ON THE PRESENCE OF DINOSAURS IN THE PIRGUA FORMATION OF THE SALTA GROUP AND THEIR CHRONOLOGIC SIGNIFICANCE

By José Bonaparte and Gerardo Bossi*

ABSTRACT

The stratigraphic aspects of new fossil localities (Aguas Calientes, Arroyo del Morterito, Salta province, Argentina) with dinosaur and crocodilian remains are given. Two lithostratigraphic profiles are included to show the exact position of the fossils.

A titanosaurid dinosaur was found in the Pirgua Formation of the Salta Group, and two teeth, one of a carnosaurian dinosaur and the other of a crocodile, were found in the Yacoraite Formation of the same Group.

The titanosaurid is described and compared with known Patagonian forms, and finally assigned to *Antarctosaurus*. As all the known South American titanosaurids, this one came from Upper Senonian strata, and according to its morphological affinities it is concluded that the Pirgua specimen belongs to that age. It is also indicated that the association of titanosaurids, carnosaurs, and crocodiles represents a good argument for considering these formations of the Salta Group as Upper Senonian.

The age of the "Dinosaur Beds" of Patagonia, and that of the Salta Group, is compared on the basis of new evidence, and it is established that the determination of the present material supports a former chronological assignment given by Schlagintweit (1941).

A brief comparison of certain biostratigraphic and physical aspects of the two Upper Cretaceous basins (Salta and Neuquén), which are probably homotaxic, is made, and some parallel significant details are emphasized. It is mentioned that the Senonian movements of Patagonia and Perú are also marked by the angular unconformity with which the Pirgua Formation sediments begin.

INTRODUCTION

In the middle of 1964, the existence of fossil bones in the region bounding Salta and Tucumán provinces was brought to our knowledge. As a result of this we visited the site accompanied by the informant Mr. Alberto R. Cuezzo, technician from the Botany Department of the Instituto Miguel Lillo, and likewise by the discoverer of the site Don Fidel Leal, who kindly took us to the site of the discovery, known to him since his youth.

---

* Original citation: Bonaparte, J. and G. Bossi. 1967. Sobre la presencia de dinosaurios en la Formación Pirgua del Grupo Salta y su significado cronologico. *Acta Geologica Lilloana* 9:25–44.

Various short works were undertaken to obtain bony material and geological information. Participating in them, besides the authors, were Mssrs. M. Vince and J. C. Leal, technicians from the Paleontology Section of the Instituto Miguel Lillo, who were occupied with the preparation of the materials. These consisted of a series of fragments, among them some of special diagnostic value pertaining to a titanosaurid dinosaur. From the other location came a few remains of a carnosaurian dinosaur and a probable crocodile. The first was extracted from the Pirgua Formation, and these latter from the Yacoraite Formation, both pertaining to the Salta Group. As they concern the first remains of dinosaurs known from these formations and in the north of Argentina, they acquire a special interest, above all for the possibilities of chronologic interpretation that begins its study, according to what we see later on.

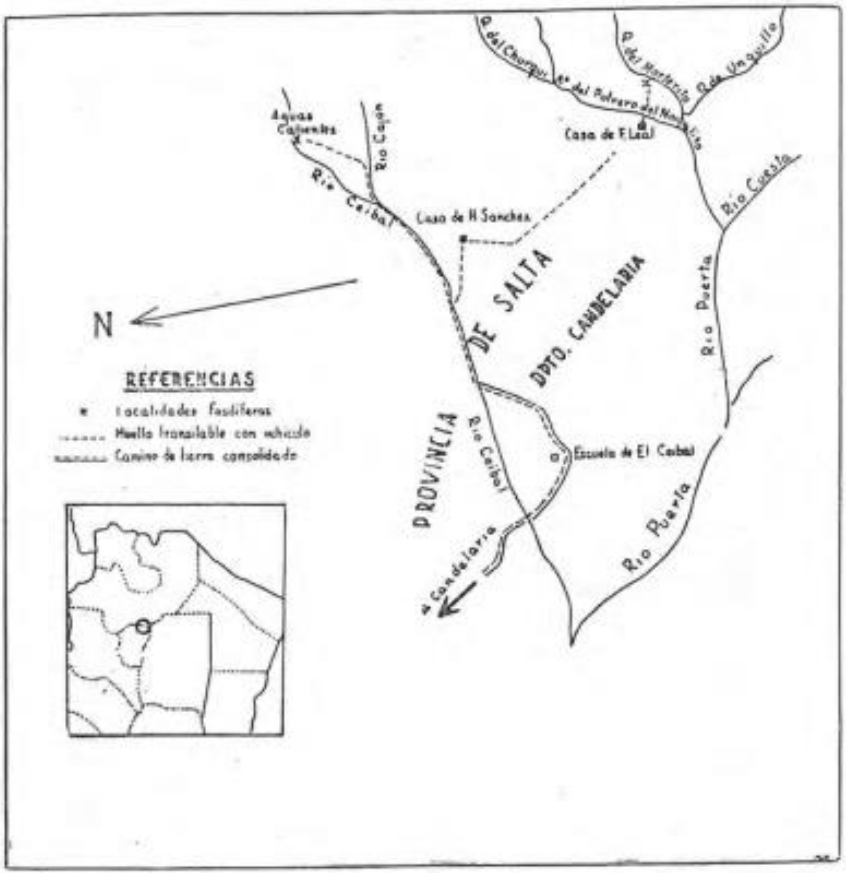


Fig. 1. — Location sketch of the localities with vertebrate vertebrates in the Pirgua and Yacoraite Formations.

GEOLOGY OF THE LOCALITY OF THE DISCOVERY

The titanosaurid dinosaur remains were discovered in a conglomeratic sandstone bed, located very close to the top of the Pirgua Formation. Such beds rest above the Precambrian of the Sierra de Castillejo, bounded there by a homogenous volcanic

block to the west and a fault to the east. The precise location of the discovery is situated 5 km from El Ceibal, Candelaria department, Salta province, within the property of Don Fidel Leal and in the vicinity of the Arroyo El Morterito (see rough sketch in figure 1).

The colored hills situated at the foot of the Sierra de Castillejo, opposite the house of Don F. Leal, are formed principally by the Pirgua Fm. and a few remnants of the Yacoraite Fm.

In Aguas Calientes (5 km further north), from which come the teeth of reptiles, one of a carnosaur and the other of a crocodile, likewise crop out over nearly the entire Yacoraite Fm., in which numerous fragments of rounded bones are encountered in addition to these teeth.

We assigned of the relevant beds (see description further below) to the Pirgua and Yacoraite Formations forming the Salta Group following the criteria used by Rassmuss (11), Schlagintweit (14) and Ruiz Huidobro (13) when they referred them to these levels. The reddish sandstone layers from a fluvial environment characterize the Pirgua Formation, distinguished securely although covered by the sandstones, caliches and multicolored clays with gastropods that form the Yacoraite Formation.

Profile of the Arroyo del Morterito (property of F. Leal)

Above:

Yacoraite Formation

1) Fine whitish to clear gray sandstones that alternate finally with fragmentary, chocolate-colored mudstones. Thickness 2.0 m.
2) Clayey, red, medium-grained sandstone with green spots. Thickness uncertain, only 1.0 m visible.

