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JURASSIC CONCHOSTRACANS FROM PATAGONIA

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PART 1. PALEONTOLOGY AND PALEOECOLOGY

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ABSTRACT

Two new species (and three others) of the conchostracan genus *Cyzicus* are described and figured. All are Jurassic (Callovian) in age and from the Cañadón Asfalto Formation (Southern Facies of VOLKHEIMER), Chubut Province, Argentina.

Mesozoic cyzicids from Gondwana continents including Antarctica, as well as from Asia and Russia are reviewed. Details are given on Triassic and Jurassic cyzicids from Brazil, Venezuela, Colombia, and Argentina.

A seasonal sedimentation rate of $1.0 \pm \text{mm/year}$ is determined by data on successive conchostracan generations and by counting seasonal bands in fossiliferous shale slabs. Duration of conchostracans in ponds or lake pools is estimated to have been three to five or more months. Total duration of a given pond/pool site was one or two decades.

Deep red brown coloration of valves at one locality is attributed to low oxygen and hence a shrinking pond/pool situation. The Patagonian conchostracan species, it is suggested, thrived in the warmer season of the austral year.

INTRODUCTION

VOLKHEIMER's collection of Mesozoic conchostracans from Patagonia, Argentina, is important for three reasons: 1) Mention of Jurassic "*Estheria*" species has occurred in the literature for over a decade (STIPANICIC, *et al.*, 1968, p. 82, col. 2, paragraph 2, for references). Such fossils have been found by STIPANICIC and others to range from the Lias to the Dogger-Malm of Patagonia. The VOLKHEIMER collection advances previous knowledge of Patagonian conchostracans by providing a detailed facies and stratigraphically related, describable sample that supplements the limited published information on Triassic con-

chostracans of Mendoza (RUSCONI, 1948). 2) It further permits certain paleoecological observations which can be used as reference material for other southern hemisphere Mesozoic clam shrimp beds. 3) Finally, coming from Patagonia, this Jurassic collection has special significance for Drift Theory (Du TOIT, 1937)—a theme explored elsewhere (TASCH, 1970).

In addition to the VOLKHEIMER collection, other material from Jurassic beds exposed at Colan Conhué (located to the north and west of the VAs localities, this paper; see Part 2, Fig. 5) was loaned by Dr. AMOS from the Museo de la Plata.

RECORD OF TRIASSIC-JURASSIC CONCHOSTRACANS FROM SOUTH AMERICA

Rhaetic conchostracans have been described from Brazil—Botucatú Sandstone (ALMEIDA, 1950), Colombia—shale near Montebel, and Venezuela—shale near Merida (Bock, 1953), as well as Argentina—Mendoza, San Juan, etc. (RUSCONI, 1948; cf. YRIGOEYEN, *et al.*, 1967; BONAPARTE, *et al.*, 1967).

By contrast, information on the Jurassic conchostracans of South America is much more sparse. CARDOSA (1965, 1966) described and referred to conchostracans from the Brazilian Upper Jurassic—Japoatã Formation, State of Sergipe and the Aliança Formation, state of Pernambuco.

GROEBER, *et al.* (1952) referred to various Jurassic conchostracan-bearing beds in Chubut Province (at Cerro Carnerero, Río Genoa, Mulanquíño, Nueva Lubecka). One reference was made directly to the Cañadón Asfalto Formation, and mention is made of estheriids and associated flora in these beds. STIPANICIC & REIG (1956, fig. 1 and text) reported abundant remains of *Estheria* in tuffaceous or laminated lutites—the so-called “Estheria shale” of Santa Cruz Province. The estheriid localities in this last-named province include: Malacara, La Matilde, Tordillo, Laguna del Molino, and Laguna del Carbón. Santa Cruz Province is directly south of Chubut Province.

It is obvious that estheriid-bearing beds of Jurassic age are extensive in at least two provinces of Argentina, as are Triassic beds in Mendoza. STIPANICIC & REIG (1956, fig. 2, 4, and p. 153 for measured section) provided excellent stratigraphic data on the estheriid-bearing beds of Santa Cruz. Nevertheless, none of the Argentine estheriids of Jurassic age have been figured and described previously, with placement in a stratigraphic context, as in Part 2 of this paper.

The South American Mesozoic conchostracan species may be grouped in two assemblages: 1) all non-cyziciid genera such as *Paleolimnadia*, *Graptoestheriella*, etc., and 2) cyziciid species including subgenera, *Euestheria* and *Lioestheria*. For present purposes the second grouping is most pertinent. Data on the second group, by countries, are as follows:

BRAZIL: (Upper Triassic)

a) *Bairdetheria barbosai* (= *Cyzicus* (*Lioestheria*) *barbosai*): height, 3.6 mm, length, 4.8 mm, h/l, 0.75.

Subovate; posterior margin less curved than anterior; umbo small, subterminal.

b) *Euestheria mendesi* (= *Cyzicus* (*Lioestheria*) *mendesi*): height, 6.0 mm, length, 9.3 mm, h/l, 0.64. Eccentrically ovate with short straight dorsal margin; umbo subterminal anastomosing fine radials in intervals.

(Upper Jurassic)

c) *Pseudoestheria pricei* (= *Cyzicus* (*Lioestheria*) *pricei*): height, 3.3 mm, length, 5.0 mm, h/l, 0.66. Subovate, posterior margin curved less than anterior, but not as great as in *C. (L.) mendesi*.

ARGENTINA: (Upper Triassic)

d) *Euestheria forbesi* (= *Cyzicus* (*Euestheria*) *forbesi*): height, 6.8 mm, length, 10.3 mm, h/l, 0.66. Ovate to ovate-oblong with equicurved anterior and posterior margins; dorsal margin straight.

e) *Euestheria striolatisima* (= *Cyzicus* (*Lioestheria*) *striolatisima*): height, 6.2 mm, length, 10.2 mm, h/l, 0.60. Ovate-oblong.

f) *Cyzicus* (*Euestheria*) *draperi*: height, 10.3 mm, length, 15 mm, h/l, 0.68. Straight dorsal margin; subovate.

VENEZUELA (Upper Triassic)

g) *Isaura olsoni* (= *Cyzicus* (*Lioestheria*) *olsoni*): height, 1.5 mm, length, 2.1 mm, h/l, 0.71. Dimorphic-male, ovate; female, elliptical to subrectangular; coarse hachure type markings in intervals.

COLOMBIA: (Upper Triassic)

h) *Houellites columbianus* (= *Cyzicus* (*Lioestheria*) *columbianus*) male: height, 3.2 mm, length, 5.5 mm, h/l, 0.58; ovate-elliptical; female: height, 2.8 mm, length, 1-6.0 mm, h/l, 0.46.

The only South American species of those here cited that needs to be considered with reference to the new species described herein, *Cyzicus* (*Euestheria*) *volkheimeri*, is species “d”—*forbesi*. These two species share (at least in some specimens) valves that yield the same h/l ratio (0.66). This, of course, arises from similar configuration regardless of dimensions. Ornamentation is likewise similar, which explains why both species are assigned to the subgenus *Euestheria*.

In three aspects the two species differ: *Cyzicus* (*Euestheria*) *volkheimeri* has three sets of growth lines and *C. (E.) forbesi* only one set; the first species shows beading or a beaded aspect of the ventral margin of successive growth bands, whereas the second has no beading. Finally, *C. (E.) volkheimeri* has a slightly arched dorsal margin, contrasting with the straight margin of *C. (E.) forbesi*.

It should be observed that number of growth bands merely expresses the lifespan of a given clam shrimp, and is not genetically determined. Numbers of growth bands per unit of time (sets) relates to the rate of molting which may also be influenced by external factors of the environment. Two other aspects are genetically related, however: curvature of the dorsal margin and beading versus non-beading. These last features are thus considered to have specific value.

STRATIGRAPHIC POSITION OF ARGENTINE JURASSIC CONCHOSTRACANS

The stratigraphic setting is given in detail in Part 2 by VOLKHEIMER. Here it suffices to indicate that younger to geologically older Jurassic conchostracan-bearing beds are represented in our collection as follows: Upper third of Cañadón Asfalto—VAs 2, VAs 3, and roughly equivalent to VAs 2- VAs 9, bed VCh 15; middle third of Cañadón Asfalto Formation—VAs 9; older than VAs beds, sample from Colan Conhué, and VCh 2.

LIOESTHERIID SPECIES

Of the three lioestheriid species described herein, only one can be identified specifically owing to poor preservation of many specimens. All of these lioestheriids share characteristics of valve configuration (ovate/subovate) and h/l ratios of 0.70-0.72 (except sp. C for which h/l = 0.83).

Cyzicus (Lioestheria) patagoniensis TASCH, n. sp., has beak subterminal to subcentral, but in *Cyzicus (Lioestheria)* sp. A, it is subcentral and in *Cyzicus (Lioestheria)* sp. B subterminal. Ornamentation differs in these species. Species A has hachure-like markings in the intervalles, whereas the other two species are pustulate. The new species also has a straight dorsal margin, but in the other species it is slightly arched.

GONDWANA AND OTHER MESOZOIC CYZICIDS EXCLUSIVE OF SOUTH AMERICA AND ANTARCTICA

In the southern hemisphere and Russian and Asiatic Mesozoic rocks, cyzicids have been reported from the Triassic and Cretaceous of Australia (MITCHELL, 1927; TALENT, 1965), Mesozoic of southern, central, and western Africa (HAUGHTON, 1924; DEFRETIN-LE FRANC, 1967), Triassic and Jurassic of India (JONES, 1862), and from the Mongolian, Chinese and Russian Mesozoic (NOVOZHILOV, 1946, 1954, 1958, cit. TASCH, 1969).

