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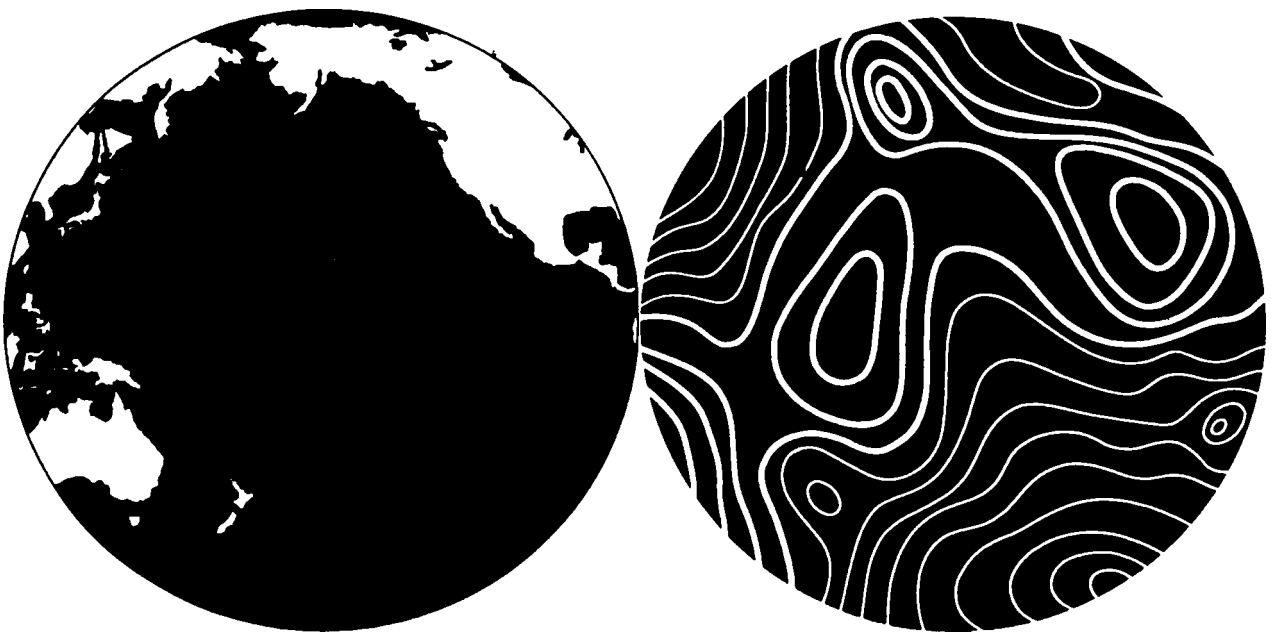

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THE TRIASSIC/JURASSIC MARINE TRANSITION OF COASTAL CENTRAL CHILE

by

G. Cecioni and G. E. G. Westermann

University of Chile, Santiago, Chile and McMaster University, Hamilton, Ontario.

Abstract

A 3,000–4,000 m thick Triassic and lowermost Jurassic sequence is exposed along the coastal cliff south of Los Vilos, Coquimbo and Aconcagua province, consisting of graywackes, marine sandstones, conglomerates, shales, some continental beds, keratophyres and some andesites. It appears that the Anisian El Quereo formation was deposited in an eugeosynclinal trough, and the lowermost Jurassic Los Molles formation, to the south, in a foredeep trough.

The Triassic sequence contains in the lower third the Upper Anisian assemblage *Daonella dubia* (GABB.), (?) *Sturia* and (?) *Gymnites*, in the middle the Upper Norian '*Sandlingites*' and " Los Molles flora ", and at the top the Norian/Rhaetian assemblage of *Arcestes*, *Cladiscites*, *Oxytoma* cf. *inequivalvis* (SOW.), and (?) *Minetrigonia* sp. nov. aff. *M. otamitensis* (TRECH.). The overlying approximately 100 m shales contain ?*Cardinia* cf. *listeri* (SOW.) and (?) *Otapiria* cf. *ussuriensis* (VOR.) and may be of Rhaetian age. The above following Hettangian assemblages permit, for the first time in the Americas, the distinction of the *Psiloceras planorbis* and *P. johnstoni* subzones with *P.* cf. *planorbis* (SOW.) and *P.* cf. *peruvianum* LANGE, respectively, and probably of intermediate beds with *P.* aff. *planorbis erugatum* (BEAN) which may be equivalent to the French *P. plicatulus* beds. The *P. planorbis* Zone is overlain by the *Schlotheimia angulata* Zone. Above is a thick flysch sequence with rare arietitids and, slightly higher, *Polymorphites*, respectively of Sinemurian and early Pliensbachian age. The reasonably well known Hettangian faunas are probably identical with those described from Peru and show close affinities to North American and especially Europe an ones, while the poorly known western Pacific faunas seem to be less closely related.

Preface

The stratigraphical and petrological studies, as well as the related cartographic work, was carried out since 1960 by G. CECIONI and his collaborators, students of the Escuela de Geologia. Mr. RAUL VICENCIO and Mr. ARMANDO FASOLA also assisted G. E. G. WESTERMANN in fossil collecting during August of 1965. G. E. G. WESTERMANN did the paleontological and biostratigraphical work including the revision of molluscan faunas collected and described previously by H. FUENZALIDA V. The results have partly been incorporated in the stratigraphical part of this paper.

A. Stratigraphy——by G. Cecioni

Some definitions

In order to avoid erroneous interpretation of terms for some sedimentary facies, definitions are here given for those terms not already recently redefined by the author (CECIONI, 1964). They are descriptive and not interpretative; some definitions are closely related to the concept of sedimentary formation with special consideration of mappability.

Sorted graded bedding: The grain mass (preferred to the grain size) at a single level, except where lenticularities are developed, is uniform and varies upward and/or downward; the grains are in contact, the interstitial matrix is absent or very scarce. The primary permeability may be very good; fossils may be abundant; feldspar grains are generally altered.

Muddy graded bedding: The grain mass at a single level is uniform; lenticularities are very scarce; only insignificant cross-bedding has been described in some recent sands and old arenites. The main decrease of the grain mass is graded upward; the matrix is very abundant and the grains are not in contact. According to KUENEN and MIGLIORINI (1950) the maximum mass grains are at the base of the bed, but my own abundant observations have shown that they are generally located at the top of the lowermost third part of the bed, and that the basal position is exceptional (CECIONI, 1964, Fig. 10); the muddy graded bedding may also occur repeatedly in a single bed (observed five times). The lower contact of the graded bedding is abrupt with the subjacent siltstone or shale. Primary permeability is absent; fossils occur in the sandy portions.

Schlier: A mappable series of alternating shales and siltstones, with laminae thickness usually under 1 cm. Muddy graded bedding may be observed in the siltstones, although generally difficult to recognize even under the microscope. Fossils, generally, are very abundant only in the top of the shaly beds (CECIONI, 1964, Fig. 8; MCBRIDE, 1962, Fig. 4).

Graywacke: Arenites usually with muddy graded bedding; matrix of the same mineralogical composition as the larger angular grains which may be rock fragments. Feldspar generally fresh. The mineralogical composition of the grains and of the matrix has not been considered in the present definition. Field observations give evidence that the graywackes constitute a mappably monotonous series which may include shale, siltstones, para-conglomerate and/or breccias. Their composition generally is the same for a limited thickness. The total thickness may reach some hundred meters. Primary permeability of the series is absent.