Pirgua Formation

3) Reddish and partly whitish sandstones, thick with conglomeratics, with milky quartz pebbles and a few phyllitic; limestones, the hard parts forming lenses and very durable irregular beds between other beds that are soft and friable. Some markedly conglomeratic layers and others of medium-grained, purplish-red, slabby sandstone are intercalated. Thickness 17.0 m.
4) Friable, reddish, conglomeratic sandstone with irregular 10 to 15 cm lenses of a conglomeratic, calcareous, grayish, very hard sandstone. Thickness 1.0 m.
5) Friable, micaceous, grayish-red sandstone with quartz pebbles furrowed with small carbonate veins. *In the base of this layer the titanosaurid dinosaur remains described were discovered.* Above the layer with bones appears a lens

of thick, greenish-gray, calcareous, very hard sandstone with pebbles and gravel. The bones were covered by a "halo" of the same rock but of greenish or grayish color, especially visible because the normal sediment is red. Thickness 1.5 m.

6) Reddish-brown, dark, muddy, micaceous, somewhat slabby, fine sandstone. Thickness 0.3 m.

7) Reddish conglomeratic sandstone with irregular calcareous sectors of grayish color around the base. Thickness 0.7 m.

8) Pink, mostly calcareous conglomerate with 2 and 3 cm pebbles (quartz and a few of feldspath and phyllite) with thick to medium sandstone matrix. Thickness 0.6 m.

9) Sandstone the same as 7, with a conglomeratic intercalation in the middle part of a type similar to 8. Thickness 3.2 m.

10) Reddish, medium- to fine-grained, friable sandstones that become calcareous toward the base, thicker and with gravels. In all the banks, this basal sector is conglomeratic and always more cemented than the upper part. In total six beds of 1.0 to 3.0 m individual potential. Total thickness 12.0 m. (Strike: N 30° E and dip: 10° SW.)

11) Thick, reddish, conglomeratic sandstones furrowed by small calcite veins that fill diaclases and mark the stratification plane. In each layer the color becomes clear brown toward the bottom. These beds alternate with other gray limestones, of lesser thickness, hard and with an irregular surface. Total thickness 6.5 m.

12) Fine reddish-brown, calcareous conglomerates with quartz pebbles and some of phyllite and feldspath, in general 2 to 3 cm in diameter with a maximum of 10 cm. Calcareous or friable, medium sandstones are intercalated above, that pass into thick sandstones or conglomerates below, red-brown and grayish-white in color in the most calcareous. A marked augmentation is observed in the size of the pebbles toward the bottom of the conglomeratic intercalated layer. Total thickness 16.5 m.

13) Medium, clear pink, calcareous conglomerate with pebbles of 5 to 10 cm (or more) principally of milky quartz; the stratification of the entire assembly is of parallel type and hardly visible, normally very disturbed by truncations and other erosion structures. Some fine, brick red, hard sandstone beds are intercalated. Thickness 5.0 m.

14) Medium to fine, dark purplish-red, very coherent sandstone with irregular lenses or balls of a similar whitish-gray, calcareous sandstone. These calcareous lenses predominate above and diminish toward the base. The last

three meters become gradually conglomeratic, with subangular pebbles of milky quartz. Total thickness 18.0 m.

15) Medium conglomerate with pebbles that are mostly angular and subangular quartz, with a few of phyllitic type. Parallel stratification slightly visible. Also here the cementation is irregular and emphasizes some lenses and hard conglomeratic sandstone balls. Thickness 10.0 m.

Approximate total: 92.0 meters.

Angular discordance

Precambrian

16) Greenish-gray hard phyllites with well-defined foliation, but partly finely folded into larger flexures. (Strike: N 45° E and dip: 69° SW.)

The following profile includes most of the Yacoraite Fm. and was developed on the Aguas Calientes locality.

Above:

Yacoraite Formation

1) Red, muddy, semi-calcareous, thick- to medium-grained sandstone, with some layers muddy and of darker coloration. Thickness 50.0 m.
2) Gray, calcareous sandstones, in 0.5 m hard and massive beds that alternate with grayish-green lutites or finely muddy slabs. Thickness 3.0 m.
3) Reddish-brown, medium to fine sandstones, thick in the upper part and slightly conglomeratic. The calcareous cementation is only evident in the upper sector, whereas the rest is friable. In the lower third, of pink color, some small yellowish banks with gastropod remains are intercalated. It is possible to find bony remains in this entire assembly. Irregular chocolate-colored lenses of muddy-clayey texture are also intercalated. Total thickness: 12.5 m. (In the upper third of this section a tooth of a carnosaurian dinosaur and numerous bony fragments were found.)
4) Calcareous sandstones of grayish, sometimes reddish-brown color, medium- to fine-grained, micaceous, slabby or massive, stratified in layers of lesser thickness that alternate with mudstones and dark gray, greenish or purplish lutites. In all the banks the poorly preserved remains of gastropods abound. Thickness 4.0 m. (Strike: N-S, dip: 20° W.)
5) Muddy and micaceous reddish-brown sandstone, massive or fragmented thickness, with numerous white limestone spots, remains of gastropods, and some fine clayey mud intercalations in the upper part. Thickness 2.0 m.

6) Green, micaceous, muddy sandstones, somewhat fissile, at times fragmentary, with sandy small beds and lenses, followed toward the bottom by medium sandy, calcareous, micaceous slabs of yellowish, grayish-red color that alternate with reddish- or yellowish-gray caliches with undulatory upper surfaces and gastropods. Thickness 2.5 m.
7) Grayish-red, somewhat slabby and calcareous sandstone with well-marked fine stratification. Toward the bottom it turns yellowish, calcareous, finely cross-stratified, and finally becomes very friable and pink. Thickness 2.8 m.
8) Yellowish-green and reddish-gray mudstone and claystone, slabby and at times micaceous. Stratified in thin (of 10 to 20 cm), somewhat undulatory beds. Alternate with micaceous, yellowish or gray sandstones with somewhat undulatory or subparallel stratification, marked by a concentration of mica in certain layers, at times with ocher spots. A hard, grayish-red sandy bank at the base. In the middle part the tooth of a crocodile was found within a greenish-gray mudstone slab with reddish and purplish spots. Thickness 5.0 m.
9) Pink, friable sandstone with darker layers that mark a planar, low-angle cross-stratification. With clayey, dark gray "pebbles." Thickness 2.8 m.
10) Grayish-red, friable sandstones, partly well compacted, micaceous, with marked slabby partition and some layers partially cemented by calcite. Thickness 3.0 m.
11) Purplish, grayish-red, muddy, slabby (limestones) and friable sandstones with intercalations of hard, pale pink tufas in 5 cm layers. Some banks near the base have greenish spots. Thickness 15.0 m.

Total thickness: 102 meters.

Pirgua Formation

12) Thick pinkish and whitish, conglomeratic sandstones, friable or calcareous in parts. Thickness not determined.