Although many species bear homologies to the Argentinian cyzicids, belonging to same genus and subgenus, the latter appear to be dissimilar in several nongeneric characters. Thus, although the Belgian Congo Wealdian has yielded *Bairdestheria* (= *Lioestheria*) *kasacensis* MARLIERE

(DEFRETIN-LE FRANC, 1967, pl. 4) with growth bands which appear marginally beaded, the interval ornament consists of hachure-like radials and not polygonal granulae as in *Cyzicus (Euestheria) volkheimeri* TASCH, n. sp., of this paper. Similarly, although *Euestheria sambiensis* (= *Cyzicus (Euestheria)*) from the Lower Cretaceous of the Congo has an interval pattern very much like that of *C. (E.) volkheimeri*, the ventral margin of growth bands is not beaded, and other valve characters differ also.

The Indian species can be ruled out by the following line of reasoning: *Cyzicus (Lioestheria) kotahensis* (JONES), TASCH, 1967, has an h/l ratio of 0.78, which makes its shape class unlike that of *C. (L.) patagoniensis* of this paper. The other Indian species, *C. (Euestheria) mangaliensis*, possesses a straight dorsal margin and terminal beak, which are features unlike those in *C. (E.) volkheimeri*.

By equivalent comparisons, one can eliminate each and every cyzicid referred to above.

HAUGHTON cited the occurrence of *Euestheria draperi* (= *Cyzicus (Euestheria) draperi*) in the Cave Sandstone of the upper Karroo, Triassic of Cape Colony, South Africa. An estheriid like *Euestheria draperi* was reported to occur in carbonaceous black shale associated with plant fossils in the Argentinian Triassic (Zona de Villavicencio-Uspallata) (GROEBER & STIPANICIC, *et al.*, 1952, p. 53). Since systematic paleontological data are lacking for the suggested Argentinian assignment, it can hardly be credited without further study. Such relationships are of course altogether possible when Africa and South America are restored to their postulated pre-Drift position.

CHERNYSHEV (1930) described and figured *Estheria reticulata* (= *Cyzicus (Euestheria) reticulata*) from the Jurassic of Siberia and Mongolia. Other Siberian polygraptids (i.e., lioestheriids) have been described from the Siberian Permian-Triassic in NOVOZHILOV's publications.

These Mesozoic occurrences point to a widespread distribution of cyzicids. The basis for this may be attributed to proximity of southern hemisphere continents—a theme explored elsewhere (TASCH, 1970).

ANTARCTIC JURASSIC CONCHOSTRACANS

Antarctic Jurassic conchostracan collections are now available from Victoria Land (Brimstone

Peak, Carapace Nunatak), and the Central Transantarctic Mts. (Queen Alexandra Range, Mauger Nunatak) (references cit. ELLIOT & TASCH, 1967, and TASCH collection, austral summer 1969-70). These are chiefly lioestheriid cyzicids, although euestheriid cyzicids also occur.

The cyzicid species (lioestheriids and euestheriids) at all these localities are quite close to each other morphologically. It has already been remarked that the Jurassic conchostracan-bearing beds of Antarctica are probably time-correlates (ELLIOT & TASCH, 1967). The stratigraphic relationship of the Patagonian Jurassic, especially the conchostracan-bearing beds, to similar beds in Antarctica cited above, requires more study and will be reported elsewhere (TASCH, 1970).

Both in Antarctica and Patagonia the cyzicids are associated with ostracode faunas. The new species described in this paper, *Cyzicus (Euestheria) volkheimeri*, at least in its more elongate shape, appears to be distinct from any of the above Antarctic species (presently at hand in my laboratory). The true shape of the lioestheriids from Brimstone Peak (Victoria Land) is difficult to ascertain in the British Museum material. Insofar as crushed specimens permit me to determine, these had a subterminal beak and growth characteristics reminiscent of *C. (L.) patagoniensis*. This determination extends to the h/l ratio also: 0.60-0.73 (Brimstone Peak), and 0.66-0.77 (Patagonia).

PALEOECOLOGY

PALEOCLIMATOLOGY.—Abundant floral evidence, as well as reptilian fossils and various sedimentary clues, suggest a warm climate during the Middle-Upper Jurassic of Patagonia (and the rest of Argentina) (VOLKHEIMER, 1970).

The Patagonian conchostracans from one locality (VAs 3) occur in a banded shale, 6 cm long, 5 cm wide and almost 2 cm thick. Seasonal events are reflected. Fifteen (possibly more) successive seasons are represented in a thickness of 19 mm. This points to a seasonal sedimentation rate of 1 mm or less. Other evidence discussed subsequently (growth bands) point to wet-dry cycles in the water bodies inhabited by the conchostracans of this study.

SUCCESSIVE GENERATIONS OF CONCHOSTRACANS.—Other slabs (VAs 2, for example) bearing *Cyzicus (Lioestheria) volkheimeri* TASCH, n. sp.,

some 10.0 mm thick, have seven bands. Direct measurement of these bands, obviously seasonal, range from 1.0 to slightly more than 1.0 mm/yr. A check on this sedimentation rate can be obtained from the 13 successive conchostracan generations on the same slab. The smallest separation between two generations ranges from 0.03 to 0.07 mm (interpreted to be same-season generations), the largest separation being 1.90 mm. These figures give an average of 1.0+mm. Accordingly, these independent ways of determining sedimentation rate are in good agreement.

GEOCHRONOLOGY.—The total time represented by a given conchostracan-bearing slab can readily be evaluated once the sedimentation rate is determined. Thus, in the example cited above, a slab 19 mm thick (VAs 3) represents 19 seasons (years), and one 10 mm thick (VAs 2), 10 years. As shown in the next section only a small portion of this time was represented by conchostracan occupancy.

POND OR LAKE POOL DURATION.—One can infer the length of time that a given conchostracan-bearing bed indicates, by counting growth lines. Table 1 indicates that the ponds or pools lasted for at least three to five months. Since conchostracan occupancy was intermittent, pond duration was no doubt longer by an amount equivalent to the barren intervals. Intermittent occupancy by conchostracans in itself denotes seasonal drying-wetting cycles.

TABLE 1.—Duration of Patagonian Ponds or Lake Pools (Jurassic).

LOCALITY	NUMBER OF VALVES $n_1=179$	GROWTH LINE RANGE (Minimum-Maximum)	DURATION OF PONDS OR LAKE POOLS (MONTHS)	CALCULATED TIME REPRESENTED (Years based on rate of sedimentation)
VAs 2*	87	2-39	4—	10
VAs 3	67	2-59	5+	19
VAs 9**	25	4-35	3+	

* Geologically youngest bed (see Part 2).

** Geologically oldest bed.

GROWTH-BAND SETS.—Independent evidence on pond or pool duration can be obtained from a study of growth-band sets, determined by their variable spacing. Naupliid and early adult growth bands are generally more widely spaced than later ones. More closely spaced bands tend to occur as terminal sets on a given valve.

Growth bands that occur in distinct sets (not always seen) present the following spacing (in

specimens from Patagonia): wide, followed by medium, then by close or closely spaced bands, and by wide, etc. When a given pond or pool partially dries up, the conchostracan growth cycle is brought nearer to a close (growth bands more tightly spaced). Subsequent refill of the basin to its old level restores conditions conducive to conchostracan growth (rejuvenation).

Closer-spaced growth lines on conchostracan valves appear to indicate an abbreviated pause between successive moltings. A question that merits further study is whether modern clam shrimps with advent of adverse conditions (shrinking water level and consequent decline of available oxygen, nutrients, etc.) accelerate molting?

There is also the aspect of multiple generations of conchostracans in the same pond or pool during the same season (wet-dry-wet conditions prevailing). Closer-spaced bands succeeded by wider-spaced ones, may be the equivalent in a single conchostracan generation of a succession of generations in the same water body.

VALVE COLORATION.—A deep red-brown coloration characterizes valves of *Cyzicus* (*Euestheria*) *volkheimeri* from locality VAs 2. Valves of living forms observed by me change from a yellow or bright red to a deep red brown hue prior to, or upon, demise. What this denotes is presence of hemolymph in the valve at time of demise; synthesis of blood hemoglobin occurs at times of low oxygen (Fox, 1954, cit. Tasch, 1967) and hence prior to demise of the Patagonian specimens, or when individuals in life began to respond to the decrease of oxygen in the valves' "blood-chambers." In conchostracans the valves serve a respiratory function. In turn, the second item above signifies a "shrinking" pond or pool. Normal evaporation can explain the lowering of the water level.

TEMPERATURE AND SEASON OF YEAR.—Evidence from living forms (*Limnadia stanleyana*) of the southern hemisphere (eastern Australia) indicates that the active stage is during warmer months of the year. During the austral winter eggs of this species were in diapause (a state of spontaneous arrested development) (Bishop, 1967). For the southern hemisphere Patagonian fossil species this type of cycle could have prevailed in Jurassic time. If so, the conchostracan-bearing beds would represent the "warmer" season of the austral year. Of course one must expect generic and specific differences and variation in such responses.

SYSTEMATIC PALEONTOLOGY

Genus *CYZICUS* Audouin, 1837

Subgenus *CYZICUS* (*EUESTHERIA*)

Depéret & Mazeran, 1912

CYZICUS (*EUESTHERIA*) *VOLKHEIMERI* Tasch, n. sp.

