson identified four taxa including *Pseudostylops subquadratus*, *Degonia* or *Eohyrax* sp. (frags), ?*Archaeohyrax* sp., and *Propyrotherium ?saxum*. According to Simpson, and appropriate to the state of knowledge at the time, these fossil mammals indicated a Mustersan age. Marcelo Reguero (in Reguero *et al.* 2003) was the first to establish that Feruglio had actually discovered the fauna from GBV-4 "La Cancha."

The Simpson Papers at the American Philosophical Society (APS) include three typewritten pages (along with four small pen-and-ink profiles) listing collecting localities (numbered from 1 to 18) in the form of an itinerary, giving directions for access to each. This document reads like an itinerary for a field expedition on which Feruglio made handwritten annotations, dated and signed 30 Noviembre 1930. Someone later, in pencil, made brief additional comments on this document, e.g., no vale, poco interés, no existe, Campamento no. 2, Campamento número 4, etc., suggesting this itinerary was followed (at least in part) and at least some of the sites were visited (see below). The geographic coincidence between this itinerary and the actual itinerary followed by the Scarritt Expedition must be more than simple coincidence.

In addition to this itinerary, another document of six handwritten pages reads "Colección de Mamíferos fósiles de Patagonia del Dr. Egidio Feruglio" and lists and describes the fossil yield from 53 localities. Each entry begins with a number (1, 2, 2bis, 3, 3bis, 3ter, 4, etc. ending with 53), followed by a name, then a description of the geographic situation and major stratigraphic features of each. Following the description of each locality is a date, presumed to be the date the locality was originally worked.

Feruglio took at least some of the fossils with him back to Bologna in Italy in 1932, and in 1934 shipped at least some of them to Simpson in New York, just before fleeing Italy to return to Argentina. The contribution of Feruglio to the success of the Scarritt Patagonia Expeditions was considerable, another example of how a European refugee from fascism provided disinterested support to a US paleontologist (see Madden *et al.* 1997).

In correspondence from Simpson to Feruglio on 3 January 1935, Simpson informs that "other specimens in your collection merit more detailed study: the maxilla of *Pseudostylops* from Locality 31 … it would be useful to have more details about this locality." Somewhat later, on 12 March 1935, Simpson writes Feruglio to say "we also have some fossils from your Locality 31." To be sure, Simpson did not collect fossils from Feruglio's locality, but Coleman S. Williams collected some important material from near the top of Profile M at a level corresponding to Feruglio's Locality 31.

George Gaylord Simpson and the Scarritt Expeditions

The American Museum of Natural History's (AMNH) Scarritt Expeditions of 1930–31 and 1932–33 set the standard for all later fieldwork at Gran Barranca and scientific productivity, although 37 years elapsed between the first field season at Gran Barranca and the eventual publication (Simpson 1967a) of the last part of his monographic revision of the older faunas. Two significant parts of the Scarritt Expedition work at Gran Barranca have never been published, Patterson's incomplete revision of the fossils from the Deseadan and Colhuehuapian levels, and the stratigraphic context of levels above the Barrancan, especially the Mustersan.

A lasting contribution of the Scarritt Expeditions is the detailed records of their field activities. Simpson's (GGS) system of note-taking during the 1930–31 expedition involved four separate records, all accessible to researchers: (1) a book of rough notes, the "Rough Book" (at the APS), (2) a field book of annotated technical notes (at the AMNH), (3) a photograph log (APS), and (4) a personal diary or journal (APS). The field books (annotated technical notes) in the archives of the AMNH had accession numbers for each specimen added subsequent to the fieldwork. The 1930–31 journal was the basis for *Attending Marvels* (Simpson 1934).

The "Patagonia, (Rough Book), 1930, G. G. Simpson" contains rough sketches in pencil or ink with brief notes labeling features of profiles, lists, sketches, and descriptions of some photographs, a tally of fossil specimens to measure progress with collecting effort, brief descriptions of strata, measured thicknesses, mineral or rock samples, quarry levels, and highlights of daily activities at Gran Barranca. The Rough Book sketches include one of Coley's Quarry. GGS also made sketches of photographs to help memory, and the Photograph Log also includes a sketch of this same Mustersan quarry. The notes made on 11 November 1930, the morning he took photographs, includes a sketch of a photograph of Coleman "Coley" S. Williams in the vicinity of GBV-19 "La Cantera" (Fig. 1.2). Another note confirms that the "Toba del Cocodrilo" is Simpson's Y Tuff. A separate page of "Analysis" establishes an approximate comparison of yield for Colhue-Huapi and Valle Hermoso, made on the basis of field specimen numbers, and establishes the essential facts about the quality of the fossil record at Gran Barranca. From the *Notostylops* beds, Simpson tallied 3 skulls, 25 upper and lower jaws, and 80 isolated or more fragmentary specimens, while in the *Astraponotus* beds only 1 skull, 7 jaws, and 35 other specimens, mostly isolated teeth. Even more sparse were the *Pyrotherium* beds where only 3 jaws and 14 other specimens were found. By contrast, the *Colpodon* beds yielded 9 skulls, 53 jaws, and 40 other specimens, by far the richest beds Simpson encountered anywhere in Patagonia, "and rather spoiled for us the laborious collecting in the older levels" (Simpson 19 April 1932 correspondence to E. S. Riggs).

Fig. 1.2. Simpson Photo #20 is a detail of Profile A, a photograph of the slopes around GBV-19 "La Cantera." Coleman "Coley" S. Williams appears in the middle foreground, with his pick. The photo is described on the back as "Middle part of Colhue-Huapi barranca, 11/11/30, Near West End." (Courtesy of the American Philosophical Society.)