Relationships with the neighboring areas

The profile described reaches a tiny thickness compared to those indicated in the correlation table for neighboring localities (see e.g. the profiles of Cañizares and Morenillos to the west and east of the studied locality, respectively, fig. 2). We interpret these strong differences in thickness noted between distinct neighboring

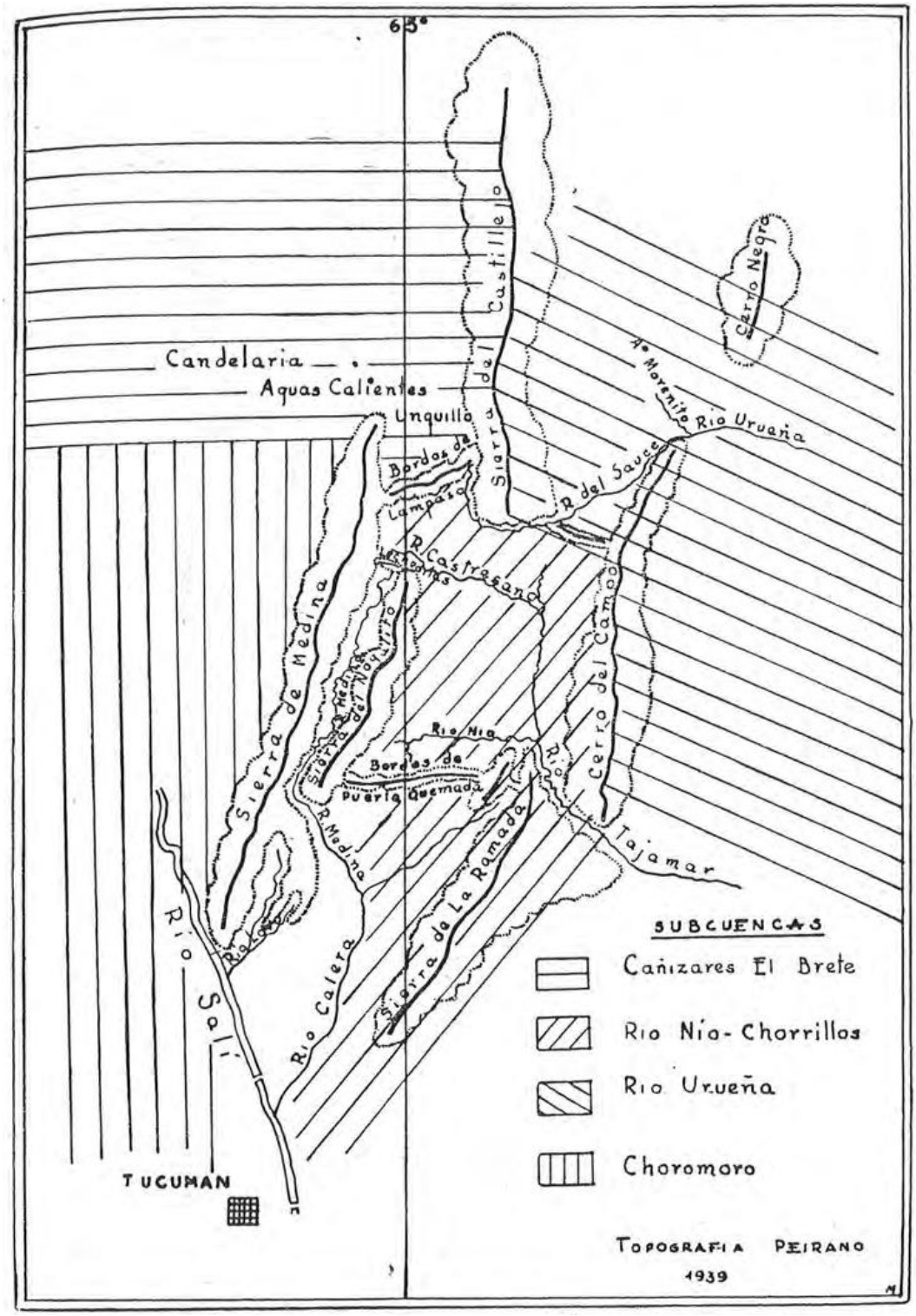


Fig. 2. — Stratigraphic columns of the studied zone and nearby areas with possible correlations between them.

profiles as the result of the control exercised by the basement during the deposition of these formations. This control was exercised in two possible ways: 1) original relief,

producing differences primarily by accumulation in distinct points; b) differential subsidence of distinct basement blocks that gradually accentuated the thicknesses accumulated on them. In this manner the profile of the studied zone represents an area of little sedimentation next to the boundary between two lithologically distinct sub-basins[1] (Cañizares-El Brete to the west, and Morenillos-Requelme to the east), fig. 4. The ancient border of the Salta Group basin would have been rather more to the east, because these formations are still encountered in the Cerro Colorado (64°30' long. W).

It is evident that a series of sub-basins existed (fig. 4) whose natural limits still cannot be specified, but which have their own generally definable characteristics. It is worth noticing that in many cases recent geographic accidents partially materialize such limits of the sub-basins (for example, the Sierra de Castillejo divides the Cañizares-El Brete sub-basin from the Morenillos-Requelme; and the Bordos del Lampazo separates the first sub-basin of the Nío). Another interesting case, although of distinct significance from that constituting the Cumbres Calchaquíes, is that separating the third sub-basin of the Cretaceous-Tertiary Santa María Valley from the valley of the Choromoros. This coincidence of recent relief with the morphological details of the Upper Cretaceous basin must have happened in the successive tectonic phases since the Paleozoic, the reactivation being verified in the same tectonic lines.

The sub-basin that includes our profile is extended toward the west, passing by Cañizares at least up to El Brete, increasing the thickness of the accumulated sediments although with a notable persistence in its lithologic and fossiliferous characteristics. We insisted on the importance of the sub-basins within the Salta Group basin being these limits of subregional character of great value for the paleoenvironmental interpretation of the primitive basin. On the other hand, the recent basin is divided into a series of intermontane relicts, some with their own different characteristics, that must be studied at great length before applying specific terms to formations defined for zones considered typical. In our case, we have used the denominations Pirgua and Yacoraite Formations that still seem suitable to use within the Cañizares-El Brete sub-basin, because the crude facies characteristics and the presence of "melanic" gastropods persist. The sandstone facies with quartz pebbles, incipient calcareous cementation and reddish color could be easily correlated with the Pirgua Fm. of the Cañizares and El Brete Ravine to the west; and with certain difficulty with the similar sandstones of Requelme, Nío River and Loro River in Tucumán, because lamentably the lacustrine facies guide with "melanics" of the Yacoraite Fm. disappears near the geographic limit and does not pass into Tucumán province.

[1] The term sub-basin is used to involve smaller depositional environments, with certain special characteristics produced by: local drainage, origin, paleogeographic position, etc. that differentiate them from other contemporaneous entites of the same category. The assembly of sub-basins constitutes the primitive basin.

The correlations with profiles further away from the Salta Group seem to be secure, as much for the persistence of the lithologic facies as for the rather constant paleontological content (which is mentioned more ahead).

Paleontological Analysis.