Figure 1,1-3

DIAGNOSIS.—Valve shape ovate-elongate with eccentric shape variants (possibly due to flattening); dorsal margin gently arched, equivalent roundness of dorsal anterior and dorsal posterior margins. Beak area generally covered (or eroded) but a subcentral-to-subterminal position may be inferred from a few preserved umbonal growth bands.

Growth bands occur in three distinct sets (umbonal set excluded). These were observed from median sector to ventral margin, starting below the umbonal region. Set 1 (wide-spaced), bands 0.22 mm apart; set 2 (medium-spaced), bands 0.11 mm apart; set 3 (close-spaced), bands 0.04 mm apart.

Ornamentation consists of a polygonal/granule pattern in the intervalles between growth lines. "Beading" or beaded aspect of the ventral margin of successive growth bands may be related to setae-attachment sites. In modern cyzicids and other genera, the growth band margin is dense with closely spaced, minute setae.

MATERIAL.—An abundance of fragmentary valves occurs on two separate carbonaceous shale slabs, along with a few nearly complete flattened valves. On one face, 15 such valves were counted. The opposite face of the same slab had more valves. The slab is 11.0 cm long, 6.0 cm wide, and 1+ cm thick. Conchostracan fragments occur throughout this thickness.

MEASUREMENTS.—Specimen 1: length, 7.3 mm, height, 5.6 mm, h/l, 0.77; six to seven beadlike components occur in a 0.66 mm linear distance along a growth band ventral margin. Specimen 2: length, 7.0 mm, height, 4.6 mm, h/l, 0.66 (on this specimen ornamentation is clearly polygonal and the "beaded" aspect of growth band margins clearly visible). Specimens 1 and 2 constitute syntypes.

LOCALITY.—VAs 2.

CYZICUS (*EUESTHERIA*) sp. A

DIAGNOSIS.—Like *Cyzicus* (*Euestheria*) *volkheimeri* in all respects except in its lack of beaded aspect of ventral margin of growth bands.

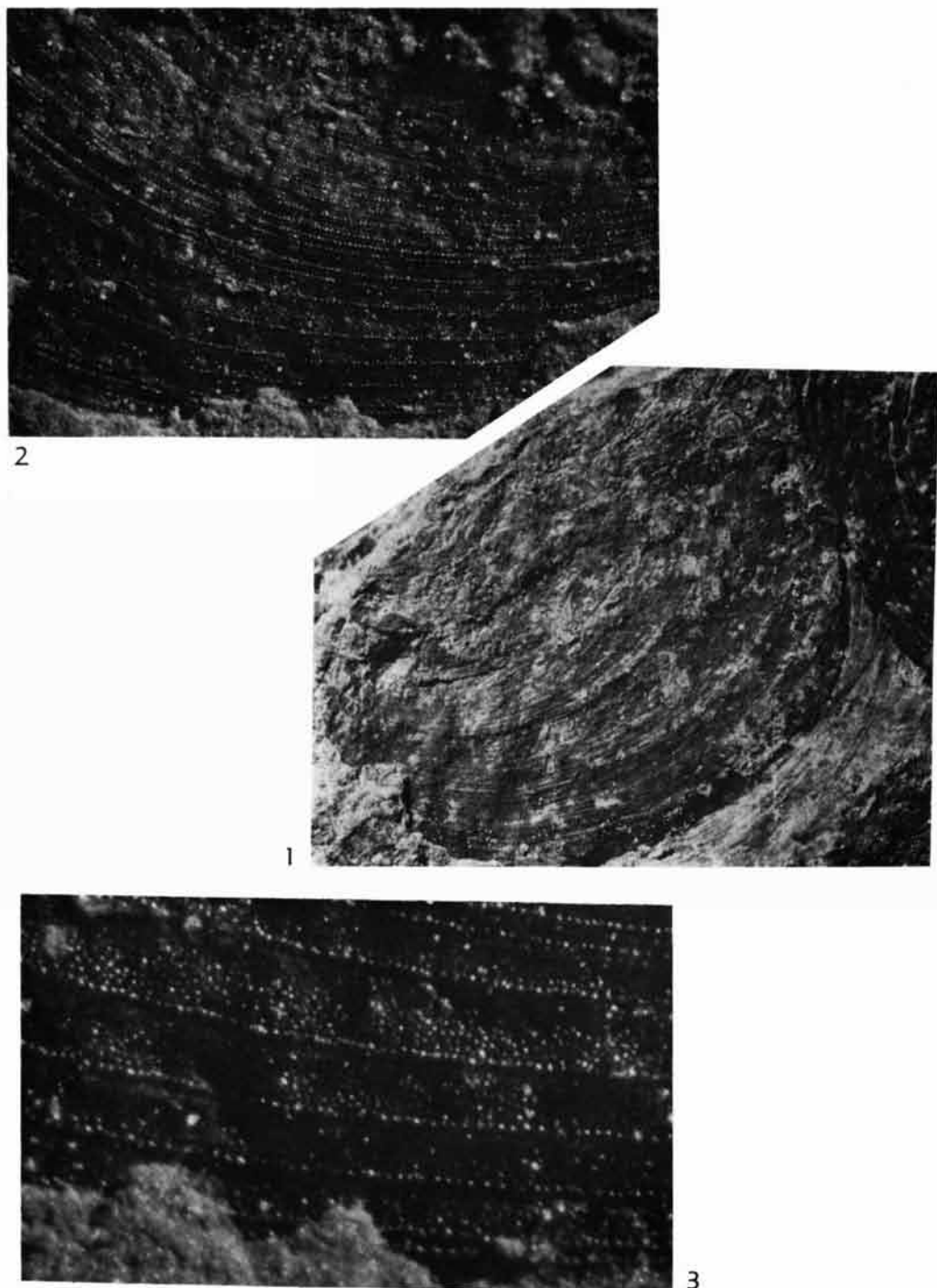


FIG. 1. *Cyzicus* (*Euestheria*) *volkheimeri* TASCH, n. sp.

1. Syntype, specimen 1 (Loc. VAs 2). Length 7.3 mm, height 0.77 mm.—2-3. Same species (on same slab, side A), but specimen 2 of syntype, showing polygonal

ornamentation and prominent beaded aspect of growth band margins. Length 7.0 mm, height 4.6 mm.

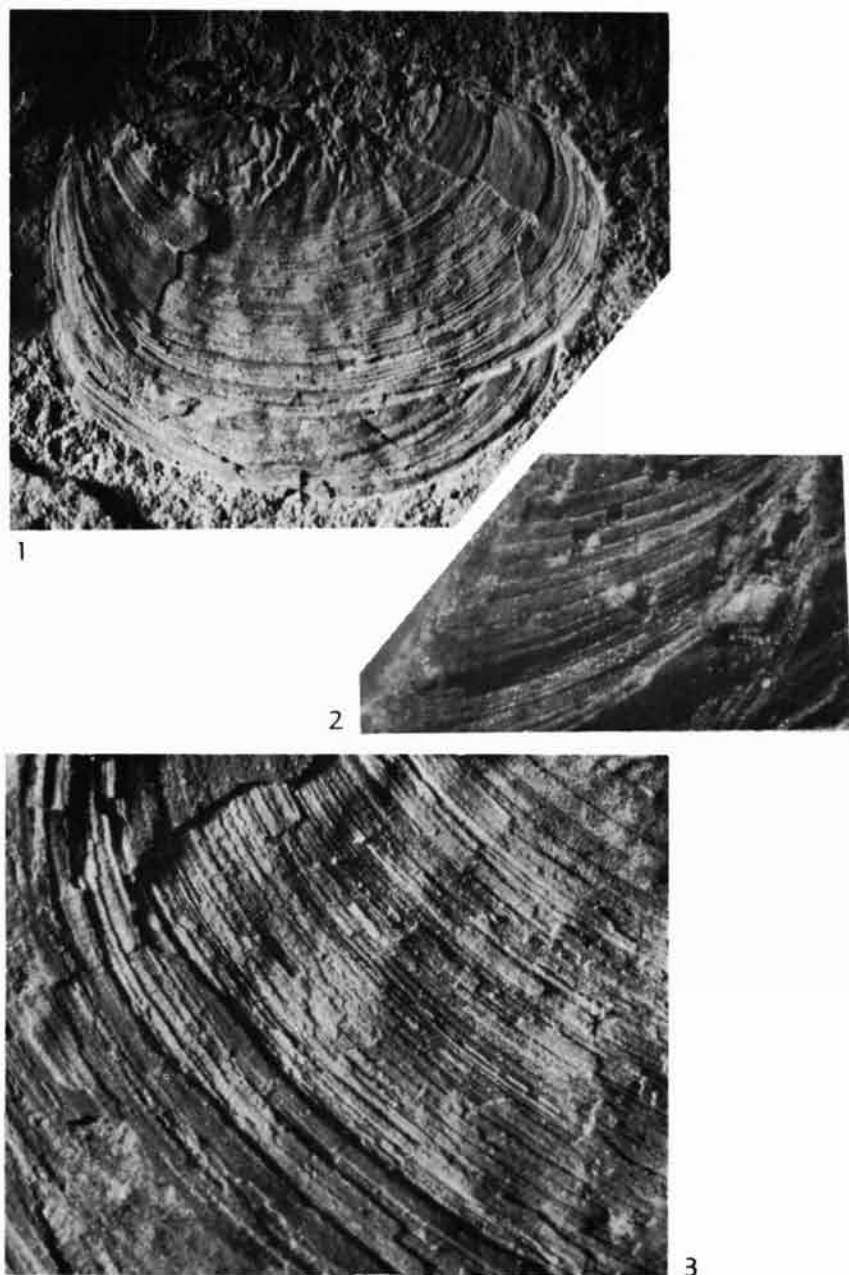


FIG. 2. *Cyzicus (Lioestheria) patagoniensis* TASCH, n. sp.

