"Discovery of sauropods in the Bajo Barreal Formation of Ocho Hermanos, Sierra de San Bernardo, and their chronological significance"[*]

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ORIGINAL ENGLISH ABSTRACT

An association of sauropod remains found at the Lower Member of the Bajo Barreal Formation (Chubut Group) at Estancia Ocho Hermanos, province of Chubut, is reported. It includes bones and teeth referred to Titanosauridae and to another group of dinosaurs more related with the Jurassic and Early Cretaceous lineages of non-titanosaurid sauropods. The age of the Lower Member of the Bajo Barreal Formation at Ocho Hermanos is considered as Aptian-early Senonian.

I. INTRODUCTION

The sauropod dinosaurs constitute a group that is present with much frequency in the outcrops of Cretaceous sediments of Patagonia, a characteristic for which they are recognized with the name of "Strata with Dinosaurs" (Chubut Group).

A large part of the recovered forms pertain to the family Titanosauridae, principally documented in the upper extremes of the Senonian (Huene, 1929; Bonaparte and Gasparini, 1979; Powell, 1986). In the South American Lower Cretaceous sauropods of the family Dicraeosauridae (Bonaparte, 1986), *Chubutisaurus insignis* (Del Corro, 1975; Bonaparte and Gasparini, 1979), and other unpublished materials have been discovered. The forms of the Lower Cretaceous constitute remnants of lineages of sauropod dinosaurs of the Upper Jurassic of Gondwana and Laurasia, that have not been recorded to date in the Upper Senonian where the family Titanosauridae is common.

The objective of the present work is to bring to light the discovery of new remains of dinosaurs in the Province of Chubut, that document for the first time in South America a significant association: titanosaurids and sauropods of Jurassic-Early Cretaceous lineages in the Cretaceous of South America.

The material that is announced comes from the Lower Member of the Bajo Barreal Formation of the Sierra de San Bernardo, Province of Chubut. Although the remains are fragmentary, they constitute significant evidence that allow one to reinterpret aspects of the chronology of the Chubut Group.

The remains described here have been obtained in the course of a series of exploratory trips carried out previously by personnel from the Universidad Nacional de la Patagonia "S. J. Bosco", that took place between 1984 and 1986.

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The abbreviation UNPSJB-PV corresponds to the Colección de Paleontologia de Vertebrados of the Universidad Nacional de la Patagonia "San Juan Bosco".

II. BACKGROUND

The territory of the Province of Chubut has attracted the attention of explorers, as much geologists as paleontologists, that collected and reported the discovery of dinosaur remains in the area of the Sierra de San Bernardo. Notable among them are Santiago Roth, Carlos Ameghino, E. S. Riggs, von Huene (1929), Feruglio, E. (1949), and more recently Bonaparte (1978).

In 1979 and 1980, Dr. J. F. Bonaparte and his team carried out works of paleontologic exploration, thanks to data provided by the Lic. Juan C. Sciutto on the discovery of bony remains of dinosaurs obtained in the course of a geologic report.

The material obtained by Bonaparte and collaborators includes carnosaurs, sauropods, and a turtle.

Part of the material corresponds to sauropods that were reported by Powell (1986, 1987) who described *Epachthosaurus sciuttoi* assigned with doubts to the family Titanosauridae.

The most significant carnosaur remains were described by Martínez et al. (1986), who brought to light a form assigned to the Abelisauridae: *Xenotarsosaurus bonapartei*.

III. GEOGRAPHIC LOCATION OF THE LOCALITY

The locality is found in the Estancia Ocho Hermanos, somewhat north of Las Pulgas, in the northern region of the Sierra de San Bernardo, Dep. Sarmiento, Prov. of Chubut.

The most direct access is achieved over the Provincial Route No. 270 (formerly Nac. No. 20) until Las Pulgas, where it is left for a path toward the north, passing by Puesto Etcheto, Laguna Colorada, and Estancia Ocho Hermanos. 2 km from this last point a secondary path deviates toward the east, that leads to the area of the locality, after 3 km. A geologic outline of the area was presented by Martínez et al. (1986).