Flysch: A series of alternating beds of graywackes with shales and/or siltstones in relative thickness of about 1 : 1. Exceptionally, other sediments are present, such as chert, detrital limestones, marls, para-conglomerates, breccias; but their volumes are generally insignificant. Synsedimentary folds of highly variable extent (several mm to several m) may be present encompassing part of a single bed (generally at the top), or a series of beds, and sometimes producing inversion of the muddy graded bedding. These disturbed beds are covered by undisturbed, contiguous and modelling sediments of the same facies. At the base of the graywacke, some centimeters of sediments may be developed in schlier facies (CECIONI, 1957, Figs. 6, 9 and 10; MCBRIDE, 1962, Fig. 6; CECIONI, 1964, Figs. 1, 4, 5, 6, and 7; PETTIJOHN and POTTER, 1964, pl. 5a—lower Liassic not Tertiary). Discordant discontinuities are evidently hydrodialeimas (SANDERS, 1957), with either very small (CECIONI, 1964, Fig. 9) or strong angularity (CECIONI, 1957, Fig. 9). The lower surface of the graywacke beds have very abundant load, groove, flute casts and/or marks, which, generally, are of the same direction and sense for a limited thickness of the series.

Macigno (Macigno facies or macigno formation): " Flysch " composed prevalently of graywacke; thickness of the graywacke beds at least 1 m, of the shaly or silty intercalations less than 0.5 meter; at the base of the graywackes is often para-conglomerate (CECIONI, 1964, Fig. 3), or, rarely, para-microbreccia developed. In USA nomenclature, the " macigno " is included in " flysch ", but the two sedimentary types should be distinguished in the field because the macigno is essentially a sandy formation. The graywackes are as defined above. The type locality of this facies, or formation, is in the Northern Apennines, where some graywacke beds form fossiliferous microbreccias with Eocene *Nummulites* and are interbedded

with Oligocene shales (CECIONI, 1946). The fossils of these graywackes also indicate a shallow water environment. The pebbles of the paramicroconglomerate are rounded and of various and strange lithology; but in the para-microbreccia, some elements may present the same lithology as the matrix. In my opinion, the Shochary Ridge member (MCBRIDE, 1962, p. 71) is an Appalachian macigno.

Wildflysch: A flysch or macigno containing mappable para-conglomerates and/or mappable breccias (which may be a para-breccia with distantly distributed fragments). This alpine facies occurs also in southernmost and central Chile (CECIONI, 1957, Figs. 3 and 10, 1964; ZEIL, 1958; KATZ, 1963, Figs. 7 and 8). The relative stratigraphical position of wildflysch is in the lower part, at the top, or as intercalation of the flysch. The author assumes that the wildflysch is more closely related to the macigno. These stratigraphical relations are well evident in Chile. Schlier, flysch, macigno and wildflysch are genetically related. However, it is possible that genetically non-related mappable sediments may be intercalated in the flysch and its allied sediments, such as black, massive shales apparently deposited in deep marine environment.

Molasse: All sediments which are not genetically related with flysch and its allied sediments are here included in the term molasse. These sediments were deposited in a fluid medium (air, marine or continental waters), by a solid agent (ice), by gravity and/or by lateral transport. Included are igneous rocks such as lava, ash, mud flows, fanglomerates etc. The sandstones have generally rounded elements, predominantly quartz grains, and the feldspar is frequently altered. These sandstones show generally sorted graded bedding or cross-bedding, indicating a shallow water environment. The term " shelf deposits " is interpretative, since geologists have not yet demonstrated the presence of ancient shelves but only of sediments or biological environments comparable to those of the shelf.

In my opinion, there is no rule regarding the relative stratigraphic position of molasse sediments to flysch and genetically related sediments (flysch sensu lato); in Chile, the molasse may be present subjacent, intercalated or superjacent to the flysch. Laterally, they may be interfingering as directly observed in the field in the Patagonian Andes (SCOTT, 1966) or as inferred by faunal evidence such as in the Ordovician of northernmost Argentina. Exceptionally, a few beds of muddy graded bedded graywackes may be recognized within molasse, such as near the base of a sandstone series of delta facies. A single example was observed in the upper El Quereo formation. Vertical and lateral transition from molasse to flysch, and reversely from flysch to molasse, are apparently very rare in the Alps, the Carpathians, the southern Uplands of Scotland, the Appalachians, the Quachita Mts., California and Oregon DZULYNSKI and SMITH, 1964), Cuba (BRONNIMANN and RIGASSI, 1963) and the Pyrenees, probably because of their tectonic disturbance. However, the Chilean Mesozoic sediments are generally only slightly folded (CECIONI, 1962) and have been well exposed by the sea or rivers. The author believes that some modifications of the term flysch (sub-flysch, preflysch, flysch-like, etc.) are accomplished by the term " graded bedding ", which as here defined may be " sorted " or " muddy ".

Facies Interpretations

Under *tectogenesis* is understood the phase of folds and faults production during the sinking of the trough, and under *orogenesis* the phase of uplift above sea level of the trough's sediments; during both and/or the latter movement, igneous activity may be developed.

Investigations by Lamont Geological Observatory have shown beyond doubt that turbidity currents are responsible for the muddy graded bedding in sandy or silty deep water marine

environment. Mr. D. B. Ericson has kindly permitted the author to study (December 1961) deep Atlantic bottom cores, some of which show Recent or Pleistocene miniature flysch with graywackes (Hollister and Heezen, 1964). Controversy as to the origin of the graywackes by turbidity currents still exists because well sorted sandstones also occur. It is important to note that turbidity currents can produce a graywacke only if intercepted by a submarine obstacle which abruptly arrests the viscous mass producing a rapid sedimentation (Cecioni, 1964, p. 188); if arrest is not sufficiently abrupt, the grains of major sizes sink to the botton, the turbidity current looses its velocity and viscosity gradually, and normal sedimentation takes place with sorted graded bedding, porosity and permeability, favourable for petroleum accumulation. Some micropaleontological studies of the shaly sediments of the flysch indicate a benthonic fauna deeper than 1,000 m. (for ex. Herm, 1965, with bibliography). I know of no other satisfactory hypothesis when accounting for the observation that all the schlier facies marine deposits are highly fossiliferous. Examples are the Hettangian *Schlotheimia angulata* Zone and the lower Pliensbachian laminae with Polymorphitidae in the Los Molles formation, the lower Ordovician laminae of northernmost Argentina with numerous graptolites, and abundant *Parabolinella andina* in laminae of black silty shale in the Entre Rios formation. Repeated deposition of graywacke indicates, if correctly interpreted, repeated turbidity currents; this rhythmical repetition indicates that the flysch (and allied rocks) were deposited during a tectogenic phase (syntectogenic flysch) which was or was not related to a continental uplift. The repetition could also indicate a co-seismic origin (Cecioni, 1965) of graywacke or para-conglomerate with frequently repeated earthquakes (co-seismic flysch); finally, it could be that the flysch is the result of redeposition of a sedimentary series by large negative eustatic or isostatic movements, during which material of the continental shelf was removed and/or transported by oceanic bottom currents (epeirogenic flysch), with or without concurrent glaciations.