1. Holotype, left valve superimposed on right valve (Loc. VAs 3), $\times 12.5$.—2. Another specimen of same species. Detail showing hachure-type ornamentation of intervalles (Loc. VAs 3), much enlarged.—3. An-

other specimen of same species. Two features shown are wide- and close-spaced bands and hachure-type ornamentation (close-spaced bands) that anastomoses in younger bands (wider-spaced), $\times 63$.

MATERIAL.—Specimens badly eroded, fragmented and incomplete.

DISCUSSION.—It is possible that this is a distinct species occurring as it does in a distinct facies, i.e.,

northern facies, and in beds (VCh 2) somewhat older than those of the VAs localities. (See Part 2 for section in which species occurs.)

LOCALITY.—VCh 2.

Subgenus CYZICUS (LIOESTHERIA)

Depéret & Mazeran, 1912

CYZICUS (LIOESTHERIA) PATAGONIENSIS

Tasch, n. sp.

Figure 2,1-3

DIAGNOSIS.—Ovate to subovate or subelliptical valves; beak from subcentral to subterminal; dorsal margin comparatively straight; dorsoanterior more sharply rounded than dorsoposterior. Early growth stages represented by wider spaced growth zones ($10 \pm$ in number), succeeded by a variable number of adult growth-stage bands that are comparatively more closely spaced. Ornamentation in intervals between growth lines is the lioestheriid hachure-type marking. They are closely spaced and very fine. In younger bands, the markings tend to anastomose (Fig. 2,2).

MATERIAL.—Numerous paired and individual valves, that are flattened on a hard, banded argillite containing carbonaceous fragments.

MEASUREMENTS.—Holotype (left valve superimposed on right valve): length, 6.60 mm, height, 3.75 mm, h/l, 0.57. Growth bands, 59 in number, with 12 to 13, 13 mm apart (wide-spaced) and 44+, to 0.15+ mm apart (close-spaced). Paratype (right valve): length, 4.50 mm, height, 3.30 mm, h/l, 0.70. Growth bands 13+ in number, last three more closely spaced.

LOCALITY.—VAs 3.

CYZICUS (LIOESTHERIA) sp. A

Figure 3,1-2

DIAGNOSIS.—Paired ovate valves with slightly arched dorsal margin; beak subcentral in position and slightly elevated above dorsal margin. Numerous growth bands, few well preserved. Ornamentation not preserved, although some fragments on the same slab show pustules in the intervals.

MATERIAL.—On two small rock slices several fragments of this species occur. The unflattened specimen figured is the best one and was obviously partly buried in the substrate when the animal died. Only the right valve and dorsal margin/umbonal area of the buried left valve are exposed. The major biotic associates were ostracodes represented by dozens of valves.

MEASUREMENTS.—Length, 4.50 mm, height, 3.15 mm, h/l, 0.70. (Right valve only.)

DISCUSSION.—It is impossible to relate this species to the lioestheriid species at VAs 3 or species undetermined B, since telltale patterns of growth bands and ornamented intervals have been eroded. The uncrushed, robust valves in contact give the appearance of living *Cyzicus*.

LOCALITY.—VAs 9.

CYZICUS (LIOESTHERIA) sp. B

Figure 3,3

DIAGNOSIS.—Enamel-like whitish films on bedding planes, bear growth bands. Beak inferred to be subterminal; configuration, ovate-subovate; pustulae visible on some growth bands (appearing as darker colored dots on whitish films when wetted). Growth bands are numerous and close together in final phase of valve growth.

MATERIAL.—Four individual pieces of green-to-red well-indurated, thin-bedded shale (readily scratched with a knife) contain on bedding planes, numerous crushed, incomplete and flattened valves. Nature of preservation of valves is reminiscent of beds subjected to metamorphism.

MEASUREMENTS.—Length, 6.15 mm, height, 4.65 mm, h/l, 0.72 (determined on an almost complete specimen).

DISCUSSION.—The exact relationship of this species to other lioestheriids collected at the VAs localities cannot be determined from the incomplete, badly distorted material. It is important to note that the specimens of this species come from locality Colan Conhué (see Part 2 for location), which is somewhat older Jurassic than the VAs localities.

CYZICUS (LIOESTHERIA) sp. C

DIAGNOSIS.—Like *Cyzicus (Lioestheria) patagoniensis* TASCH, n. sp., except in h/l ratio which is 0.83. Numerous specimens but generally incomplete and badly eroded.

LOCALITY.—VCh 15.

REGISTER OF COLLECTIONS FROM JURASSIC CONCHOSTRACAN-BEARING BEDS OF CHUBUT PROVINCE, ARGENTINA, OR REPORTS ON THEM

1. VAS LOCALITIES, this paper, Cañadón Asfalto Fm., southern facies. VOLKHEIMER Collection. (See Part 2, Fig. 4.) (Equivalent to beds listed under "3b" below.) Species include: *Cyzicus (Lioestheria) pat-*

agoniensis TASCH, n. sp., *Cyzicus* (*Euestheria*)
volkheimeri TASCH, n. sp., *Cyzicus* (*Lioestheria*) sp.
A.

2. VCH LOCALITIES. Cañadón La Chacra. Northern facies of Cañadón Asfalto Fm. (For measured section see Part 2.) Species include: *Cyzicus* (*Euestheria*) sp. A; *Cyzicus* (*Lioestheria*) sp. C.

3. CAÑADÓN ASFALTO FM. a) Southern facies. Section measured by STIPANICIC, *et al.* (1968). Bed 5, conchostracan-bearing bed. (See Part 2.) b) Southern facies. Profile by FERUGLIO (1949). Conchostracan-bearing beds, 3, 5, 7 are equivalent to bed "3a." VAs localities are also equivalents. (Part 2, Fig. 4,2).



3



1



2

FIG. 3. *Cyzicus* (*Lioestheria*) sp. undet.

1. Sp. A, right valve uppermost with half-buried left valve in contact at dorsal margin (Loc. VAs 9), $\times 25$.
—2. Same specimen showing beak and valves in contact at dorsal margin, $\times 40$. —3. Sp. B, conchos-

tracan valves subjected to metamorphism and preserved as enamel-like films on bedding plane (Loc. Colan Conhué), $\times 3$.

4. COLAN CONHUÉ. Collection by Dr. FERULLO, on loan from Museo de la Plata. These conchostracans are probably somewhat older than those from VAS localities, according to VOLKHEIMER. Species include: *Cyzicus (Lioestheria)* sp. B. Type and other material from items 1-3 above are on deposit at the Museo Argentino de Ciencias Naturales, Buenos Aires.

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PART 2. STRATIGRAPHIC SETTING

WOLFGANG VOLKHEIMER

ABSTRACT

The stratigraphic setting is in the middle valley of the Chubut River (Patagonia), between Estancia Berwyn and Cerro Condor village (Fig. 5) where the following formations of Mesozoic age outcrop (see Fig. 10). 1) The volcanic Pampa de Agnía Formation of Bathonian age lying unconformably on crystalline basement is composed mainly of andesitic flows and tuffs. 2) The mainly lacustrine Cañadón Asfalto Formation, of Callovian age, contains a northern facies with frequent algal limestones distinguished from a southern facies where bituminous shales prevail. The conchostracans described in Part 1 were collected from this southern facies. The lithology, thickness, areal extent, stratigraphic relations, facies, age, paleontological features, origin, and paleoclimate of the formation are treated. 3) The continental Los Adobes Formation, of Early Cretaceous age, overlies the Cañadón Asfalto strata or older formations with angular unconformity.

RESUMEN.—Conchostracos jurásicos de la Patagonia, estratigrafía. Se da un resumen de las formaciones mesozoicas que afloran en el valle medio del río Chubut, entre estancia Berwyn y la localidad Cerro Condor. Se presentan con más detalle nuevas observaciones hechas en la Formación Cañadón Asfalto (Coloviano). De ella se describen una facies septentrional con frecuentes calizas algales lacustres y una facies austral caracterizada por lutitas bituminosas. De esta facies austral provienen los conchostracos descritos por PAUL TASCH. Se tratan litología, espesores, extensión areal, relaciones estratigráficas, facies, edad, rasgos paleontológicos generales, origen, y paleoclima de la Formación Cañadón Asfalto.

INTRODUCTION

The geology of the middle valley of the Chubut River has been studied by FERUGLIO (1949), SUERO (1946), and principally by FLORES (1948). STIPANICIC, RODRIGO, BAULÍES, & MARTÍNEZ (1968) considered the zone in a concise synthesis on the stratigraphy of the north Patagonian massif. Neighboring areas were studied by PETERSEN (1946) and VOLKHEIMER (1965).

STRATIGRAPHY

The crystalline basement covered by several Jurassic and Cretaceous formations is visible only in a few areas. Marine Lower and Middle Jurassic can be found only in the nearby Pampa de Agnía Hills. The volcanic Pampa de Agnía Formation, mainly of Bathonian age, gives characteristic features to the valley of the Chubut River, and the Callovian Cañadón Asfalto Formation, composed of tuffs and lacustrine sediments, includes an interesting fossil flora, lacustrine algal limestones

The area belongs to Extra-andean Patagonia. It is a semiarid region with major rainfall during the winter. Field work is possible in this zone nearly throughout the year, but the best climatic conditions prevail from October to April. A consolidated road crosses the area from north to south. It can be reached from Buenos Aires by car in four days.

and abundant conchostracans (Fig. 4-8). On the high mesetas, this formation is covered by the Lower Cretaceous Los Adobes Formation.