IV. GEOLOGY

1. General characteristics

From the center and the south of Chubut Province, to the north of Santa Cruz, outcrop sedimentary units of Cretaceous age, known by the name of the Chubut Group (Lesta and Ferello, 1972). This entity corresponds to the term "Chubutiano" utilized in previous works.

The Chubut Group is composed by three units recognized in the highlands of San Bernardo and surroundings. The lowest is the Castillo Formation, the middle the Bajo Barreal Formation and the upper the Laguna Palacios Formation (Sciutto, 1981) and correspond to the "Tobas Verdes", "Tobas Grises" and "Tobas Amarillas" (Feruglio, 1949) respectively. The units mentioned have subsurface equivalents in the Golfo San

Jorge Basin and outcrops in the northern area. Some authors have proposed diverse variants, for the subdivision of the Group and equivalency between the units.

On the Chubut Group lie unconformably, in some areas, the Paso del Sapo Formation and the Lefipán Formation, composed by Maastrichtian marine deposits, and the Salamanca Formation and Río Chico Formation, the first also marine and the second continental of Paleocene age, and extensive basaltic sheets.

2. Characteristics of the Bajo Barreal Formation in Ocho Hermanos

Following Sciutto (1978), the Bajo Barreal Formation is represented in Ocho Hermanos by two members: a lower with a thickness of 148 m and an upper of 107 m.

In the Lower Member tuffs and sandstones predominate with intercalations of sandy tuffs and scarce levels of ashy tuffs. The sandstones progressively increase in proportion until they predominate in the top of the member. A cycle that usually is present is the following: graded sandstones, where disseminated remains of dinosaurs appear, that pass transitionally to tuffs, on these that a paleosol is developed, later covered by clear and whitish laminated tuffaceous banks.

The thick sandstones of the upper sector are those that are associated with the most clear fossil soils and that possess a large quantity of bony reptile remains.

The Upper Member evidences a marked decrease in sandstones, incorporating banks more muddy each time. Horizons of small roots and paleosols are common. The sandstones are of lenticular section and have characteristics of aquaeous meandering streams.

V. SYSTEMATIC PALEONTOLOGY

ORDER SAURISCHIA

SUBORDER SAUROPODA

FAMILY TITANOSAURIDAE

SUBFAMILY TITANOSAURINAE

Caudal vertebrae

5 caudal vertebrae have been discovered (UNPSJB-PV 175/176/177/876/877; Fig. 2: A and B) associated with an incomplete right femur (UNPSJB-PV 172), two haemapophyses (Fig. 2: C and D), and indeterminate remains.

The vertebrae are procoelous, with a relatively short centrum. The neural arch is completely displaced forward and is of robust structure. The body is narrow in ventral view and with concave lateral walls. The vertebral body has normal spongy tissue. The neural spine is not preserved. One of the vertebrae preserves the prezygapophyses, that surpass the plane of the anterior articular surface. The preserved transverse processes project laterally and backward.

One of the vertebrae (UNPSJB-PV 730, Fig. 2 G) that does not pertain to the series previously described, presents the posterior articular cone with the apex prominent

and eccentric, located above the center of the articular surface as in *Titanosaurus* (Powell, 1986) and *Epachthosaurus*[1] (Powell, 1987).

Haemopophyses

There are two haemopophyses (UNPSJB-PV 186/873; Fig. 2[2], C and D.). They have the form of a "Y". The distal extreme is laterally compressed and is wide. The articular surfaces are separated from each other. The point where the rami unite is anteroposteriorly compressed.

Family TITANOSAURIDAE indet.

Teeth

An isolated complete tooth has been found (UNPSJB-PV 874; Fig. 3, D[2]). It is of cylindrical form, with the axis curved, concave toward the lingual side. The labial face of the tooth in transverse section shows more convexity than the lingual. Toward the apical extreme, this convexity is less accentuated, and it has obvious angular lateral borders. The enamel is smooth, except in the middle part of the lingual surface. An apical wear facet is not observed. The root is short , with a large pulp cavity, wide below and becoming more narrow toward the corona.