Whatever hypothesis is accepted, the genesis of flysch is related to concurrent diastrophic processes; macigno indicates intensification of this process with well developed turbidity currents (graywackes). Together with some sliding and slumping they produced repeated series of synsedimentary folds and wildflysch on the continental slope. A turbidity current which does not slide on but rather flows above the bottom, may produce in passing, a rain of fine material which is deposited as schlier. The turbidness of the waters between the turbidity current and the ocean bottom may result in the mass extinction of some benthonic life by suffocation; such process could explain the abundance of fossil fauna in the schlier.

When the diastrophic activity decreases and calms, molassic sediments are deposited; deposition increases with decreasing diastrophism in the absence of subsidence. Molassic sediments may be abyssal to lacustrine in origin.

Lithostratigraphy and petrology

The Triassic and Lower Jurassic formations, here described, are located along the coastal cliff in the Chilean Coastal Range between Los Vilos and Estero Ballena, south of Caleta Los Molles (Approximately 32°S, 70°30'W); the southern part of this area is in Aconcagua and the northern area in Coquimbo Province. This series is both marine and continental in facies and dips southward. Previous descriptions are by Muñoz-Cristi (1938, 1942 etc.), Fuenzalida (1937), Cecioni (1961, 1962a), Groeber (1963).

The following formations are present from north to south: Los Vilos, El Quereo (**Fig. 1**), Pichidangui, El Puquén, Los Molles (**Fig. 2**), La Caleta and again the Pichidangui formation. Some of these formations were studied and named by Cecioni and his students in 1960

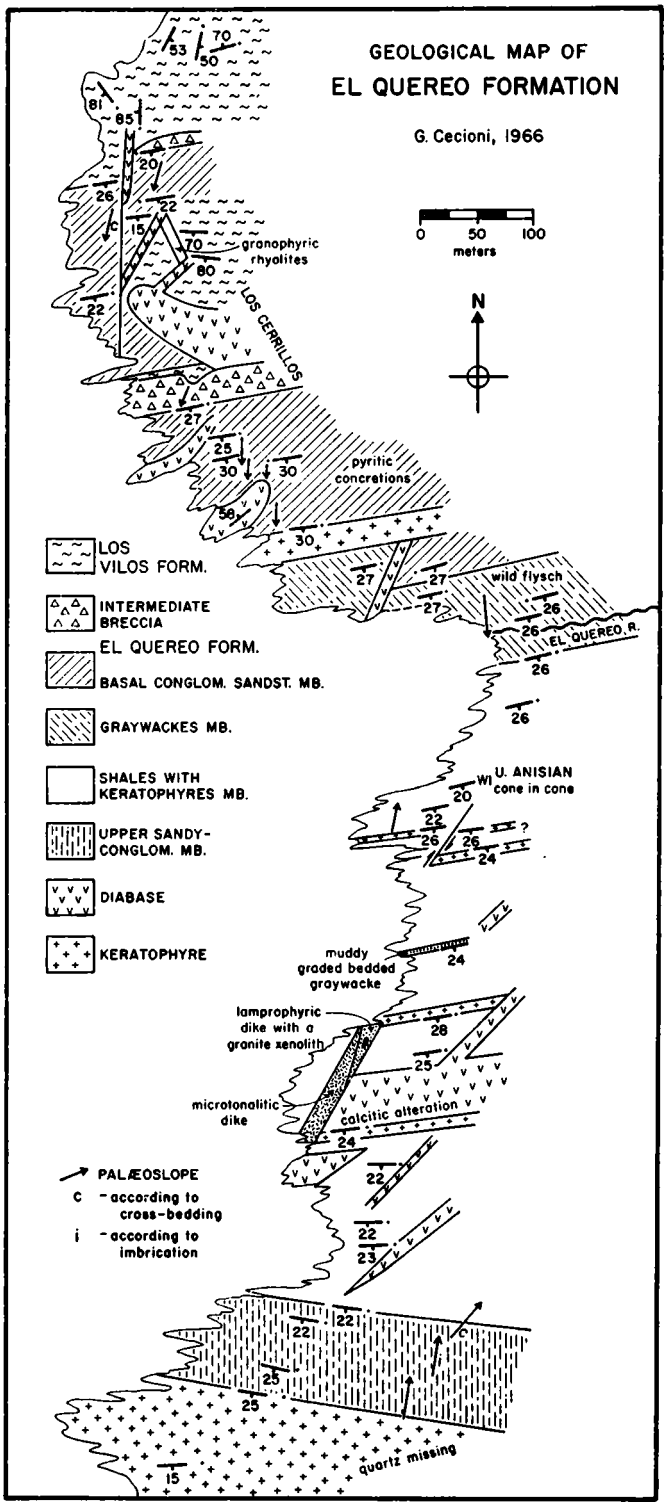


Fig. 1 Geological map of the El Quereo formation, approximately 30 km north of point Los Molles. Fossil locality (W 1) indicated.