MARINE LOWER AND MIDDLE JURASSIC

In the area considered in this paper, no outcrops of marine Lower and Middle Jurassic exist. They can be found in the nearby Pampa de Agnía Hills, however, where the upper Sinemurian is represented by tuffs and thin limestone layers with *Oxynticeras*, while the Toarcian is characterized by tuffs, sandy tuffites and thin limestone inter-

calations with *Harpoceras subplanatum*. The lower Aalenian bears *Leioceras opalinum*, and the higher Aalenian *Posidonomya alpina*, *Witchellia argentina* and "*Harpoceras*" *hauthali* (GROEBER, *et al.*, 1952; STIPANICIC, *et al.*, 1968).

CERRO CARNERERO FORMATION (BAJOCIAN)

The type section of this formation, first called "Estratos del Cerro Carnerero" by SUERO (GROEBER, *et al.*, 1952, p. 301-305), is on the eastern slope of the Cerro Carnerero (Pampa de Agnía Hills). The lower part of the formation consists of sandstones, tuffs, and tuffites 100 m thick, with conchostracans and the sauropod reptile *Amygdalodon patagonicus*. The upper part comprises 260 m of conglomerates, sandy tuffites, and cineritic tuffs.

The Cerro Carnerero Formation lies on marine Aalenian and probably is of Middle Bajocian age. The sediments of this unit were deposited in a piedmont area of fluvial and lacustrine environments and with participation of volcanic processes. The strong lithological change presented by this formation compared with the underlying marine strata may indicate tectonic movements (Languineo Phase of STIPANICIC, *et al.*, 1968, p. 86).

PAMPA DE AGNÍA FORMATION (MAINLY BATHONIAN)

NAME AND TYPE SECTION.—The Pampa de Agnía Formation forms part of the Complejo Porfírico de la Patagonia Extra-Andina (FERUGLIO, 1949, p. 118 ff.), and of the Complejo de la Sierra de Olte in the middle valley of the Chubut River (FERUGLIO, *op. cit.*). STIPANICIC, *et al.* (1968, p. 86-88) proposed the name Pampa de Agnía Formation. They did not describe the section of the type area, but gave a profile of the formation in the middle valley of the Chubut River.

LITHOLOGY.—The Pampa de Agnía Formation begins, in the middle valley of the Chubut River, with thick andesitic flows of violet, dark colors. The middle part is formed by light-colored grayish-yellowish tuffs. The upper third is built of violet, dark andesitic flows with intercalations of tuffs.

THICKNESS AND AREAL EXTENT.—The total thickness of the formation in the middle valley of the Chubut River is about 800 m. For the Cerro Condor area, FLORES (1948) estimated more

than 1500 m. The formation extends in areas of the Pampa de Agnía Hills and middle valley of the Chubut River.

STRATIGRAPHIC RELATIONS.—In the middle Chubut River, the Pampa de Agnía Formation lies with strong angular unconformity on plutonic and metamorphic rocks of the "crystalline basement," as can be observed just southwest of the Cerro Condor. In the Pampa de Agnía Hills it lies with very slight angular unconformity on the Cerro Carnerero Formation. The contact Pampa de Agnía—Cañadón Asfalto is marked by change from volcanic rocks to clastic and biochemical sediments which alternate with tuffs. The limit between both units may be slight unconformity, as stated by some authors.

AGE.—For stratigraphic reasons, the minimum age of the formation is late Bajocian, indicated by Middle Bajocian age of the underlying Cerro Carnerero Formation. Regional considerations, especially comparison with the Chon Aike Formation of southern Chubut and northern Santa Cruz, indicate a Bathonian age of the Pampa de Agnía Formation (STIPANICIC, *et al.*, 1968).

Absolute dating supports these conclusions. The age indicated by argon potassium ratios in flows of the upper part of the formation at Cerro Carnerero is 158 ± 6 million years (Esso Argentina, *cit.* STIPANICIC & BONETTI, 1969).

CORRELATION.—The Pampa de Agnía Formation corresponds to the Chon Aike Formation of Santa Cruz and southern Chubut and partly to the "Complejo Porfírico," which covers wide areas of Extra-andean Patagonia between 40° and 45° S.

CAÑADÓN ASFALTO FORMATION (CALLOVIAN-?OXFORDIAN)

NAME AND TYPE SECTION.—This unit is the upper part of the "Complejo" Sierra de Olte (FERUGLIO, 1949). FLORES (1948) named it "Sección Esquistosa" in the Cerro Condor area, and STIPANICIC, *et al.* (1968) called it Cañadón Asfalto Formation, giving a type section on the right (west-southwestern) side of the Chubut River between Cañadón Asfalto and Estancia Berwyn.

LITHOLOGY.—In the type area, STIPANICIC, *et al.* reported the following section (Fig. 4, "Southern Facies"):

*Section of Los Adobes and Pampa de Agnía Beds
in Type Area*

8) Los Adobes Formation (*ex* "Chubutiano")

——Angular Unconformity——

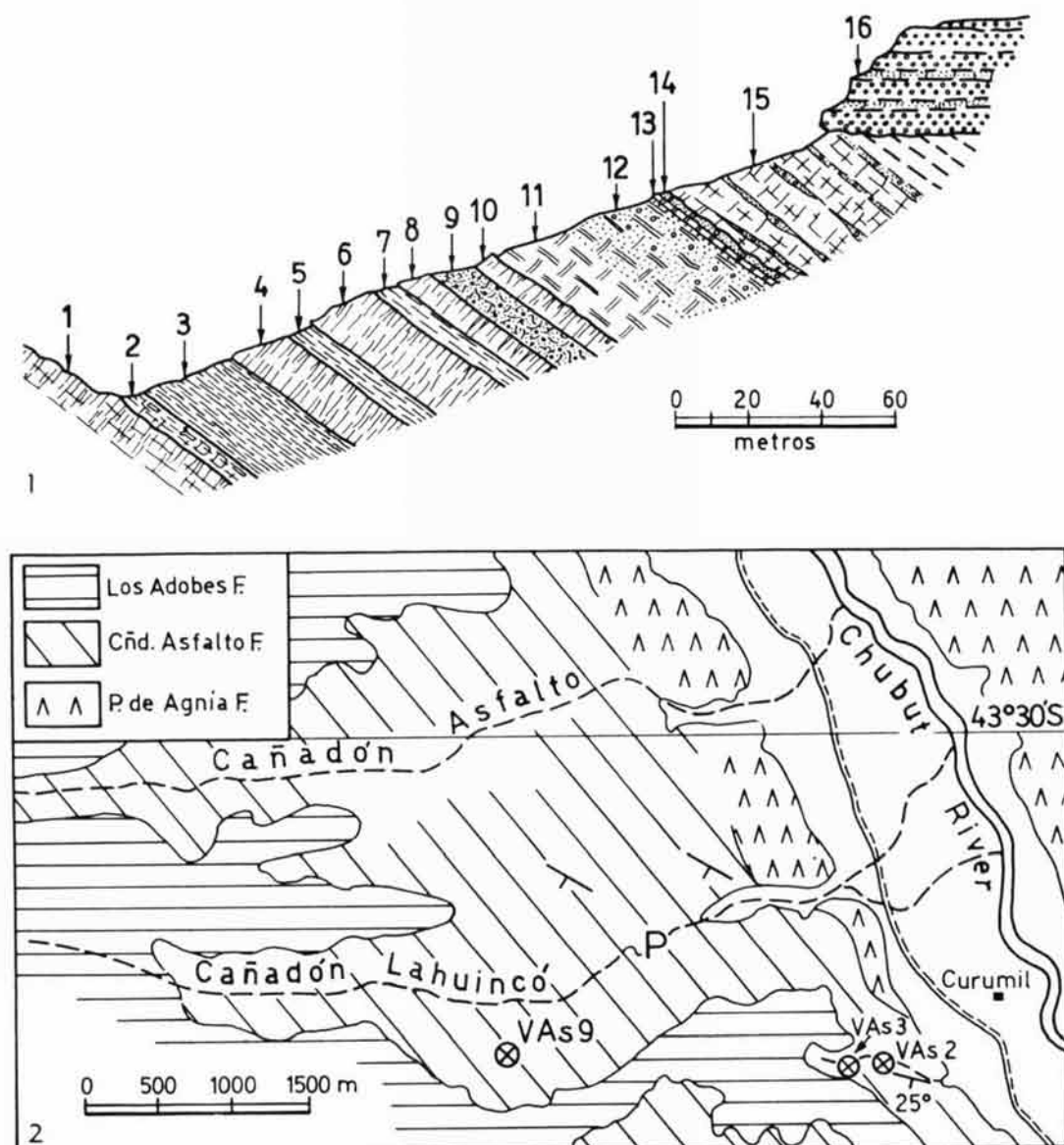


FIG. 4. Section and map of Cañadón Asfalto.

1. Section showing the Cañadón Asfalto Formation covered unconformably by the Los Adobes Formation (from FERUGLIO, 1949, p. 79)—1, 4, 6, 8, 10, diabase-sills; 2, tuffs with fossil woods; 3, 5, 7, bituminous shales*; 9, gray-green and dark tuffs; 11, fine grained tuffs; 12, brecciated tuff; 13, whitish tuff; 14, conglomeratic breccia; 15, reddish and violet tuffs with lenses of conglomeratic breccia; 16, conglomerates, sandstones, clays and fine-grained tuffs of Los Adobes Formation. (*Conchostracan-bearing beds.) Beds 3,

5, 7 correspond to unit 5 of STIPANICIC, and bed 5, Fig. 5, "Southern Facies." STIPANICIC reportedly collected conchostracans from unit 3, at a site located above the "3-arrow." This bed is slightly older than localities VAs2 and VAs3. The entire section measured along Cañadón Asfalto is S and SSE of the Northern Facies (Fig. 5).—2. Sketch map showing the location of the conchostracan-bearing samples (VAs2, VAs3, VAs9). Planimetry and lower limit of Los Adobes Formation simplified from FERUGLIO (1949, p. 77).