Vertebrae

A caudal vertebral centrum (UNPSJB-PV 182; Fig. 2, E and F) has been prepared. It is slightly procoelous, with a smoothly cylindrical, laterally excavated body, narrowing in ventral view. The articular cone, slightly pronounced, is smoothly divided into three parts by a sulcus in the form an inverted "Y". The trace that the neural arch has left, indicate that it was robust and was strongly displaced forward.

SAUROPODA indet. (not Titanosauridae)

Six caudal vertebrae, a left premaxilla, and isolated teeth were obtained from this locality, that with difficulty belong to the same individual.

Premaxilla

The almost complete left premaxilla (UNPSJB-PV 669) is relatively high, with its external surface somewhat convex in transverse aspect. In lateral view the medial contour that limits the plane of the symphysis shows its maximum convexity toward the half of the same. The medial or symphyseal face is narrow as in *Patagosaurus fariasi* Bonaparte (1986) from the Jurassic of Chubut. The maxillary articular surface is almost flat and measures 3.4 cm in its middle part. This face is linked with the plane of the symphysis, by means of a surface oriented posterodorsally, strongly convex in the form

[1] The authors probably meant to refer to *Aeolosaurus* rather than *Epachthosaurus*, since the caudal series of *Epachthosaurus* was undescribed at the time of their publication (and remains undescribed). Furthermore, they cite Powell, 1987, which includes a description of a specimen referred to *Aeolosaurus* from the Los Alamitos Formation of Río Negro, Argentina, the caudals of which resemble that in Fig. 2G (UNPSJB-PV 730).

[2] Original publication refers to Fig. 3C, this is a typographical error.

of a saddle. The premaxilla has a general morphology resembling that of *Patagosaurus fariasi*
(PVL 4076) that would shape a muzzle in dihedral angle, with a relatively narrow symphyseal face, clearly different from the unique premaxilla known from the
titanosaurids assigned to the subfamily Titanosaurinae (Powell, 1979), that possess a smoothly convex anterior contour of the muzzle and a wide symphyseal face.

Teeth

One of the best preserved teeth (UNPSJB-PV 672, Fig. 3: A, B, and C[3]) is of the "camarasauriform" type. It is spatulate with a high crown, with rugosity in the enamel similar to those described by White (1958) for *Camarasaurus*. In the apical extreme an incipient beveled wear surface is observed. Its axis is recurved caudally as in *Camarasaurus*, *Brachiosaurus*, and *Cetiosaurus*. The labial face is spherical, but slightly concave near the borders of the tooth. The lingual surface is less transversely convex and concave in the sense of the tooth axis. A central elevation delimits two wide grooves situated in parallel form and near to the borders of the tooth.

The remaining teeth, in general, are incomplete. However, pieces like UNPSJB-PV 208, which is only lacking a superficial portion of the labial side and the region of the root, allows to establish that they are of teeth very similar to those of *Campylodoniscus ameghinoi* (Huene, 1929). The external surface is spherical and the axis of the tooth is recurved in its apical extreme toward one of its sides. The crown is delimited below by a weak neck. In some pieces (UNPSJB-PV 209-212), an apical wear facet is preserved, developed almost perpendicular to the axis of the tooth. The surface of the enamel is grooved by weakly developed longitudinal striations in UNPSJB-PV 209/212/214, similar to those observed in *Campylodoniscus ameghinoi*, as has been pointed out above, and has a structure intermediate between the spatulate "camarasauriform" dental model that is present in the cetiosaurids, camarasaurids, and brachiosaurids, and the "diplodociform" cylindrical model characteristic of others, the diplodocids and titanosaurids.

Caudal vertebrae

5[4]?middle caudal vertebrae have been discovered (UNPSJB-PV 1/2/3/178/179/180/181/595/872; Fig. 1 A-G), one of them almost complete (UNPSJB-PV 595).