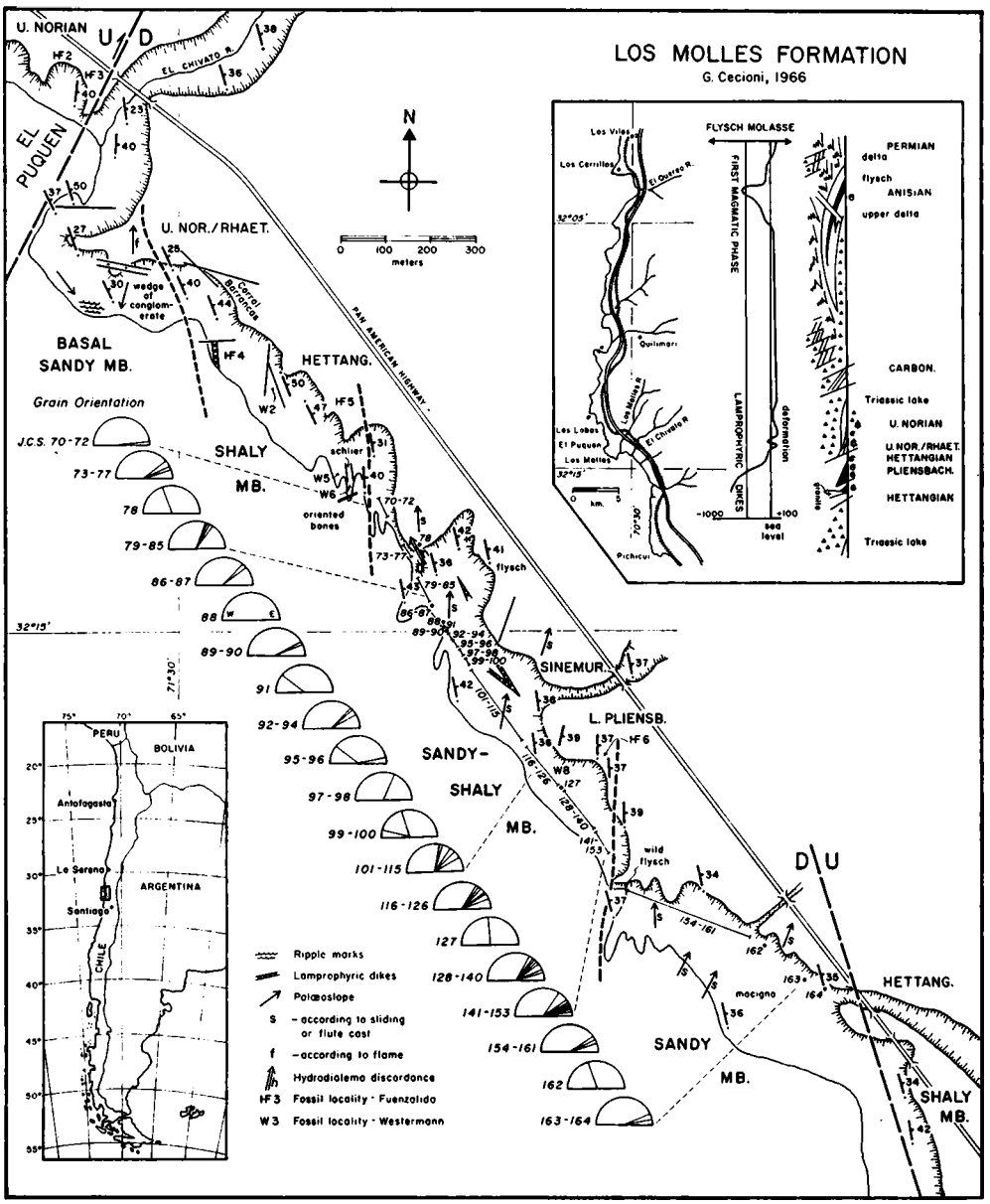


Fig. 2 Shore line exposure of the Los Molles formation, Upper Triassic to Lower Jurassic, southeast of point Los Molles. Measurements of grain orientation for the upper two members are presented graphically. The formation is partly structurally repeated to the southeast, and in fault contact with the older El Puquén formation to the northwest. The fossil localities are indicated.—Upper right : the total coastal exposure under investigation is essentially a monoclinal sequence dipping southward. Bathymetry and tectonics are presented graphically.—Lower left : geographical location of the total area under investigation.

(unpublished).

CAÑAS investigated the Los Molles formation (unpublished thesis, Univ. Santiago, 1964).

Los Vilos Formation: For ' Capas de Los Vilos ' of MUÑOZ-CRISTI (1942). Sandstones intercalated with slates, highly folded and overlain by the El Quereo formation with strong angular unconformity; thickness unknown; Carboniferous in age because of the presence of *Lepidodendron* (TAVERA, unpublished).

El Quereo Formation: For part of ' Capas de El Quereo ' beds of MUÑOZ-CRISTI (1942) and for ' Pizarras de Quereo ' of Fuenzalida (*in* HOFFSTETTER *et al.*, 1957, p. 361). 712.50 m thick; the sandstones at the base of the formation indicate a N 30°E source of material while

at its top the source is clearly from N. The grain feldspars are altered and the matrix is immature. The uppermost sandstones contain pyrite concretions. The formation consists of 4 members (from bottom to top).

1 a) At the base is a violet breccia of 0–35 m thickness. Below, this breccia consists only of fragments of Los Vilos formation rocks, and it is impossible to establish the exact lower contact owing to intergradation. In the upper portion are well rounded little quartz pebbles indicating that the upper breccia was redeposited by rivers, while the lower breccia is *in situ*. This breccia could perhaps be regarded as an independent stratigraphic unit. It is in need of further studies, including the consideration of possible peri-glacial origin. According to the well exposed contact in the southernmost outcrop of this breccia, near the Los Cerrillos locality, the surface of the Los Vilos formation is a sinuous unconformity indicating a southward quadrant paleoslope.

1 b) The *basal conglomeratic sandstones member*, 110 m thick, consisting of deltaic cross-bedded, conglomeratic yellow sandstones which grade upward into fine grained sandstones.

2) The *graywackes member*, 122.50 m thick, consists of graywackes, shales, para-conglomerates and intraformational breccias. The pebbles of the paraconglomerates are of quartz and are well rounded, and well matured; in contrast, the matrix, because of its texture and feldspar content, is immature; synsedimentary folds are developed, and a few gravitational folds (flap structure) indicate that the marine bottom was inclined approximately from N. to the S. (CECIONI, 1964, photo n°4), consistent with a deltaic source. This member with its flysch and wildflysch facies contrasts strongly with the first member which is in molasse facies. In the basal flysch series, some well rounded great boulders up to 70 cm in diameter sank to the sea bottom, bending the unconsolidated beds, and were covered by modelling and horizontal beds. Icebergs or, perhaps, floating trees may have transported the boulders (**Pl. II, Fig. 2**). Curiously, some of the boulders consist of sediments which could be interpreted as an old flysch, and their lithology resembles the upper Paleozoic beds south of Puerto Manso.

3) The *shales with keratophyres member*, 402.50 m thick, consists mainly of dark massive shales at the base (75 m), intermediary shales with some intercalated sandstones and limestones with cone-in-cone texture, lighter in colour (50 m), and an upper part which begins with a keratophyric submarine flow, up to 5 m thick, and consists of intercalated shales and sandstones. Some siltstones present volcanic material; near the middle part of this series is a 2 m para-conglomeratic "graywacke", well cemented and crystallized, with good muddy graded bedding, which strongly contrasts with the molassic facies of this member. The drag-fold at the base of the submarine keratophyres indicates a south-north sense of the flow, which is opposed to the sense of sedimentation of the basal deltaic member and of the flyschy member. At the boundary of the lower two submembers, (?) *Gymnites*, (?) *Sturia* and *Daonella dubia* (GABB.) occur, indicating Upper Anisian.

4) The *sandy conglomeratic member* consists of 77.50 m yellow sediments, very fine grained at the bottom, coarse conglomeratic and massive at the top. The basal sandstones present typical pro-delta cross-bedding and the laminations indicate a SW or S source. The imbrications of the fluviatile coarse conglomerates indicate the same source direction.

Above is an unknown thickness of keratophyres with some continental yellow sandstones at the base. These keratophyres are more basic than those which flowed at the bottom of the Anisian (or slightly younger) sea and which generally are quartz-bearing keratophyres.

Sometimes the keratophyres are cut by diabase or porphyritic diabase dikes; some microtonalitic dikes have also been recognized. Sometimes, near the base of the formation, diabase is cut by granophyric rhyolites. In the middle part of the formation, a flow of keratophyres

has forced a diabasic intrusion to alter its course along the bottom of the keratophyres flow and becomes calcareous vesicular. Some small lamprophyric dikes cut all the mentioned sedimentary and igneous rocks, and include some granitic xenoliths.

Tectonically, the El Quereo formation shows monoclinal deepening to the south. Some strike-slip dip faults are developed with NNE-SSW direction, parallel to bodies of porphyric diabase which have intruded along the faults.