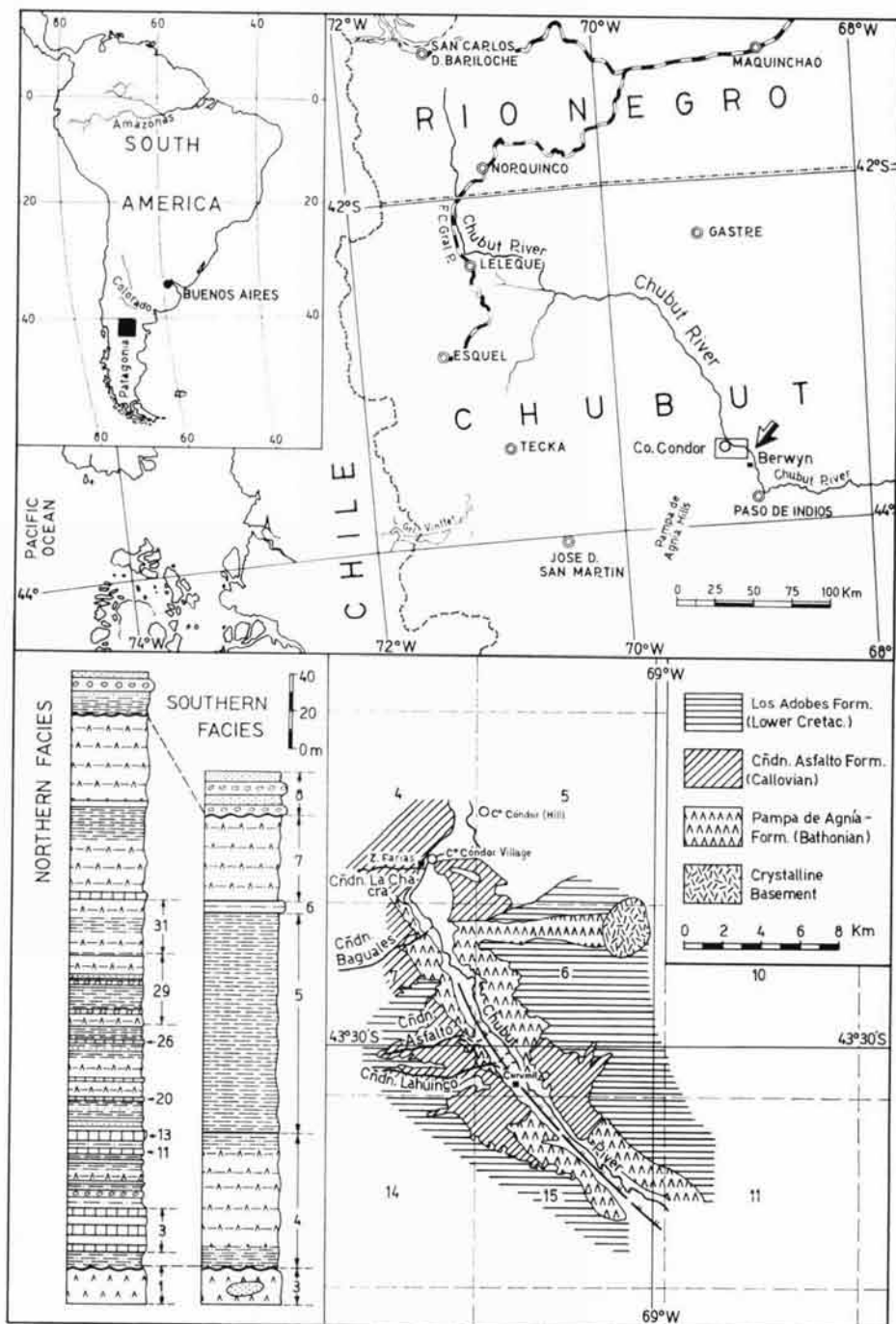


FIG. 5. Location-plan, geological sketch and generalized columnar sections.

The location-plan is taken from IGM topographical map 1: 500,000, Hoja 78, Río Chubut. The geological sketch is mainly based on the map of M. A. FLORES (1948) and completed from FERUGLIO (1949, p. 81). Numbers on the sketch correspond to subdivisions of the land-register

(catastro) of the Chubut province. Numbers on the columnar sections correspond to stratigraphic units described in two sections of the Cañadón Asfalto (see text).

The southern facies occurs between Cañadón Asfalto

- 7) Tuffs, of light gray and yellowish colors, which in the upper part become reddish. They outcrop on the western side of the Chubut River, some 15 km north of Estancia Berwyn 30-60 m.
- 6) Bed of compact, sandy tuff of gray yellowish color forming cornices. Stratification is not well defined 4-6 m.
- 5) Black shales with carbonaceous material and plant fossils generally badly preserved and very commonly with *Estheria*. The weathering surfaces are light gray, yellowish and limonitic. From these levels comes the florule found by FLORES in Cañadón Asfalto and studied by FRENGUELLI (1949). Well stratified, in part laminated. Excellent outcrops on right margin of the Chubut River north of Estancia Berwyn 100-130 m.
- 4) Tuffs and sandy tuffs of light gray and greenish-gray colors; compact banks 0.02 to 0.05 m thick which outcrop only in a few places, especially at base of the gorges which come down from the east to the Chubut River near Cañadón Sauzal and Cañadón Asfalto 70-80 m.

—Unconformity?—

- 1) to 3) Pampa de Agnía Formation; Flows and tuffs. Units 4 to 7 of the section represent the Cañadón Asfalto Formation. Between Cañadón Asfalto and the Cerro Condor village marked changes in sedimentary facies take place. The following section (Fig. 5), measured by me on the northern slope of Cañadón La Chacra (which joins the Chubut River Valley at Z. Farias-Store in the Cerro Condor village), illustrates the differences. Below a thin cover of Quaternary deposits of the high meseta a nearly complete section of the Cañadón Asfalto Formation outcrops (Fig. 5, "Northern Facies"), from top to bottom as follows:

*Section of Cañadón Asfalto Beds
on Cañadón La Chacra*

- 32) Algal limestone, strongly silicified 4.0 m.
- 31) Green and gray tuffs, nearly everywhere covered 25.0-30.0 m.
- 30) Marls; brown by weathering 0.60 m.
- 29) Tuffs and sandy tuffites, alternating with sandstones. Gray-green colors predominate. Some

- intercalations of thin beds of conglomerates with green and violet andesitic pebbles 35.0 m.
- 28) Tuffs, slightly limy, compact, gray 1.0 m.
- 27) Siltites and shales with conchostracans (VCh 15), alternating with gray marls and limestones. Some thin beds of tuffs and tuffites 8.0 m.
- 26) Algal limestone, gray, almost entirely silicified 8.0 m.
- 25) Covered interval. Probably siltites and marls 2.0 m.
- 24) Calcarene, gray, compact. Lateral transition in stromatolitic algal limestones 1.0 m.
- 23) Partly covered interval. Siltites, shales, marls and thin beds of limestones. Some layers of tuff. Gray colors predominate 1.5 m.
- 22) Algal limestone, gray, formed by several species of algae. Stromatolites common 1.6 m.
- 21) Partly covered interval. Laminated siltstones, tuffites and tuffs, with intercalations of thin limestone layers. Gray colors, some greenish 8.0 m.
- 20) Algal limestone, gray, compact forming cornice, strongly silicified. Stromatolites predominate 2.0 m.
- 19) Siltstones, marls and shales, laminated, of dark gray color, conchostracans common (VCh 2). Some badly preserved plant debris 6.0 m.
- 18) Sandstone, fine-grained, whitish-gray, with plant debris 2.0 m.
- 17) Marls, siltites and shales, dark gray, with conchostracans and plant debris. Calcareous nodules up to 1.0 m. Lenticular intercalations of algal limestone, mainly formed by stromatolites 1.6 m.
- 16) Conglomerate, fine to medium-grained. Sub-rounded to subangular pebbles of andesite. The matrix is a coarse sandstone of gray-brownish color 0.5 m.
- 15) Sandstones, fine-grained, gray, with an intercalation of 0.8 m. of conglomerate (cf. bed 16) 5.0 m.
- 14) Siltites, marls and lutites, laminated, dark gray. On some levels calcareous nodules are of all sizes. Plant debris 1.8 m.
- 13) Algal limestone, formed by a large variety of algae. Intercalation of bioclastic limestone, mainly formed by algal fragments 4.5 m.
- 12) Partly covered interval. Tuffs, greenish gray,

FIG. 5. (Continued from facing page.)

and Estancia Berwyn and the northern facies in the Cañadón La Chacra-Cerro Condor Village-Cañadón Baquales area.—Beds 3, 19, 27 of the northern facies contain conchostracans; also bed 5, black carbonaceous shale, of the southern facies yields conchostracans. The VAs localities (this paper, Fig. 4) are in the upper half of unit 5, Southern Facies.

Inverted V's—flows, tuffs, agglomerates (Pampa de Agnía Formation); inverted V's with dashes—tuffs, tuffites (Cañadón Asfalto Formation); dash-dot-dash—tuffites and silts (Cañadón Asfalto Formation). Ss, sh, ls, symbols are standard. Several beds of northern facies contain marls, including beds 19 and 27.