The material collected up to the present includes various pieces of the postcranial skeleton of a titanosaurid and some fragments attributed to a representative of the Carnosauria. In addition, an incomplete crocodilian tooth is counted. Of the first, which we refer with some reservation[(2)] to the genus *Antarctosaurus sensu* Huene (7), the following material has been extracted (incorporated into the Vertebrate Paleontology collection of the Instituto-Fundación Miguel Lillo of the Univ. Nac. de Tucumán, PVL 3670):

a) A left femur, practically complete, with the anterior part of the distal end and the proximal end affected by erosion.
b) A right humerus, partially eroded at the proximal end and incomplete at the distal end.
c) A right ulna (cubitus), with both the proximal and distal ends affected by erosion.
d) A left radius which is lacking about 10 cm from the proximal part.
e) The greater part of a right pubis, which lacks almost the whole symphyseal region and a portion of its distal region.
f) A proximal fragment of right ischium.
g) A fragment of right scapula that corresponds to a sector of the base of the scapular blade.
h) Two fragments that form almost the whole right fibula, and a distal fragment of the left fibula.
i) A cervical vertebra without a sector of the anterior region.
j) A caudal vertebra more or less complete.
k) Two vertebral centra from the caudal region.
l) Various vertebral centra affected by erosion, and other remains of very little diagnostic value.

The characters of preservation of these materials, as well as the sedimentological data of the bed which contained them, coincide in indicating that the eroded and fractured surfaces that are present on nearly all of them must be interpreted as the result of erosive fluvial action.

[(2)] The studies of Huene (7) merit a reconsideration with respect to the evaluation of the morphological characters that this investigator has used for his determinations. At least with respect to the Argentine material of *Titanosaurus, Laplatasaurus* and *Antarctosaurus* discovered in Patagonia, the morphological differences that characterize these forms are not very clear.

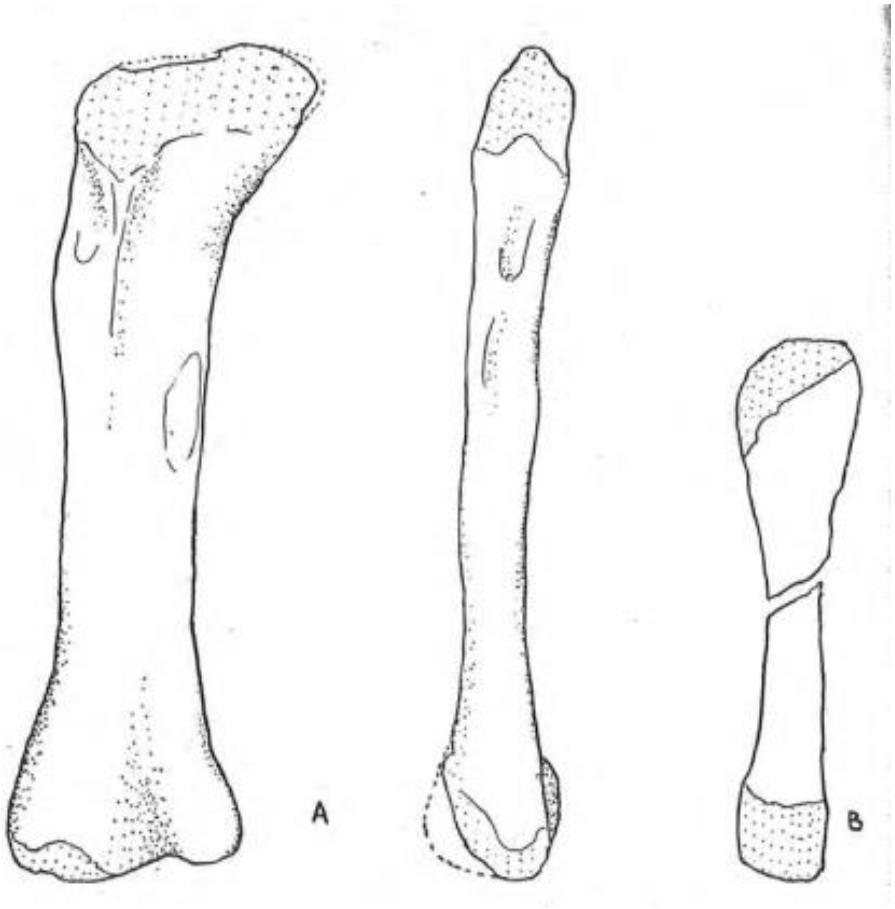


Figure 3 A and B — *Antarctosaurus* sp. PVL. 3670 X 1/10
A: Posterior and lateral views of the left femur. B: Medial view of the right fibula. The regular dotting indicates the part affected by ancient erosion. Provenance: Pirgua Fm. of the Salta Group.

The only remain of diagnostic value from the Yacoraite Fm. that pertains to a carnosaurian dinosaur is the crown of a sectorial tooth, PVL 3672. The tooth of a crocodile also comes from the same formation and has number PVL 3673.

Description of the material assigned to Antarctosaurus

Because the bony elements collected up to now do not display anatomical details revealing a new genus or species, distinct from those already known in Argentina, we believe it is sufficient to illustrate and briefly describe the principal bony pieces.

Femur
(Fig. 3A)

Measurements:

total preserved length	111 cm	estimated 115 cm
maximum proximal width	30 cm	

maximum distal width	30 cm
minimum shaft width	17 cm

It is a predominately straight bone with smooth expansions at both ends, and generally slender. In the dorsoventral direction, the entire anterior surface is slightly convex, and the posterior is somewhat concave. The barely prominent internal trochanter is located a little above the halfway point of the bone (the center of that trochanter is 64 cm from the distal end and 51 cm from the supposed proximal border). The internal edge of the femur, nearly straight in the central region of the shaft, curves smoothly toward the internal side at both ends. The lateral edge is almost parallel to the internal, except in the distal sector where it curves outward. The distal region occupied by the condyles presents a slight anteroposterior thickening. The medial condyle is more globular than the lateral, and the popliteal fossa is smooth and extended.

Humerus

(Fig. 3C)

Measurements:

total preserved length	70 cm	estimated 80 cm
maximum proximal width preserved	24 cm	
maximum distal width preserved	20 cm	
minimum shaft width	14 cm	
maximum thickness distal end	10 cm	

In posterior view (anatomically dorsal) the smooth curvature of the medial border and the less curved lateral border are evident. This signifies that the humerus is a long and narrow bone, even considering the eventual expansion of the proximal region that is not preserved in its entirety. Nor are vestiges preserved of the anterior projection of the deltoid crest. In the distal region, the entire anterior border is convex and the posterior shows a wide depression in the dorsoventral position that delimits a marked lateral elevation which culminates in the condyle for the ulna. Viewed laterally, the entire posterior face of the bone is widely concave.

Ulna

(Fig. 3D)

Measurements:

maximum preserved length	58 cm	estimated 61 cm
maximum proximal width	22 cm	
maximum distal width	14 cm	
minimum shaft width	9.5 cm	

This bone has a wide proximal expansion, in which region the cross-section is triangular, with a wide face on the posterior side. The anterior and lateral face shows an angular border, well-marked enough in the proximal sector that is extended along nearly the entire length of the bone. In general, its aspect is robust and heavy.