Pichidangui Formation: (Here) Thickness unknown; recognized between Punta Pichidanguiin the north and Punta Pichicui in the south; it is composed of keratophyre flows and tuffs, as well as of conglomeratic sandstones. The age is delimited between the upper Anisian *Daonella dubia* assemblage of the El Quereo formation and the Norian *Sandlingites* beds of the El Puquén formation. The top of this formation consists of 100–200 m continental keratophyric breccias, green and red, with thin conglomeratic and sandy beds. The Pichidangui formation is overlain by the El Puquén formation.

El Puquén Formation: For lower part of 'Capas de Los Molles' of FUENZALIDA (1938). The stratotype is 500–1,000 m north of Caleta Los Molles and just south of El Puquén (quechua term signifying blow-hole). The formation is characterized by shales and its flora but differs markedly in the separate exposures.

Los Lobos Area (**Fig. 3**): The exposed 25 m consist of very dark shales with N 20°W strike and 10°NE dip. The rich flora was studied by FUENZALIDA and again by STIPANICIC and BONETTI (GROEBER, 1952, Lexique, p. 361) and was presumed Norian or Karnian in age. Insects and crustaceans also are present. There is no evidence that these dark shales are intercalated in the keratophyric series or in the Pichidangui formation, because the exposure

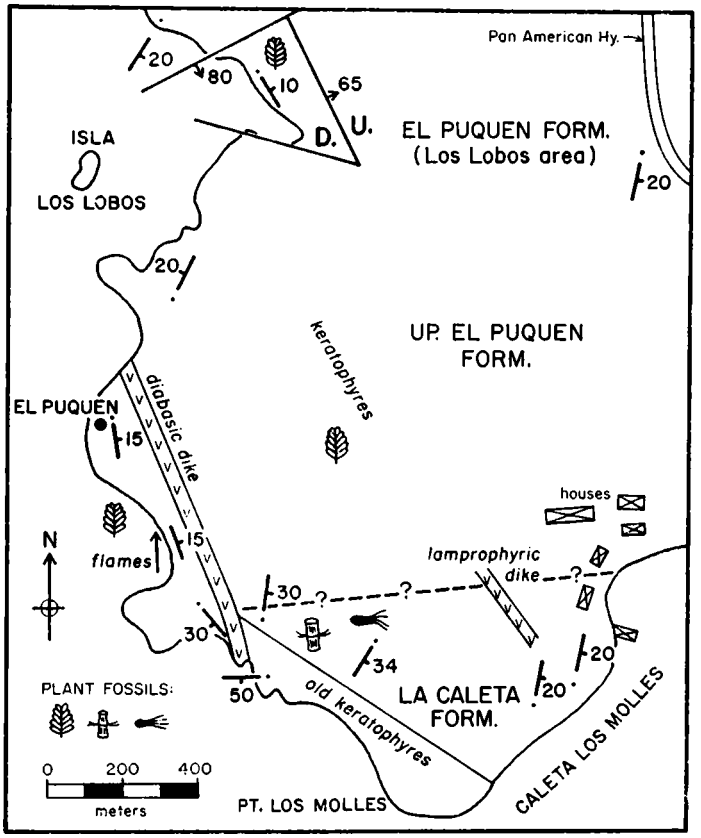


Fig. 3 Exposures of the El Puquén and La Caleta formations in the coastal area just north of point Los Molles.

is limited by the shoreline and by faults, and igneous intercalations are absent. According to L. BIRO (priv. com.) the dark colour of the shales (N 3, dry, of the Rock-Colour Chart), is due to the high proportion (60%) of mafic magnetic minerals while hydrocarbons are absent; coal is present only at 1.5%. Because of the fine texture of the shales, only quartz, feldspar and chlorite could be identified with the microscope. There can be no doubt that this shaly formation was deposited in a lacustrine environment, and that the source rocks around this lake were more basic than the keratophyres. The keratophyres are probably either absent in this area or covered by other rocks. More detailed work is needed to clarify this problem.

El Chivato area (**Fig. 2**): The 200 m exposed sediments between Estero Los Molles and Estero El Chivato consist of shales, siltstones, tuffaceous and volcanic sandstones forming a monocline. The stratigraphical relations are unknown, because these sediments are bounded by faults. Some acid lava flows are present in the lower part (40 m). In the middle part (65 m) some green and gray altered to yellow shales and slates are present together with some tuffs. Upwards there are 45 m somewhat metamorphosed brown to red sandstones and shales. These are overlain by 130 m unsorted and poorly stratified clastic gray sandstones which include igneous angular elements of predominantly diorite porphyry and also of micaceous matrix. The elongated elements are parallel, giving the impression that these sediments were produced by mixture of volcanic and unconsolidated sediments. Above follows a 70 m series of alternating shales and sandstones in which FUENZALIDA (1938) recognized the (loc. HF 3) " Los Molles flora " and (loc. HF 2) " *Nevadites* " (=' *Sandlingites* ') of late Norian age. The uppermost sediments are cut by a NNE-SSW fault. The interbedding of plant-bearing beds with sediments bearing marine faunas suggests alternation between lacustrine and marine environments. It also appears that the volcanic emissions of keratophyres have now decreased and become more basic. The flora and the presence of grains of diorite porphyry, rich in mafic minerals, suggest environmental conditions very similar to those of the Los Lobos area and the possible equivalence of the sediments in the two localities.

South of the El Puquen area: Similar dark shales and flora as in the Los Lobos area are exposed but the thickness is reduced by intercalation of some sandy beds. The sandstones resemble those of the El Chivato area. It is therefore possible that the lithology of the El Puquen area is intermediate between those of the Los Lobos and El Chivato areas. Accordingly the lake in which the Norian flora accumulated deepended northward towards the Los Lobos area. The ' flames ' present in the sandstones (**Pl. I, Fig. 1**) at the top of the dark shales in the El Puquén area indicate clearly a northward sense of sedimentation. A new floral assemblage has recently been recognized by V. AZCARATE and A. FASOLA (priv. com.) in the El Puquén formation of the Los Lobos and El Puquén exposures, consisting of *Chiropteris* aff. C. *copiapensis* STEINM. and SOLMS, *Zuberia zuberi* SZAJN, *Ctenophyllum* sp., ?*Johnstonia* aff. *coriacea* (JOHNST.) WALK., *Asplenium* sp. and dated as Karnian to Rhaetian. The late Norian dating of the " Los Molles flora " by FUENZALIDA (1938) is tentatively retained.