They are vertebrae of the amphicoelous type having a robust centrum, somewhat laterally compressed, with the anterior articular surface smaller than the posterior. They are somewhat wider than high and have rugosities in all of their extension. The ventral surface of the vertebral body has a smooth depression that narrows in the middle portion and enlarges at the ends. In the anterior third and posterior of the groove are longitudinal rugosities. The neural spine is laterally compressed and high. The vertebra (UNPSJB-PV 178) is somewhat amphicoelous, of short body and laterally excavated. In ventral view a deep groove is observed, that anteriorly and posteriorly approaches the facets for the haemopophyses. The neural arch is very robust and displaced anteriorly. The prezygapophyses are incomplete and the postzygapophyses are not preserved.

[3] Original publication refers only to Fig. 3A-B.
[4] Listed previously as 6 vertebrae; specimen numbers indicate as many as 9 may be present.

What remains of the transverse processes indicates that they would arise as wide bony laminae from the lateral portion of the neural arch.In anterior view, a well marked round depression that is situated within the transverse process is observed.

The amphicoelous caudal vertebrae constitute some of the most interesting elements; they resemble those of non-titanosaurid sauropods recorded in various parts of the world including South America. The neural arch of these vertebrae does not reach the anterior margin of the vertebral centrum. This character, as well as the absence of procoelous caudal vertebrae, permits the exclusion of these forms from the family Titanosauridae.

SAUROPODA indet.

Basicranium

The basicranium (UNPSJB-PV 875) better preserves the foramina corresponding to the cranial nerves IX-XI on the right side, the fenestra ovalis, that opens into an independent orifice for the exit of the nerves mentioned before, as in *Diplodocus* (Berman and McIntosh, 1978) and *Antarctosaurus* (Powell, 1986). More rostrally the emergence of nerve VII and the lower part of the contour of the foramen of nerve V and probably nerve III are observed.

In the anterior surface of the preserved fragment, the posterior half of the wide and deep (19 mm in diameter and 51 mm in depth) pituitary fossa is observed, perforated ventrally by a pair of foramina corresponding to the internal carotid. Laterally with respect to the pituitary fossa an opening for the emergence of nerve VI is located. This nerve penetrates the basisphenoids from the floor of the braincase to the level of the trigeminal foramen. The occipital condyle is not preserved and only the bases of the basioccipital tuberosities are observed, with a deep conical depression between them.

The Ocho Hermanos sauropod basicranium remains reveal a generalized structure, similar to that of sauropods such as *Diplodocus* (Berman and McIntosh, 1978) and *Antarctosaurus* (Huene, 1929; Powell, 1986). It differs, on the other hand, from *Saltasaurus loricatus* (Powell, 1986) for the emergence in independent apertures of nerves IX-XI and the fenestra ovalis.

VI. DISCUSSION

Though the available materials are scarce and fragmentary, they include pieces of certain value such as teeth, caudal vertebrae, and in lower grade, the premaxilla.

The separate analysis of the described pieces concludes in a coherent result that points out that we are in the presence of titanosaurid and non-titanosaurid sauropods.

The titanosaurids are clearly evidenced by the procoelous caudal vertebrae. Some of them have morphology typical of the Titanosaurinae (sensu Powell, 1986).

The remaining vertebrae, of the slightly amphicoelous type, undoubtedly correspond to non-titanosaurid sauropods, a hypothesis corroborated by other characters such as the morphology and disposition of the neural arch. These additional characters and the existence of a series that includes anterior caudal elements precludes the

possibility that they are only amphicoelous centra that are occasionally present in the caudal series of some titanosaurids (Powell, 1987).

The sauropod teeth recovered confirm the association of sauropods. On one hand, the cylindrical or "diplodociform" teeth are characteristic (although not exclusive) of the titanosaurids. The spatulate or "camarasauriform" teeth have not been documented in the family Titanosauridae and are common in sauropods of Jurassic-Lower Cretaceous lineage. The morphology of a large part of the spatulate teeth is very similar to that of *Campylodoniscus ameghinoi*. This taxon is based on a maxilla with teeth obtained by Carlos Ameghino in the area of the Sierra de San Bernardo, that as pointed out by Powell (1986), corresponds to a rather high skull of the *Camarasaurus* type. The evidence available for the moment prevents determination whether or not the materials here referred to non-titanosaurid sauropods can be included in some of the known families of sauropods, nor if they correspond to *Epachthosaurus sciuttoi* Powell, 1987.