Simpson's "Field books" for 1930–31 and 1934 contain more fully elaborated themes first noted in the rough book, with stratigraphic sections neatly drawn to scale, and a numbered entry for every specimen collected with reference to stratigraphic provenance.[1] Simpson took many photographs on the expedition but only two are serviceable images of Gran Barranca.

In the 1930–31 Travel Journal, Simpson described their activities at Gran Barranca and their collecting efforts in

[1] These exemplary works are now available to researchers through the AMNH website (http://paleo.amnh.org/notebooks/).

intermediate levels. By 28 October 1930, Simpson and party had finished work in the Colhuehuapian. Simpson writes: "Tomorrow I'll turn the lad loose on the channel beds." On 29 October, he describes the discovery of the crocodilian skull in the "massive lower volcanic ash bed" [= Simpson's Y Tuff]. On 31 October, ever optimistic, Simpson and Justino Hernandez (JH) "took a paseo to examine the barranca farther east and see the full section from Pehuenche (upper dinosaur beds) on through to the *Colpodon*. Did not find any definite fossil layer below our lower tuff, but there must be one." On this same day, JH collected in Bed X at Profile G and on 3 November, GGS and JH ascended Profile G near Cañadón Mazzoni and collected at three levels above Y.

On 4 November, while Coley worked "on a heavy gravel at the presumable base of the *Astraponotus* beds, containing very numerous isolated teeth and a few jaws, all very fragile … I spent the morning reconoitering in the upper beds, above this gravel and below the rich *Colpodon* level, but found very little except scrap of the great *Parastrapotherium* … who occupies these beds almost exclusively." Thus, that day, and only that day, Simpson and party prospected the stratigraphic interval that includes GBV-19 "La Cantera," without finding it.

On 5 November they went down to the east end of the barranca, about eight or nine miles away. This was this same day JH and GGS collected the lower levels of Profile K, but didn't ascend up to GBV-4 "La Cancha." Williams returned to his quarry in the *Astraponotus* beds the next day and later that same day, prospected up the guanaco path at Profile J, where he discovered GBV-3 "El Rosado" and the Deseadan and Colhuehuapian levels higher up that same path.

By 14 November 1930, Simpson and party had worked their way eastward to the vicinity of Profiles K and M, and in his journal GGS comments about the difficult nature of the work.

> Where we are now, the badlands seem particularly like a bad dream or a lunar landscape, something completely unearthly. The most fossiliferous zone of the Notostylopense continues hard to prospect. The only really practical scheme we have evolved is to have a troupe of mountain goats trained to wag their tails when they see a fossil – a man on a central hill with a spyglass then sends one of a corps of alpine climbers to the spot with a fish (or whatever delicacy they like, perhaps I'm thinking of seals) for the goat, and tools to extract the fossil. We'll put this in practice as soon as we have trained the goats, after we get them.

Simpson and party collected at GBV-60 "El Nuevo" on the same day Williams climbed up Profile M to collect the *Eomorphippus* material around the unconformity. Coley Williams collected these notohippids only three and a half years after Egidio Feruglio discovered the La Cancha fauna at Profile K. Friday 21 November was the Scarritt Expedition's last day of work at Gran Barranca.

The extent of Scarritt Expedition exploration of intermediate levels at Gran Barranca can also be reconstructed from handwritten notes entitled "Faunal Lists and Assemblages, Early Tertiary of Patagonia – Scarritt Expedition" (not in the handwriting style of Simpson). The document describes the organization of notes on the biostratigraphy of the collection. The procedure employed was as follows: (1) a folder (now removed except for the label) has been assigned to each locality indicated on the base map (Location #1 = Gran Barranca, according to the numbering used on the map of the Scarritt Expedition among Simpson's reprint collection at the Florida Museum of Natural History in Gainesville), (2) for each profile in a given locality a rough working section is given on a separate page, onto which lithology, thicknesses (not to scale) and field numbers of specimens are listed, and (3) for each fossiliferous horizon in each profile and working section, a separate list of specimens, with their catalog numbers (only SOME of these are identified) and collection notes is given. There is a small note "MTB 2/20/46" at the end of this paragraph and the date may explain why some of the specimens appear to be incorrectly identified. Simpson's work on the biostratigraphy at Gran Barranca was never completed (there are still a number of specimens that remain unidentified), was suspended between 1948 and 1967, and eventually rendered impossible by Simpson's departure from the AMNH.

After returning to New York in 1931, Simpson immediately began work on the new collection, and the 1930s were among the most active decades in the history of Patagonian paleontology. Through mutual consent, Simpson worked on the Mustersan, Casamayoran, and older levels, while Bryan Patterson in Chicago worked on material from the Deseadan and Colhuehuapian levels. Patterson and Simpson shared a rich correspondence over many years. Between 1936 and 1937, much of this correspondence related to finding phylogenetic continuity or connections between the Casamayoran (and older) ungulates and those from Deseadan and younger levels, "the tremendous Casamayoran–Deseadan gap, only partly filled by the Mustersan." Their conversation about the evolutionary transformation between the Casamayoran and Deseadan picked up again in 1946, at which time they had identified two central problems – the relationships of Toxodontidae, Notohippidae, Leontiniidae, and Homalodotheriidae to earlier Isotemnidae between the Casamayoran and Deseadan, and of Hegetotheriidae and Mesotheriidae to other typotherians before the Deseadan (Fig. 1.3). To further this work, Patterson received a Guggenheim Fellowship in 1951 and worked on his revision of the taxonomy of the Ameghino collection at the Museo Argentino de Ciencias Naturales between 1952 and 1955.