Los Molles Formation: (CECIONI, 1961, p. 19; for middle and upper part of ' Capas de Los Molles ' of FUENZALIDA, 1938). Stratotype: coastal cliff between the mouths of Arroyo El Chivato and Estero Ballena. To the east this formation is in contact with the Pichidangui formation by a large fault. This stratigraphical unit consists of 747 m sediments limited by faults. The northern fault may have very little displacement since there is close lithological resemblance between the basal Los Molles formation and the El Puquén formation in the El Chivato area. The Los Molles formation is divided into four members. The lower two members are of molassic facies and the upper two of flysch facies. Some faults of very little

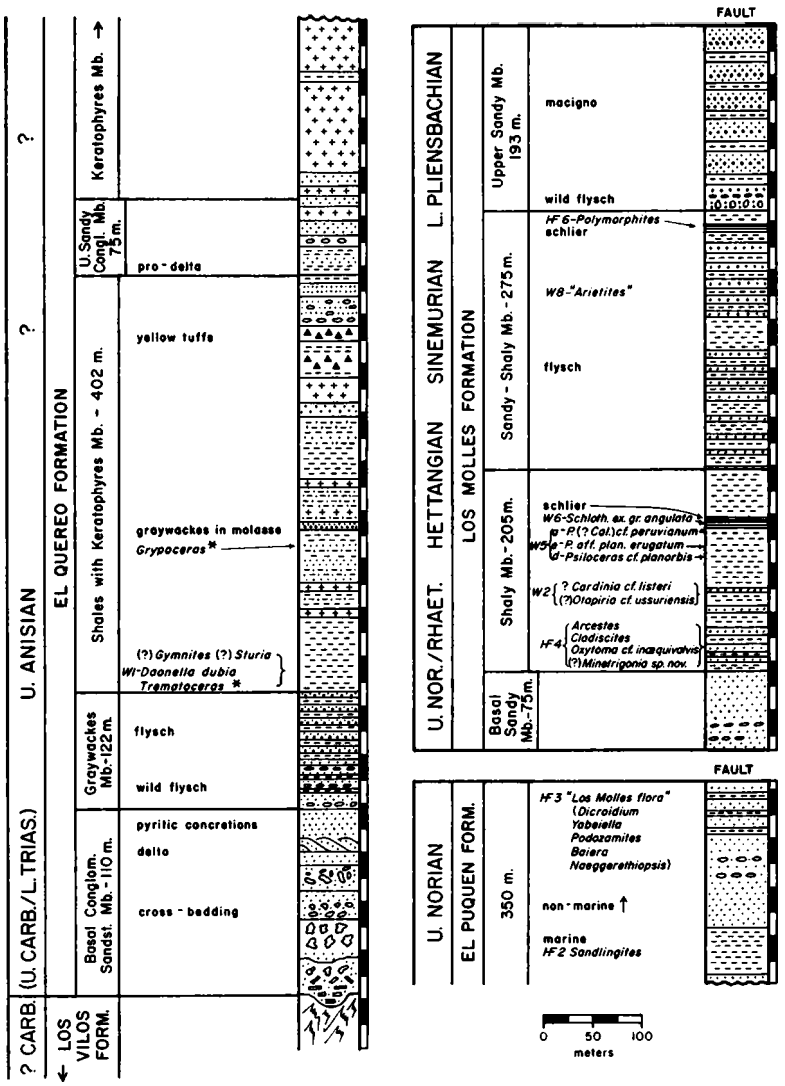


Fig. 4 Section columns of the El Quereo, El Puquén and Los Molles formations (by CECIONI). The fossil occurrences and stages are indicated (by WESTERMANN, asterisks det. G. CECIONI).

displacement are present so that the computed thicknesses may be slightly incorrect. In the south, a great transverse fault places in contact the top of this formation with the fossiliferous shaly member (**Fig. 4**).

1. The *Basal Sandy Member*, 75 m consists of yellow conglomeratic sandstone in beds up to 3 m. Subrounded quartz grains are in the matrix of microcrystalline quartz with wavy extinction and containing siliceous cement; some chips up to 10 cm in size are present. The intercalated shaly lens contains scattered quartz and feldspar grains in sericitic cement, with some elements of orthoclase, chalcedony, muscovite and biotite. Near the base, a thick sandstone bed is cross-bedded and contains three synsedimentary deformations of the type which MACAR (1958, Fig. 15) described as " sandy pocket " due to differential vertical descent of sands into the lower clay, followed by gravitational sliding apparently from N 60°W.

Some lamprophyric dikes cut this member, oriented approximately N-S, well in agreement with the similar dikes which cut the El Quereo formation. Some clastic dikes are also present.

2. The *Shaly Member*, 205 m which follows upward consists prevailingly of shales, somewhat

slaty; near the base, some yellow dark sandy intercalations are present, becoming very thin in the middle portion; some of these arenites contain quartz and orthoclase (diameter 0.02–0.04 m) and lie in a sericitic matrix. The shales are grayish at the base and become dark to black and massive at the top clearly indicating subsidence. Some lamprophyric dikes, as described above, have been observed. 50 m below the top of this member, several meters of silty-shaly laminae (24 laminae present) in schlier facies are well exposed. They are highly fossiliferous in ammonites up to 15 cm in diameter [*Schlotheimia*] and contain little shaly chips. Some bones have also been recognized (L. Bíró, unpublished); their long axes (>7 cm) are oriented N 75°E, resembling the grain orientation of the lowermost graywackes. Some small synsedimentary folds indicate a paleoslope approximately to the NE. The Hettangian fauna occurs both in schlier facies (with pebbles) and in molasse facies, indicating turbidity currents. Above the schlier are 50 m marine shales, dark and massive.

3. The *Sandy-shaly Member*, 275 m (basal part reproduced by Pettijohn and Potter, 1964, pl. 5a—Lower Liassic, not Tertiary) consists of alternating marine beds of graywacke and shales with or without siltstones, in about 1 : 1 ratio. The graywackes are poorly sorted and the grains may or may not be rounded with about 1.5 : 1 axis elongation. The elongation of clastic quartz coincides with the crystallographic axis (Pettijohn, 1963). However, controversial opinion exists with respect to indication of turbidity current direction if grain orientation is parallel (Potter and Mast, 1963) or not. The latter appears to be true for graywackes at Nice (Bouma, 1962), the macigno of Florence (Sestini and Pranzini, 1965) and for the graywackes of this area. J. Cañas took 91 oriented samples at five meter intervals throughout this member (unpublished thesis) which were studied under the petrographic microscope with the gypsum wedge, registering the extinction of the majority of the quartz crystals. The average orientation is NE-SW with partial averages clearly rotating clockwise upwards. They resemble, in this respect, the turbidites of Nice, while the rotation is probably counterclockwise in the macigno of Florence. This new detailed method is necessary if the working hypothesis of Bouma (1962, p. 101) on the influence of the Coriolis effect is to be verified. I have shown with numerous measurements (Cecioni, 1962a; Cañas, unpublished thesis) that these graywackes are totally impervious as suspected by Migliorini (1949) reaching only in a single sample a value of 2.1 millidarcys. The rock consists of 35–45% quartz grains, 10–15% combined orthoclase, chalcedony, plagioclase, microcline and calcite, and 30–40% matrix cement. As accessory minerals, magnetite, hematite, biotite and muscovite were recognized. The structure shows excellent repeated muddy graded bedding, synsedimentary folds, sliding, slumping, flames and varied casts. Some fossils occur in the schlier facies. All indicators of current directions and paleoslope give evidence for the paleoslopes and paleocurrent which were to the north or northeast, and for the axis of the trough which was directed NNW-SSE with its major declivity towards NNW. This is more or less parallel to the trough of the older El Quereo formation. 10 m below the top of this member, in typical schlier facies (Cecioni, 1964, Fig. 8), occur abundant distorted specimens of Polymorphitidae, indicating Lower Pliensbachian.