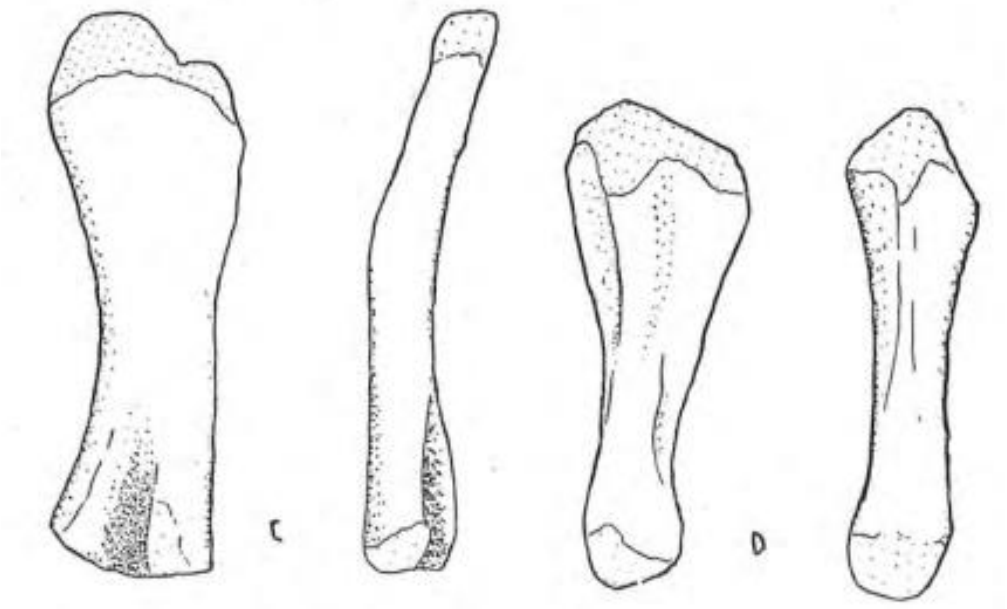


Figure 3 C and D — *Antarctosaurus* sp. PVL. 3670 X 1/10
C: Posterior and internal views of the right humerus, incomplete at both ends. D: Anterior and lateral views of the right ulna. The regular dotting indicates the part affected by ancient erosion. Provenance: Pirgua Fm. of the Salta Group.

Fibula

(Fig. 3B)

Measurements:

total preserved length	69 cm	estimated 72 cm
maximum proximal width	16 cm	
maximum distal width	11 cm	
minimum shaft width	7 cm	

We possess two fragments that seem to form the fibula from the right side, and another from the distal portion of the left fibula. Almost all the medial face is rather flat in the dorsoventral direction, and somewhat concave in the anteroposterior direction. In the lateral face and somewhat toward the middle of the bone are appreciated vestiges of a bony rugosity corresponding to the insertion point of the iliofibularis muscle. The proximal region is rather expanded, rather more than the distal. If the length of the fragments that form the right fibula is correct, estimated at 72 cm, it represents approximately 4/5 of the length of the femur.

Radius

Measurements:

maximum length preserved	47 cm	estimated 54 cm
maximum distal width	13 cm	
minimum shaft width	6 cm	

The radius that we possess is incomplete at both ends, especially the proximal, and therefore its orientation presents difficulties. The proximal cross-section is more or less subcircular and the distal somewhat more oval. The shaft, although proportionally slender, its circular cross-section confers robustness. The entire anterior edge is well curved backward.

Pubis

Measurements:

preserved length	52 cm
preserved proximal width	19 cm

The fragment of pubis, from the right side, represents more than half of its original length. The symphyseal region is entirely lacking, and what is preserved is the thickest part of the pubis. It is a laminar bone, very straight, and transversely convex on the dorsal face. The ventral face possesses a well-defined edge on the proximal half of the preserved part.

Vertebrae

Among the vertebral remains are two elements that show characters of interest. One of them represents the greater part of a cervical vertebra, possibly the tenth, which has the following measurements:

preserved length of vertebral centrum	17 cm	estimated 22 cm
width of centrum at posterior end	11 cm	
maximum height of posterior region	15 cm	

This opisthocoelous cervical vertebra presents a relatively low, elongate centrum with wide, aliform lateral processes, true diapophyses. The structure of this vertebra is typically cavernous, that is with great free cells of bony material, in reality filled with sediment.

The caudal vertebra is procoelous, a typical character of large sauropods. The bony weave that this and the remaining caudal vertebrae possess does not present those characters of pneumatization that we have indicated for the cervical vertebra. Its principal measurements are:

maximum length of vertebral centrum	13 cm
height of anterior region of centrum	10 cm
height at neural spine	17 cm

Comparison of the material

The study of the materials described and figured above led us rapidly to an identification with the titanosaurids known from the Upper Cretaceous of Patagonia, and on which we have satisfactory data principally from the studies of Lydekker (10), Ameghino (1), and in particular F. von Huene (7).

The anatomical characters of the bones, the size ratio between the fore- and hind limbs, the procoelous structure of the caudal vertebrae, the morphology of the femur, humerus and ulna, clearly indicate to us its true relationship to the sauropod family Titanosauridae. More specifically to the subfamily Titanosaurinae *fide* Romer, mostly including genera from the Upper Cretaceous of South America (Argentina, Uruguay, Brazil and Colombia) and Africa, Asia, Europe and North America.

The Argentine genera from Patagonia that we know currently are: *Titanosaurus* Lydekker, *Laplatasaurus* Huene, *Antarctosaurus* Huene and *Argyrosaurus* Lydekker represented by eloquent materials; and, in addition, *Campylodon* Huene, *Clasmodon* Ameghino and cf. *Macrurosaurus* Seeley, whose materials are more incomplete, and for that reason comparisons are more difficult.

Among the numerous titanosaurid materials from Argentina brought to light by the cited authors, the femur and humerus are perhaps the postcranial bones that best characterize the genera *Titanosaurus, Laplatasaurus, Antarctosaurus* and *Argyrosaurus*.

The referral of the material that we have described to the genus *Antarctosaurus* is based principally on the common characters that we have observed in the femur and humerus. The femur, as much in *Laplatasaurus* as in *Antarctosaurus*, is distinguished by its columnar, nearly straight aspect, and by the lesser anteroposterior thickness of its shaft. The femur from Salta, in addition to presenting these characters and being larger and proportionally thinner than those referred to *Titanosaurus*, is identified with that of *Antarctosaurus* by the small expansion in the region of the greater trochanter and by the morphology of the distal condyles.

The humerus possesses similarities with that of *Antarctosaurus* in its slenderness, the elongate and narrow shaft, and some characters of the distal condyles. The rest of the described materials show additional affinities with *Titanosaurus* and *Laplatasaurus*, in other words the assignment is based principally on the characters of the femur and humerus.