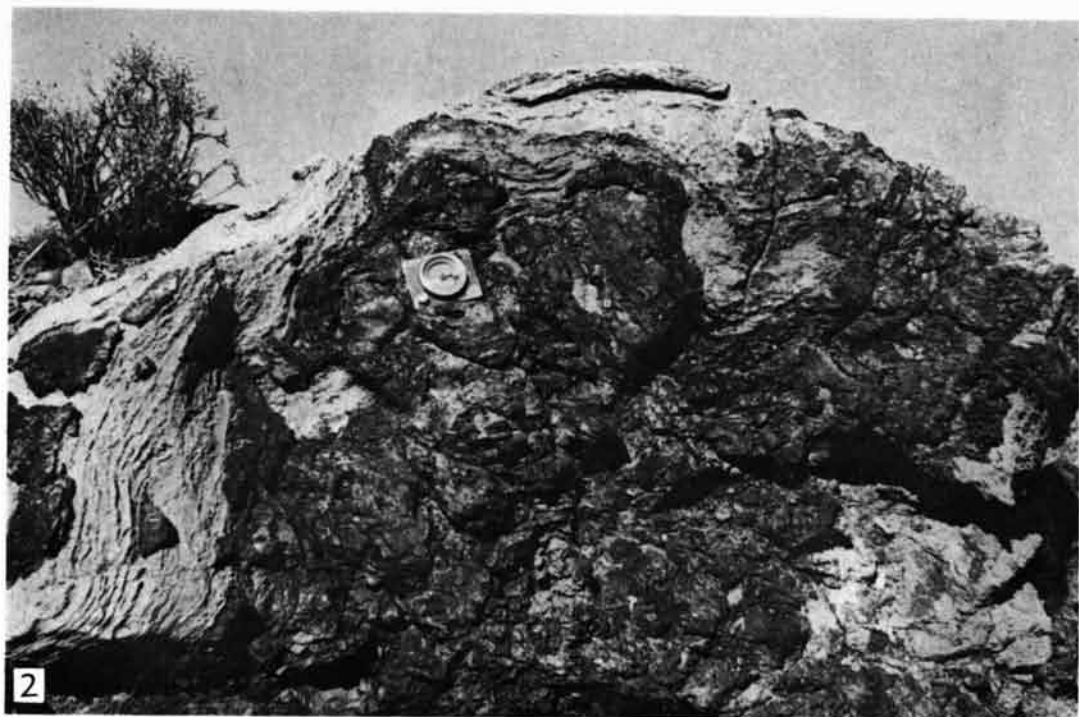


FIG. 6. Southern and northern facies of Cañadón Asfalto Formation. 1. Dark conchostracan-bearing shales of southern facies; samples VAs3 come from this outcrop. For location see Fig. 4,2.—2. Stromatolites of northern facies on silicified algal limestone. Shapes of the stromatolites mirror the microtopography of the substratum.

- | | | | |
|---|--------|---|---------|
| probably alternating with fine-grained sedi-
mentites | 4.0 m. | 9) Algal limestone, commonly brecciated (bio-
clastic), gray | 0.9 m. |
| 11) Algal limestones, gray. The upper half partly
covered and stratified, with predominance of
stromatolites; lower half more compact | 3.2 m. | 8) Tuffs and tuffaceous sandstones, greenish-gray,
fine-grained | 10.0 m. |
| 10) Siltite, greenish-gray | 3.0 m. | 7) Algal limestone, gray, lateral transition into
fine-grained calcarenite | 0.8 m. |

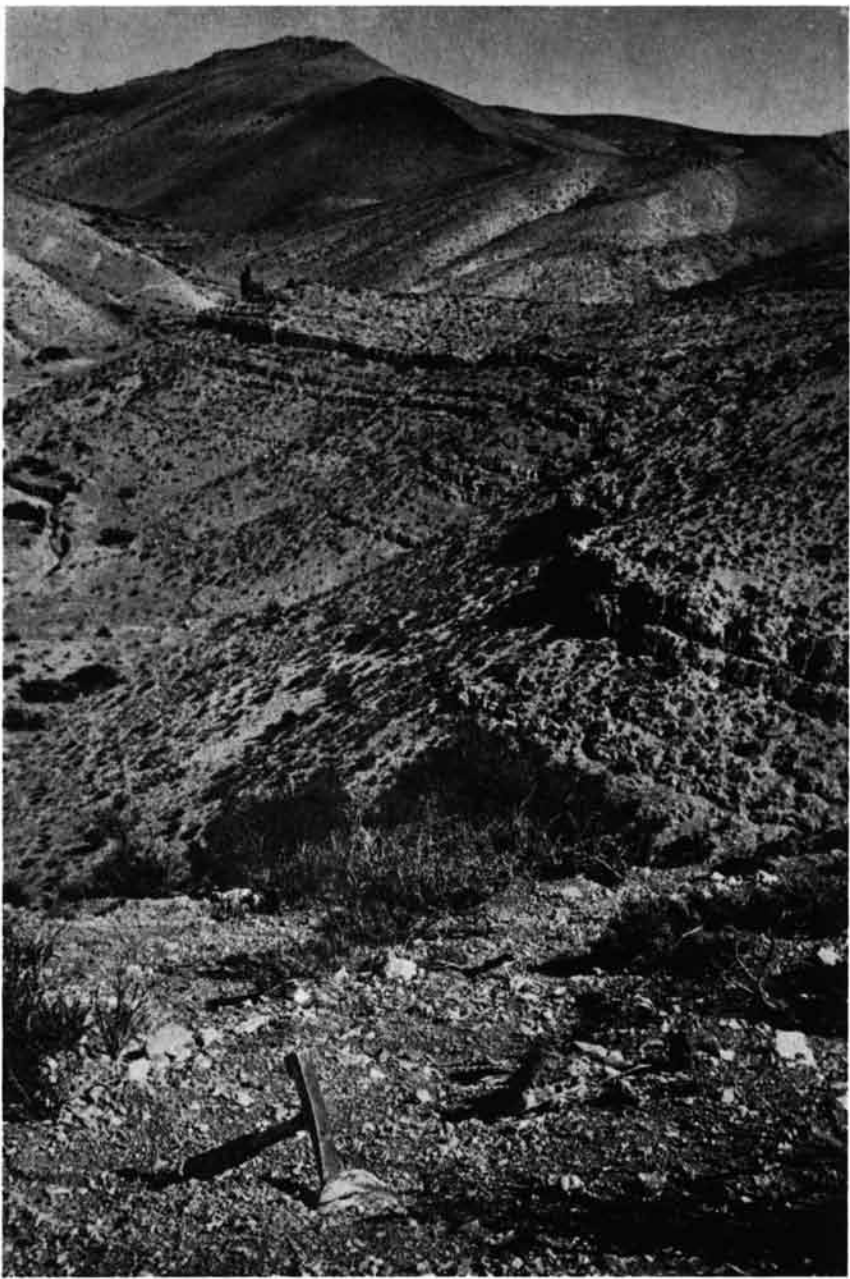


FIG. 7. General view of the northern side of Cañadón La Chaca showing the northern facies of the Cañadón Asfalto Formation. Most of the prominent beds are algal limestones. (The point of the hammer rests on a fossil reptile-bone.)

- 6) Partly covered interval. Probably tuffs and siltstones, gray-greenish 3.5 m.
 - 5) Conglomerate, medium-to-fine-grained, with intercalations of coarse sandstones. The pebbles are volcanics. Gray-greenish color 1.5 m.
 - 4) Tuffs and tuffy sandstones (tuffites), gray-greenish, compact 6.0 m.
- At this point the section ends in the creek of the Cañadón La Chacra. Its continuation can be observed halfway between La Chacra and the Zenón Farías store on both slopes of Cañadón La Chacra, some 1200 m east of the section described above.
- 3) Algal limestone with some intercalations of tuffites, marls and conchostracan-bearing shales. One thin (5 cm) gypsum layer and much secondary gypsum. These algal limestones form a lenticular complex of several thousand meters in horizontal extent (Fig. 8) 25.0 m.
 - 2) Covered interval 5.0 m.
- Unconformity?———

- 1) Several hundreds of meters of volcanic (mainly andesitic) agglomerates, flows and tuffs: Pampa de Agnía Formation. Only the upper part of this formation outcrops in the Cañadón La Chacra.

Beds 3 and 19 above are probably somewhat older than the conchostracan-bearing beds of the VAs localities (Fig. 4). Bed 27 may be roughly synchronous with beds VAs2-VAs9. Beds 3, 19, and 27 outcrop in Cañadón La Chacra immediately West of Cerro Condor Village (Fig. 5). The VAs localities are 12 km south-southeast.

THICKNESS AND AREAL EXTENT.—The formation extends in the middle valley of the Chubut River from a few km north of the Estancia Berwyn to the area north of Cerro Condor. It has also been observed in several lateral valleys of the Chubut River (Cañadón Lahuincó, C. Asfalto, C. Baguales, and C. La Chacra at the right side, and in several glens of the left (=east-northeastern) side of the Chubut River. FLORES (1948) observed the gradual thinning that occurs from north to south. In the Cerro Condor village area the formation may reach 350 m; at the north, near the basin's northern margin, it is possibly thicker. Between Cañadón Asfalto and Estancia Berwyn the formation reaches a thickness of only 205-207 m (STIPANICIC, *et al.*, 1968). The greater thickness at the north may be explained by the presence of thick biochemical sediments (algal limestones) and coarser clastics in this area.