4. *Upper Sandy Member*, ≧193 m, consisting of 6 thick graywacke beds with thin intercalated shale. The basal bed, several meters thick, consists of chaotic breccia with graywacke fragments and is a typical wildflysch. The second graywacke bed of a gray yellow colour which closely resembles the Tuscan macigno has casts indicating paleocurrent direction approximately to the north. In the third bed, a channel was observed which was perhaps excavated by a current (turbid ?) in a freshly deposited turbidite; the orientation of the channel is N 22°E but the direction is unknown. In the fourth bed, the casts indicate a turbidity current with

N 30°E direction. Upwards follow approximately 100 m sediments in schlier and flysch facies; the fifth graywacke bed has casts indicating N 30°E direction. In the sixth bed of graywacke the casts are more or less parallel to the previous ones, but in the upper portion, some gravitational folds indicate a paleoslope directed approximately towards N 40°W. Lithologically, the graywackes resemble those of the lower member.

Southwards along the coastal cliff, follow again the shales of the second member. They are fossiliferous at the top and include *Schlotheimia* cf. *angulata*. The schlier facies becomes similar to the macigno or upper sandy member while the flyschy or shaly-sandy member is reduced. The lateral facies change agrees with the southern source of material.

La Caleta Formation: Immediately to the NW of La Caleta in the Los Molles area are exposed approximately 200 m silicified sediments but their field relations are unknown. They consist, prevailingly, of bluish chaotic breccias with thinly bedded shaly-limy-sandy intercalations, or of microbreccias with some light sandstones; very thin conglomerates are also present. The pebbles or angular elements consist only of quartz and cindergray, thin-banded keratophyres which resemble those present immediately to the SW of this formation but apparently differ from those of the Pichidangui formation. The outstanding sedimentological feature of the La Caleta formation is the presence of very abundant isolated angular pebbles up to 20–30 cm in diameter. They seem to have tumbled down as a " rain " onto the still unconsolidated very fine laminated, limy-sandy sediment so that in sinking, the laminae were molded around the pebbles. This suggests intense rafting and dropping of long duration (**Pl. I, Fig. 2**). The rate of sedimentation was very rapid because some plants were embeded in vertical position. These observations and the little alteration of the feldspars suggest as a working hypothesis that sedimentation occurred in a lacustrine environment in the vicinity of a glacier which caused the " rain " of pebbles.

Regarding the age of this unusual formation, previously considered Triassic in age, its great hardness, compared to that of the surrounding authentic Triassic sediments exposed only 100 m to the NW, is to be considered. Of the few recovered plants, one resembles *Nilssonia* of Rhaetic-Cretaceous age. However, this could also be a bark fragment of *Calamites* because the supposed leaves are lacking terminations, or *Pterorrachis* (FRENGUELLI, 1942) of the Gondwana group of Argentina. Two megasporophylls were recovered which may belong to the Paleozoic *Miadesmia*. These remains may easily be mistaken for the Paleozoic *Isoetes* or *Lepidocarpum*, as well as for the upper Carboniferous *Bothrodendron*. A little fragment of well preserved tige shows the characteristic verticils of the Lower Carboniferous *Archaeocalamites goepperti* SOLMS (MORET, 1949; SEWARD, 1963, CHAPHEKAR, 1963) (**Pl. II, Fig. 1 a, b**). This interesting formation needs detailed lithological and paleontological studies, especially with regard to the supposed Gondwana continent and the Gondwana flora.

Geological History

The sediments of La Caleta formation were apparently deposited in a lacustrine glacial environment during the Lower Carboniferous. The breccia at the base of the El Quereo formation could have been deposited in a similar environment. The Upper Anisian fauna occurs 360 m above this breccia at the base of the El Quereo formation, so that the lowermost deltaic sediments of this formation may be Lower Triassic and/or uppermost Permian.

The El Quereo formation represents a complete geological cycle of short duration and limited areal extent. Deltaic sediments at the base overlie the basal breccia or lie directly on folded Carboniferous sediments. The basement rocks are poorly represented in the upper part of the basal conglomeratic sandstones, where the pebbles are made up of quartz-bearing kerato-

phyres and alkaline porphyritic granites as established by MUÑOZ-CRISTI (1936, p. 226).
The river of this early delta carried material southward to the sea in the vicinity of a supposed hinge area. Under these conditions, slumping and sinking took place along the shelf margin where deltaic sediments are in natural contact with wildflysch. This sinking could have been compensated for by elevation of the shelf by isostatic rebound. After wildflysch followed the deposition of typical flysch with a combined thickness of 122.5 m. Subsequently, 402.50 m marine shales were deposited, indicating a gradual elevation of the sea bottom until recurrence of a deltaic facies, in which the rivers now carried material to the north. The single graywacke in this molassic facies may have been caused by an earthquake as suggested by ZEIL (1960) and DZULYNSKI and WALTON (1965).
Simultaneously with these events, the first magmatic phase took place with keratophyric intrusions and effusions which continued in a molassic continental facies. The effusions grade upwards from submarine (quartz-bearing) to continental (non-quartz-bearing) origin.
The axis of this supposed eugeosyncline was oriented approximately NW-SE with its slope to the NW and apparently located near the fossiliferous Anisian sediments. The graywackes, isolated or forming a flyschy series were closely related to a delta, which provided the material for the turbidity currents, analogous to the recent shelf source. The NE coastal area of this eugeosyncline underwent more intense diastrophic movements than the SW coastal area.
The contacts between flysch or wildflysch and molassic sediments are sharp and well exposed as in the Magallanes Province and the coastal area of the Atacama Desert. However, they have been obliterated in most mountainous areas, perhaps by synsedimentary or closely following diastrophism. Possibly, the hypothetical ' Lawson's critical limit ' was not reached in this part of Chile. An orogeny occurred in the Chañaral-Taltal area where the *Psiloceras planorbis* Zone overlies the upper Paleozoic El Toco formation (CECIONI, 1960) and the presumably Triassic Cifuncho formation (CORFO, 1965; RUIZ, C., 1965) with angular unconformity.
The effusions and intrusions of the first magmatic phase, especially the keratophyric flows, decreased in the late Norian lacustrine environment, where Groeber's (*et al.*, 1952) classical " Los Molles flora " lived, producing the El Puquén formation. After some short marine inundations during late Norian times (' *Sandlingites* ' fauna), an open marine ingression took place, overrunning the lacustrine mounds in the south and depositing the marine Los Molles formation. Its basal sandy sediments show ripple-marks (NW-SE), pocket sliding (toward the SE), a conglomerate wedge (toward the S) and lacustrine flames, indicating that the maximal depth of the lake was just north of Caleta Los Molles, and that the marine ingression developed approximately from SW to NE. The contained *Arcestes-Cladiscites* fauna is of late Norian or Rhaetian age.
During the Rhaetian and/or at the very beginning of the Hettangian, the sea bottom subsided rapidly. The southwest coast of this embayment, open to the northwest, was tectonically very active, furnishing material to turbidity currents and to the slumping, producing successively schlier, flysch (s.s.), wildflysch and macigno. Only a few lamprophyric dikes cut the series and only a single sill is present. The deposition of the flysch (s.s.) terminated in the early Pliensbachian and northward catastrophic sedimentation commenced, producing, at first, wildflysch and later macigno.
The El Quereo formation was deposited in a northwesterly open embayment with northeastern synsedimentary tectonics and shows the first magmatic activity in the area. The Los Molles formation was deposited in another southeast embayment which was more active, but the synsedimentary tectonics were strong only along its southwest coast. The magmatic