AGE OF THE TITANOSAURIDS FROM PATAGONIA

F. von Huene, in his monograph on the saurischian and ornithischian dinosaurs from the Cretaceous of Argentina (7), defined their age, and in particular that of the

titanosaurids, as Senonian. Later the same author (8) considered them to be Upper Senonian.

Feruglio (4) and Groeber (6) made individual works of synthesis that included almost all the information accumulated on the Dinosaur Beds. For this reason, we refer to their amply documented chronological assessments. Feruglio (*op. cit.*) attributed a Senonian age to the "Dinosaur Beds," which at the height of Lago Argentina (Santa Cruz prov.) is intercalated with marine sediments of this age. The other observations considered by this author in relation to the "Dinosaur Beds," already from Neuquén, Chubut and Santa Cruz, corroborate the preceding chronological assessment.

Ten years later, Groeber was occupied with the relationship problems of the Upper Cretaceous of Patagonia. Based on the ammonite content produced from the region southwest of Santa Cruz, Groeber maintained that the Senonian series (marine-continental) of this Santa Cruz region begins in the Lower Campanian (Groeber 5, p. 12). Later he indicated that the last ammonite-bearing layer corresponds to the Upper Campanian.

In this manner the thickness of the "Dinosaur Beds," located superficial to them, corresponds to the Lower and Middle Maastrichtian age. Nevertheless, he admitted that in the extra-Andean region, the maximum age of this assembly could descend into the middle Upper Campanian. In addition, he indicated that the Chubutian and Pehuenche ("Dinosaur Beds") do not reach the top of the Maastrichtian, because on it exists a great thickness of marine sediments with a clearly Senonian fauna (6, p. 26). That is, the age assigned by Groeber to the Chubutian and Pehuenche with titanosaurids includes from the Middle Campanian to the Middle Maastrichtian.

Criado Roque et al. (3), in the generalized profile of the Neuquén sedimentary basin, locate the "Dinosaur Beds" (Pehuenche) as occupying the Upper Cretaceous.

As we observe, there exists a general agreement in assigning the "Dinosaur Beds" to the Senonian. Groeber's estimation that they belong between the Middle Campanian and Middle Maastrichtian seems well founded, fixing more decidedly its Senonian age. Consequently, the *Antarctosaurus* from the Pirgua Fm. seems without doubt to belong to the Upper Senonian age; more possibly Lower or Middle Maastrichtian.

This good chronologic element makes possible the reconsideration of the age of the formations of the Salta Group, at least in the area south of this sedimentary basin.

TABLE 1

AGE	STEINMANN PUNA AND BOLIVIA 1904–1906	BONARELLI INTERMONTANE REGIONS PREC. SALTO JUJERA 1921	SCHLAGINTWEIT JUJUY-BOLIVIA 1941	RUIZ HUIDOBRO SHEET 7 SALTA 1955	TURNER SANTA VICTORIA, JUJUY 1960
TERTIARY	JUJUY SCHICHSTEIN: CONGLOMERATE; SANDIGE; MERGEL	UPPER TERTIARY JUJEÑO STRATA LOWER TERTIARY TERTIARY SUBANDEAN	MULTICOLORED MARGAS	JUJUY FORMATION CARAHUASI FORMATION	AGUILAR FORMATION
CRETACEOUS	OBERE SANDSTEIN	UPPER *SANDSTONES*	Horizontal Dolomitic Limestone Calcareous Sandstones	CRETACEOUS (?): SANTA BARBARA FORMATION	MESOZOIC: SANTA BARBARA FORMATION
	PUCA SANDSTEIN: KEUPER RATIGE MERGEL		Lower Sandstones		
JURASSIC	BASAL SANDSTEIN	Horizontal Dolomitic Limestone: Upper: Variegated Clays; Keuper Ratige Mergel of Steinmann		HORIZONTAL DOLOMITIC LIMESTONE	YACORAITE FORMATION (Groeber cited by Turner)
TRIASSIC		Lower: Horizontal dolomitic limestone with *Melania* (Keidel)		PIRGUA FORMATION	LECHO FORMATION
PERMIAN		Lower Sandstones: SANDSTONES; CONGLOMERATES		TRIASSIC (?)	SALTA GROUP: PIRGUA FORMATION

COMMENTARY ON THE AGE OF THE SALTA GROUP

The Salta Group constitutes a greatly diffused entity in the north of Argentina and a great part of Bolivia. The particular lateral uniformity of the Yacoraite Formation (which includes the middle section) has permitted correlation with similar beds (Schlagintweit, 15) in Bolivia that possess a marine fauna.

The absence of fossils of precise chronologic value has maintained uncertainty as far as the validity of the numerous chronologic assignments for the Salta Group. Although in recent years an agreement was obtained in considering it of Cretaceous age, there exists no certain date that indicates to which moment in this period this geologic Group should be referred. The estimations of better-known authors are included in Table I.

Although fossil discoveries are not few in the formations of the Salta Group in Argentine territory, none of them has given sufficiently valid dates. Those of insects from the Santa Bárbara Fm., studied by Cokerell (2) and considered Tertiary, evidently do not permit secure chronologic estimations.

The frogs discovered by Ibáñez (9) in the Pirgua Formation, south of Salta and judged by Reig (12) to be Early Cretaceous, neither bear (at least in the stage of the "preliminary note" in which they were studied) a precise chronologic date, above all because in Argentina true frogs are encountered in the Liassic of Roca Blanca (Santa Cruz prov.). Ibáñez (9, p. 176) then discovered fishes in the La Tesera Ravine (more possibly in the Santa Bárbara Fm.) that were classified by Schaetter as pertaining to two distinct genera; one typical of the Upper Cretaceous, and the other from the Upper Cretaceous and Tertiary. This determination, which was not publicly expressed but which responded to a demand of Dr. Ibáñez, results in singular interest and approximation. Other sites of discovery of chelonians, fishes, insects and molluscs only reveal the relative abundance of fossils, without having obtained from them the necessary chronologic information.

Consequently, the correlation proposed by Schlagintweit (15) between the Miraflores profile (southeast Bolivia), which has more or less well-dated fossils, and that of Espinazo del Diablo and other localities of Argentina, was the most valid element for his chronologic estimation, and by way of notable precision, because Schlagintweit considered the Upper Cretaceous age of the Salta Group. Later Groeber (5) correlated the Yacoraite Formation of Argentina with the Mojo floor and the "Ayavacas Limestone" in the vicinity of Late Titicaca, on which he founded his assignment of the entire Salta Group to the Andean (Lower and Middle Cretaceous).

Finally, the remains of *Antarctosaurus* in the Pirgua Formation and the carnosaurian tooth in the Yacoraite Formation definitively indicate an Upper Senonian (Maastrichtian) age for these formations, which confirms Schlagintweit's (15) chronologic assessments.

General relationships between the Salta Group and the Chubutian and Pehuenche

Between the formations of the Salta Group and the "Dinosaur Beds" of Patagonia (especially Neuquén), both with titanosaurids, there exists a series of similarities as much geological as biological that it is worth the trouble to consider. These similarities are not only in response having taken place in apparently homotaxic situations, but also those principal physical factors having acted in a parallel manner, thus resulting in the following aspects of apparent correlation:

a) *Basal discordance*

Numerous authors have noted that the "lower sandstones" of the Pirgua Formation lie discordantly on Paleozoic or Precambrian rocks, transgressively filling an irregular and partly peneplanar relief, a situation evident in the region of the discoveries that motivated this work.