STRATIGRAPHIC RELATIONS.—The contact between the Cañadón Asfalto and the Pampa de Agnía Formations is possibly a slight angular unconformity. The limit is characterized by change from a volcanic to a mainly lacustrine environment. The contact with the Lower Cretaceous Los Adobes Formation is a marked angular unconformity.

FACIES.—The main facies of the Cañadón Asfalto Formation are represented by tuffs, dark, conchostracan- and plant-bearing shales and algal limestones. The latter are common in the northern half of the basin. At 43° 30' S lat. they have nearly disappeared. In Cañadón Lahuincó the sequence contains in the uppermost part of the formation only one bed of algal limestone, a few meters thick and strongly silicified. Conglomerates are known only from the northern margin of the basin. Six km north of the Cerro Condor village, a thick fanglomerate outcrops in the lower part of the formation (verbal communication, Dr. LESTA, Yacimientos Petrolíferos Fiscales). The conglomerates described (p. 15, 18, lithology) from Cañadón La Chacra, may be a distal facies of such fans, of the northern margin of the basin.

AGE AND PALEONTOLOGY.—The Callovian-to-Oxfordian age determination of the Cañadón Asfalto Formation is principally based on floral affinities with the Middle to Upper Jurassic La Matilde Formation of Santa Cruz province. Radiometric age determinations of the Pampa de Agnía Formation support this dating, indicating a maximum age of less than 158 ± 6 million years for the basal strata of the Cañadón Asfalto Formation.

The flora collected by FLORES in Cañadón Lahuincó, identified by FRENGUELLI (1949) and erroneously cited by this author in all later publications as "Flora from Cañadón Asfalto," contains the following species:

Flora Cited from Cañadón Asfalto

- Sphenopteris patagonica* HALLE
- Sphenopteris hallei* FRENGUELLI
- Scleropteris* cf. *furcata* HALLE
- Cladophlebis grahami* FRENGUELLI
- Pagiophyllum divaricatum* (BUNBURY) SEWARD
- Pagiophyllum feistmanteli* HALLE
- Araucarites cutchensis* FEISTMANTEL
- Athrotaxis ungeri* (HALLE) FLORIN
- Palissyia conferta* (OLDHAM) FEISTMANTEL
- Palissyia jabalpurensis* FEISTMANTEL
- Equisetites aproximatus* NATHORST



FIG. 8. Detail of Cañadón Asfalto Formation in Cañadón La Chacra. Algal limestones of Unit 3 in the described section.

The presence of algae and algal limestones in the Cañadón Asfalto Formation was first mentioned by VOLKHEIMER (1969). A large collection of the algal flora is being studied by this author.

Gastropods (*Potamolithus*) and pelecypods (*Palaeomutela*) are common in some levels. Conchostracans are the most abundant fossils of the formation and can be found in nearly all shales,

marls and siltites of the sequence. Owing to the abundance of these fossils, decades ago the formation was named, "Estratos con *Estheria*."

In some levels, especially associated with algal limestones, bones of large reptiles (sauropods) are numerous. They have not yet been described.

LOCATION OF CONCHOSTRACAN-BEARING SAMPLES.—The geographic location of conchostracan-bearing samples described in Part 1 is shown in Figure 4. VAs2 and VAs3 (Fig. 4,2) are from a little glen immediately southeast of Cañadón Lahuinco. Both samples are from the upper third of the outcropping part of Cañadón Asfalto Formation at this place (VAs2, 40 m stratigraphically below the angular unconformity with the Cretaceous Los Adobes Formation), and VAs3 (30 m stratigraphically below the unconformity mentioned).

VAs9 is from a glen on the southern slope of Cañadón Lahuinco, stratigraphically some 120 m below the unconformity between Los Adobes and Cañadón Asfalto Formation. The whole sequence of the Cañadón Asfalto Formation dips 15° to 35° to SSW in the area of sampling with changing strike. VAs9 is situated at a distance of more than 2200 m WNW of VAs3. During the short time of sampling it was not possible to follow outcropping beds between VAs3 and VAs9. Accordingly, it can only be said very generally that VAs3 and VAs9 come from similar stratigraphic positions.

ORIGIN.—The Cañadón Asfalto Formation seems to have been deposited in a small mainly lacustrine basin. In its southern part poor bottom ventilation prevailed, as indicated by abundance of bituminous shales. Near the northern limit the stratigraphic relationship can be observed, with interfingering coarse-grained alluvial fan deposits. Similar coarse deposits may encircle the lake sediments on other sides, where no outcrops are found. Gypsum crusts have formed in some marginal areas.

Colonies of limestone-building blue-green and other algae during some moments of the history of this Jurassic lake occupied most of the northern third of the basin. The shapes of the colonies mirror the microtopography of the substratum (Fig. 9,2).

A low salinity (lacustrine) is reflected by the presence of marls (flocculating of clay by elec-

trolytes) bearing conchostracans and small gastropods and pelecypods. Considering the characteristics of some algae, it cannot be ruled out entirely that in some moments during deposition of the Cañadón Asfalto Formation a very shallow connection with the Pacific Ocean was established. Thus, transient higher salinities would be accounted for.

CORRELATION.—Formations correlative with the Cañadón Asfalto Formation are: 1) The Cañadón Puelman Formation in the Sierra de Pampa de Agnía. 2) The Cañadón del Zaino Formation in the Sierra de Taquetren (BONETTI, 1963; STIPANICIC, *et al.*, 1968). 3) The La Matilde Formation of northern Extra-andean Santa Cruz province.

PALEOCLIMATE.—The Cañadón Asfalto Formation contains excellent climatic indicators. The combined evidence of its fauna of large reptiles, its carbonate facies represented by algal limestones, and lacustrine marls associated with some gypsum layers indicate warm and semiarid conditions. The value of lacustrine carbonates, especially lacustrine marls, as climatic indicators recently has been emphasized by FAIRBRIDGE (1967) who notes their restriction to generally dry climates where ground waters are not unduly acid. As a consequence of dry conditions the vegetation cover was not continuous and only along the rivers and bordering lakes it was abundant, as indicated by the fossil flora from Cañadón Lahuinco.

LOS ADOBES FORMATION (LOWER CRETACEOUS)

During last decades all continental deposits of Cretaceous age which overlie the Jurassic sequences in the middle valley of the Chubut River with pronounced angular unconformity have been assigned to the "Chubutiano" or "Chubutense," presumably of Maastrichtian age. Modern studies, mainly in the Golfo San Jorge Basin (LESTA, 1968) led to a more complicated picture and showed that much of the presumed "Chubutiano" is older than Maastrichtian, belonging to several formations separated by unconformities.

The Cretaceous sequence of northern and western Chubut, including that of the middle valley of the Chubut River, was assigned by STIPANICIC & RODRIGO (1969) to the Lower Cretaceous (Hauterivian to Aptian), and the name Los

Adobes Formation was proposed for it. In the area of Cañadón Lahuincó-Cerro Condor it is composed of cross-bedded sandstone conglomerates, siltstones and tuffs.

At the present state of knowledge it cannot be

ruled out that eventually the upper part of the Cretaceous sequence of the area considered must be separated from the Los Adobes Formation and assigned to the Maastrichtian Chubut Group. This possibility was taken into consideration in Fig. 10.



FIG. 9, 1. Valley of Chubut River and Cerro Condor village, north to left, south to right. Cañadón Asfalto Formation, northern facies; in background prominent lenticular beds of algal limestones can be seen.—2. Cañadón Asfalto Formation, northern facies, algae on bedding-surface of limestone.

A G E S		FORMATIONS	L I T H O L O G Y	THICKNESS in met	PROCESSES	
C R E T A C E O U S	U P P E R	Maastrichtian	Chubut Group	Sandstones, siltites, tuffs, tuffites, conglomerates	Several hundreds	Continental sedimentation
		Senonian				Uplift and erosion
		Turonian				
		Cenomanian				
	L O W E R	Albian				
		Aptian				
		Barremian	Los Adobes-F	Sandstones, tuffites, tuffs	Several hundreds	
		Hauterivian				
		Valanginian				
		Berriasian				
U P P E R	Portlandian				Uplift and erosion	
	Kimmeridgian					
	Oxfordian					
	J U R A S S I C	M I D D L E	Callovian	Cañadón Asfalto-Formation		Tuffs, tuffites, dark conchostracan and plant-bearing shales & siltites, lacustrine marls & algal limestones
						Uplift and erosion
Bathonian		Pampa de Agnia Formation	Andesitic flows, agglomerates and tuffs	800	Volcanic activity	
		Bayoc.	U			
M			Cerro Carnerero F	Conglomerates, sandstones and some conchostracan-bearing tuffs	340	Continental sedimentation
L						
Toarcian		Marine Strata	Tuffs, limestones, marls and sandstones	75	Marine sedimentation	
Pliensbachian						Uplift
Sinemurian		Marine Strata	Tuffs, limestones, conglomerates	30	Marine sedimentation	
Hettangian						Uplift and erosion
JURASSIC AND CRETACEOUS FORMATIONS OF THE MIDDLE CHUBUT RIVER AREA						

FIG. 10. Stratigraphic relationships of Jurassic and Cretaceous formations in the middle Chubut area (age assignments of formations and tectonic events after authors cited in text) (see STIPANICIC, *et al.*, 1968).

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NOTE ADDED IN PROOF.—From a microflora found in the lower third of the Cañadón Asfalto Formation (6 km north of Cerro Condor village) I am now inclined to deduce a Late Jurassic age of the Cañadón Asfalto Formation, Oxfordian or, at most, Kimmeridgian.

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