VII. CONSIDERATIONS ON THE AGE OF THE BAJO BARREAL FORMATION IN OCHO HERMANOS

The age assigned to the Chubut Group has been the object of diverse interpretations, though it has been traditionally referred to the Upper Cretaceous: Senonian (Huene, 1929; Feruglio, 1949), Maastrichtian (Menendez, 1959); Upper Cretaceous (Gonzalez, 1971), Senonian-Danian (Vilela, 1971) and pre-Maastrichtian Senonian (Bonaparte and Gasparini, 1979).

Later, Lesta and Ferello (1972) appropriated these sediments to the Valanginian-Lower Senonian interval, and more recently Lesta et al. (1980) to the Barremian-Campanian.

The plant remains known as the Flora of Cerro Cachetemán, from the Castillo Formation, were referred by Menendez (1959) to the Maastrichtian, while a fossil flora determined by Hicken was assigned to the Cenomanian by Frenguelli (1930). Following more recent paleobotanical studies this unit would have an Aptian-Turonian age (Romero and Arguijo, 1981).

The sauropod association of the Bajo Barreal Formation that is presented in this work is a new judgment, particularly significant from a chronostratigraphic point of view. Powell (1986) pointed out that no less than 47 fossiliferous localities with titanosaurid sauropods are known in South America, the locality of Ocho Hermanos being the first in which remains of non-titanosaurid sauropods with amphiplatyan caudal vertebrae and teeth of the "camarasauriform" type are documented in association. Sauropods with these characteristics are known almost exclusively in the Jurassic and Lower Cretaceous.

In Gondwana, the only localities where associations of titanosaurids and sauropods of "Jurassic-Lower Cretaceous stock" have been documented are located in the Aptian of Niger (Taquet, 1976) and the Cenomanian of Egypt (Stromer, 1932).

On the basis of these records, it is considered that the association of Bajo Barreal in Ocho Hermanos would have a similar age (Aptian to Cenomanian), without discarding the possibility that it might still reach low levels of the Senonian.

This point of view concurs in part with others in focus (Romero and Arguijo, 1981; Lesta et al., 1980; Frenguelli, 1930) differing from the interpretations made by Huene (1929), Menendez (1959), and Bonaparte and Gasparini (1979). However, it is

necessary to point out that very probably the Bajo Barreal Formation was deposited during a wide period and that its limits cross time lines revealing distinct ages in different points of the Golfo San Jorge Basin, just as has been interpreted by various authors, among them Lesta et al. (1980).

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BIBLIOGRAPHIC REFERENCES see original publication

PLATE LEGENDS

Fig. 1
Middle caudal vertebra (UNPSJB-PV 595) in anterior (A), lateral (B), posterior (C), and dorsal (D) views.
Caudal vertebra (UNPSJB-PV 178) in anterior (E), lateral (F), and posterior (G) views.
Left premaxilla (UNPSJB-PV 669) in lateral (H) and medial (I) views.
Abbreviations ES.: Neural spine; POZ.: Postzygapophysis; PRZ.: Prezygapophysis; PS.: Plane of the symphysis.

Fig. 2
Titanosaurinae indet. Caudal vertebra (UNPSJB-PV 876[5]) in lateral (A) and anterior (B) views. Haemopophysis (UNPSJB-PV 186) in posterior (C) and right lateral (D) views. Caudal vertebra (UNPSJB-PV 182) in lateral (E) and posterior (F) views. Caudal vertebra (UNPSJB-PV 730) in lateral view (G).

Fig. 3
"Camarasauriform" tooth (UNPSJB-PV 672) in lingual (A), labial (B), and ?anterior (C) views. D. Titanosaurid tooth (UNPSJB-PV 874).

[5] "86" in original publication; this is a typographical error.