The "Dinosaur Beds" in Neuquén (Feruglio 4, p. 240 and others) lie, at times in pronounced discordance, "on terrains of very diverse age, on ancient crystalline rocks." Groeber (6) refers to the irregular relief in which the deposition of the Chubutian and the transgressive character of the upper groups of the Pehuenche and Chubutian are verified.

This discordance presented below the "Dinosaur Beds" of Patagonia is interpreted as proving an inter-Senonian movement that is contained between the Santonian? and Lower Campanian?, *vide* Groeber (6, p. 12?).

The relationship of the discordance that observed between the Pirgua Formation of Salta and the adjacent rocks could well be interpreted as representing in this zone the Upper Cretaceous movement detected in Patagonia and Peru (Peruan folding, Steinmann).

b) *Process of filling the basins*

The evolution of the basin filling of Upper Cretaceous sediments of Neuquén is similar, in broad features, to that of the Salta Group. We hold that both possess the following fundamental characteristics:

Neuquén Basin (summary from Feruglio 4, p. 240–241)	*Salta Basin*
upper section: somewhat more than 700 m of yellow and reddish sandstones with red clays, containing remains of *Corbicula* (Allen Beds), *Viviparus*, teeth of *Ceratodus* and crocodiles, and turtle shells	*upper section:* more than 800 m of variegated clays with marly periods, with fishes, insects and turtles
middle section:	*middle section:*

300 m of moderate and thick sandstones (Candeleros Beds)	more than 300 m of calcareous sandstones, caliches and clays with *Pucalithus, Melania* sp.?, teeth of crocodiles and carnosaur remains
lower section: 550 m of somewhat clayey sandstone, variegated sandstones with remains of dinosaurs, clayey sandstones and limestone beds, and conglomerates at the base	*lower section:* 700 m of sandstones of diverse types, with dinosaurs and frogs, sandy clays and conglomerates

T A B L E II

REGIONAL CORRELATIONS

SALTA GROUP	*"DINOSAUR BEDS"*	*ENTRE RIOS*	*URUGUAY*
Santa Bárbara Fm. fishes insects.	Upper Section crocodiles turtles fishes.	? /\ |	? /\ |
Yacoraite Fm. dinosaurs crocodiles	Middle Section	|	|
Pirgua Fm. dinosaurs frogs	Lower Section dinosaurs	Sandstones with dinosaurs |	"Palacio Sandstones" dinosaurs.
discordance	discordance	\/ d	discordance

In both cases dinosaur remains are presented principally in the rather conglomeratic sandstones of the lower section; and remains of crocodiles, fishes and molluscs in the higher sections, of clayey and calcareous type. There also exist indications of a brackish habit for the sedimentation of the upper part of both basins. Schlagintweit (15, p. 349–350) maintained that the Yacoraite Formation is mostly fresh water in Argentina, whereas in Yavi (Jujuy) it has flat oysters that indicate a certain marine influence. In Miraflores (Bolivia) "the marine component of the fauna of this formation is more pronounced" (15). These details indicate the existence of a marked parallelism between the upper section of the "Dinosaur Beds" of Neuquén and at least the beds of the middle section of the Salta Group (see Table II). On the other hand, the culmination of the Upper Cretaceous sedimentary cycle with lacustrine-lagoonal facies, in both basins and in beds of similar age in Chile, holds a fundamental importance that we use to reconstruct the general panorama of the western edge of the continent during the Upper Cretaceous. In this manner we believe that

the Upper Cretaceous or Peruan movements would have made possible the formation of continental-type (primarily fluvial and certainly lacustrine) basins approximately at sea level, connected transitionally with them.

BIBLIOGRAPHY

AMEGHINO, F. 1899. *Nota preliminar sobre el "*Loncosaurus argentinus*," un representante de la familia de los Megalosauridae en la República Argentina*. – An. Soc. cient. argent. *47*:61.

COKERELL. *Cited by Schlagintweit* (1937).

CRIADO ROQUE, P. et alii 1960. *Cuencas Sedimentarias de la Argentina*. – Bol. Inf. Petrol. no. 320.

FERUGLIO, E. 1949. *Descripción Geológica de la Patagonia*. – Minist. Ind. y Com., YPF.

GROEBER, P. 1952. *Mesozoico,* in *Geografía de la República Argentina*. – GAEA, *2*, 1.

———— 1959. *Supracretácico*, in *Geografía de la República Argentina*. – GAEA, *2*, 2.

HUENE, F. von. 1929. *Los Saurisquios y Ornitisquios del Cretácico Argentino*. – An. Mus. La Plata, *3*, 2nd ser.

———— 1956. *Paleontologie und Phylogenie der Niederen Tetrapoden*. Fischer, Jena.

IBÁÑEZ, M. A. 1960. *Informe preliminar sobre el hallazgo de Anuros en las "Areniscas Inferiores" de la quebrada del río Las Conchas (prov. de Salta), Argentina*. – Acta geol. lilloana, *3*.

LYDEKKER, R. 1893. *The Dinosaurs of Patagonia*. – An. Mus. La Plata, *2*.

RASSMUSS, J. 1925. *Las Termas de Rosario de la Frontera*. – Bol. Direcc. Min. geol., *13F*.

REIG, O. A. 1950. *Primeros datos descriptivos sobre los anuros del Eocretácico de la Provincia de Salta (Rep. Argentina)*. – Ameghiniana, *1*, 4.

RUIZ HUIDOBRO, O. 1960. *El Horizonte Calcáreo Dolomítico en la Provincia de Tucumán*. – Acta. geol. lilloana, *3*.

SCHLAGINTWEIT, O. 1937. *Observaciones estratigráficas en el Norte Argentina*. – Bol. Inf. Petrol. no. 156.

———— 1941. *Correlación de la calizas de Miraflores en Bolivia con el Horizonte Calcáreo Dolomítico del Norte Argentina*. – Notas Mus. La Plata

LA YESERA
GARCIA y VILELA
(1956)

YERBA HUASI
DANIELI
(1957)

INDIA MUERTA

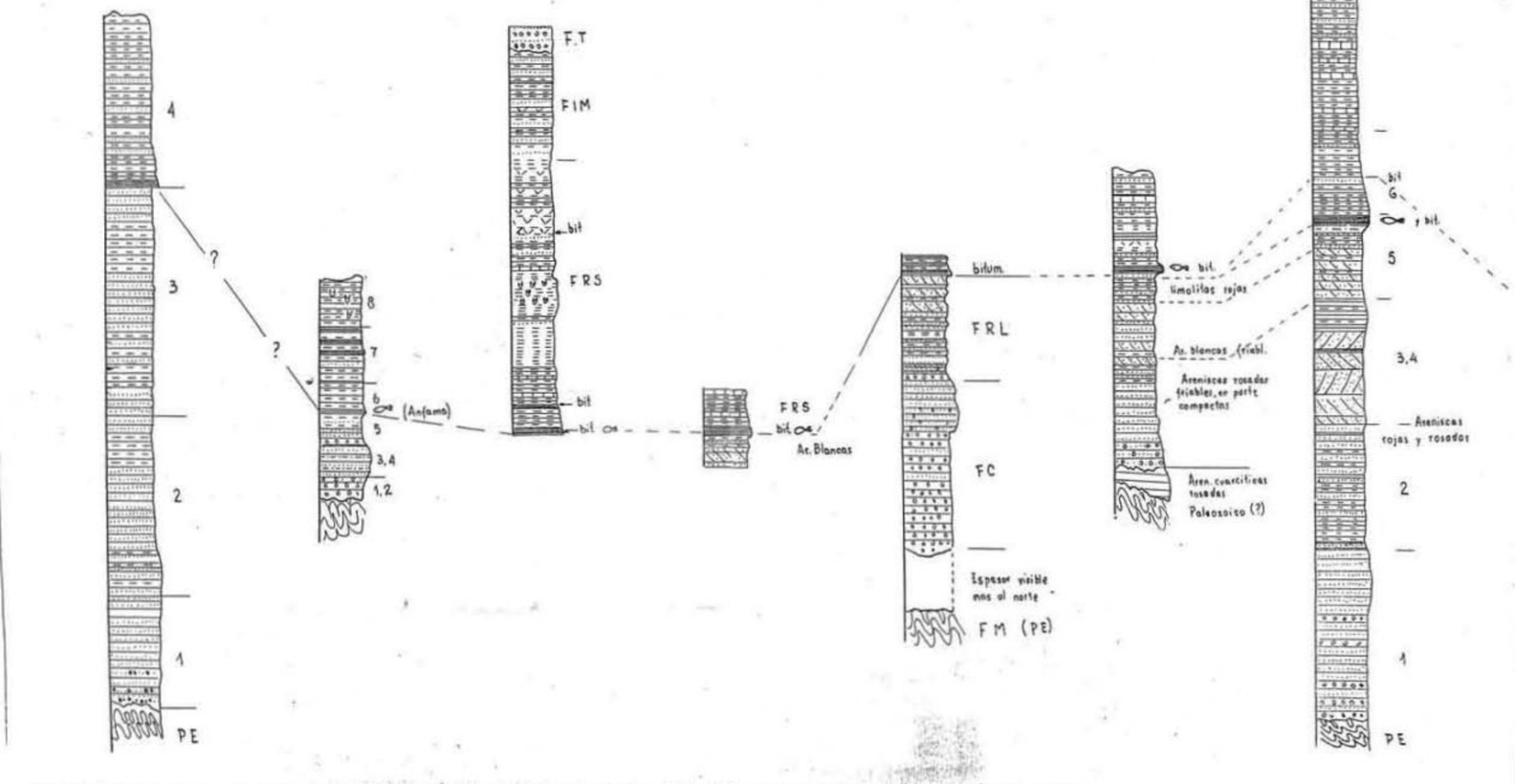
LA SALINA

EL CADILLAL y RIO LORO

REQUELME
(Aº SECO)
PERFIL APROXIMADO

MORENILLO
Aº MORENILLO
SCHLAGINTWEIT
(1937)
PERFIL APROXIMADO

C
R.
(
P.E

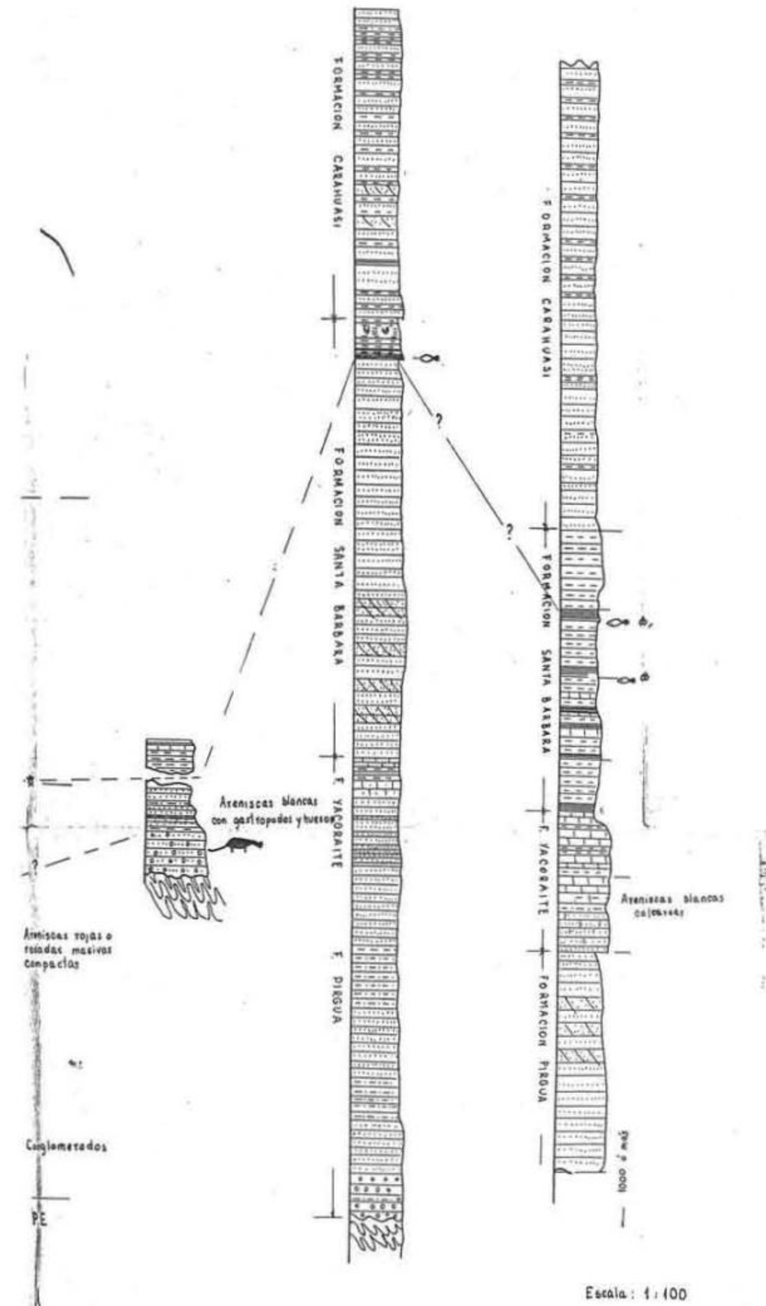


FM: FORMACION MEDINA ; F.C: FORMACION EL CADILLAL; F.R.L: FORMACION RIO LORO; F.R.S: FORMACION RIO SALI ; F.T: FORMACION TICUCHO

AGUAS CALIENTES
PERFILES DE LA ZONA
DE A. CALIENTES Y Q. del
MORTERITO

ALEMANIA
SINCLINAL DE COPACABANA
Y HUIDOBRO
(1949)

PEÑAS AZULES
BOSSI - CABELLO
(1960)



Escala: 1:100