rocks, which intruded the El Quereo formation, did not continue into the Los Molles formation, suggesting independence of the embayment. It appears, therefore, that the Los Molles embayment was not superposed to the El Quereo embayment, and that the crustal deformation was southwestwardly displaced between the Triassic and Rhaetian/Liassic. The greatest crustal deformation occurred apparently in the area of the La Caleta formation, which may have delimited the two embayments. The El Quereo embayment may be considered as the eugeosynclinal trough and the Los Molles embayment as the foredeep trough; Triassic-Liassic orogenic tectonics has not been observed here. Recent field work in the distant Santa Cruz Province of Argentina (Stipanicic, priv. com.) has shown that the Upper Sinemurian *Oxynoticeras oxynotum* Zone, corresponding to the upper flysch series of the Los Molles formation, overlies thick conglomeratic series and that continental Liassic *Otozamites*-bearing beds lie with angular unconformity on continental Middle Triassic *Dicroidium*-bearing beds. The effects of such Triassic-Jurassic orogenic activity are unknown from the central Chilean region described herein.

B. Paleontology—by G. E. G. Westermann

Biostratigraphy

Triassic

El Quereo Formation: Only the shaly sequence in the lower part of the Shales and Keratophyres Member have yielded fossil faunas. From approximately 30 m above the base of the member:

(?) *Gymnites* sp., (?) *Sturia* sp., *Trematoceras* sp. [coll. et det. GECIONI]

Loc. W 1 *Daonella dubia* GABB, frequent

This fauna belongs in the Middle Triassic and *Daonella dubia* indicates with some certainty Upper Anisian. The previously supposed Karnian age (MUÑOZ-CRISTI, see ZEIL, 1964, p. 51) was probably based on the misidentification of the *Daonella* with *Halobia.*

125 m higher up in the same member, *Grypoceras* sp. was found and identified by CECIONI. Since this genus has a long range through the Triassic the above assemblage constitutes the only age fixation for the thick formation.

El Puquén Formation: The very sparce fauna from the marine interval (loc. HF 2) collected and described as probably Norian by FUENZALIDA (1938) almost certainly included '*Sandlingites*' ex gr. *lissoni* and *sutanensis* (JAW.) which are characteristic for the Upper Norian of Peru. The non-marine/lacustrine intervals contain Fuenzalida's "Los Molles flora" (loc. HF 3) which has not here been reinvestigated.

Los Molles Formation, lower part: Approximately 30 m above the base of the Shaly Member is Fuenzalida's locality No. 4 (HF 4) which has been reinvestigated. The ammonoids collected and described by FUENZALIDA are lost. The revised faunal list is:

Loc. HF 4 *Arcestes* (?*Arcestes*) sp. indet. cf. *A. andersoni* HYATT and SMITH

Cladiscites sp. [coll. FUENZALIDA]

Oxytoma cf. *O. inaequivalvis* (SOW.) [coll. FUENZALIDA]

(?) *Minetrigonia* sp. nov., aff. *M. otamitensis* (TRECH.) [coll. FUENZALIDA]

This assemblage indicates (Upper Karnian) Norian or Rhaetian; *Oxytoma inaequivalvis* if correctly identified would suggest Rhaetian. A very late Norian age was originally proposed by FUENZALIDA (1938).

Approximately 50 m higher occur poorly preserved bivalves:

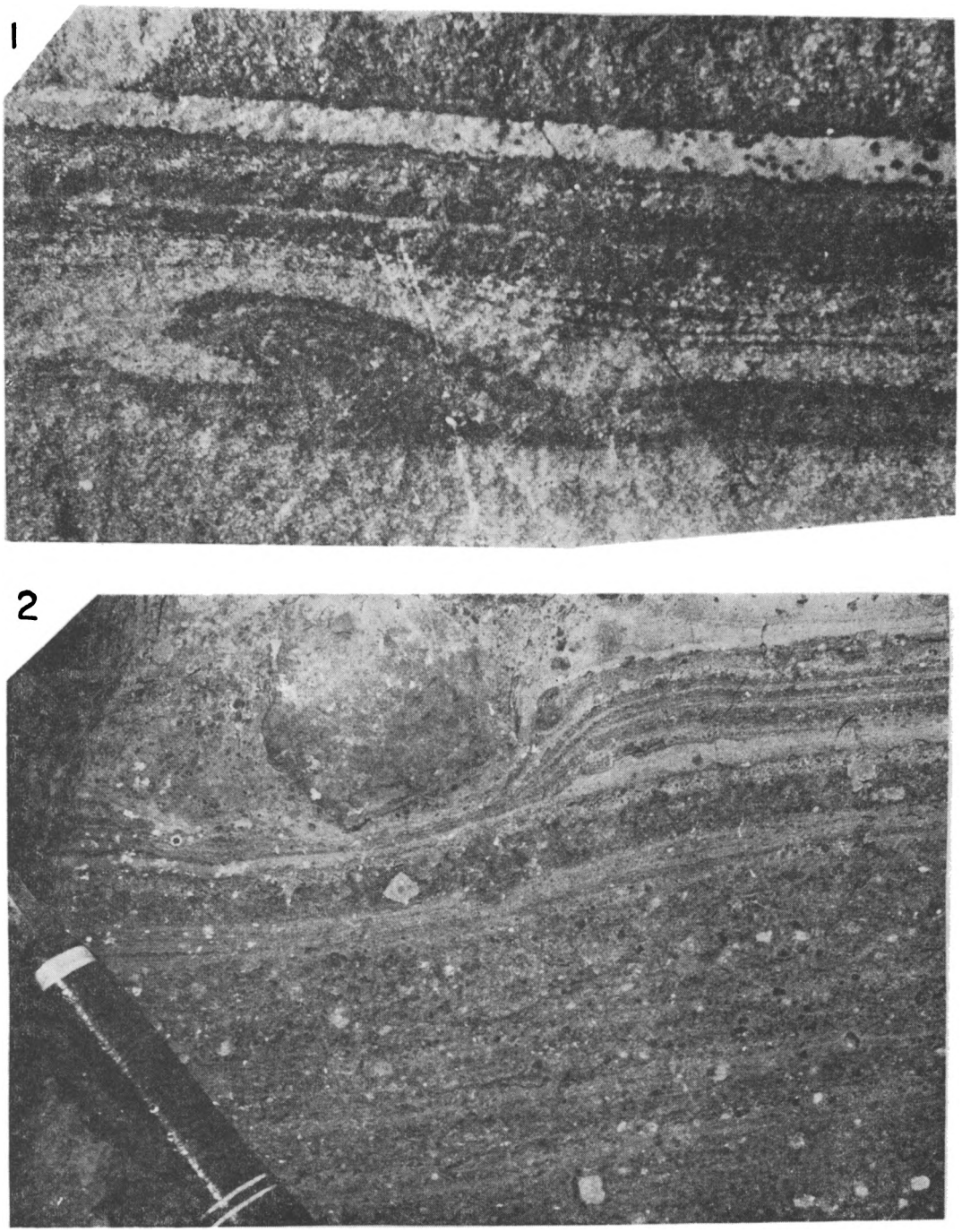


Plate I

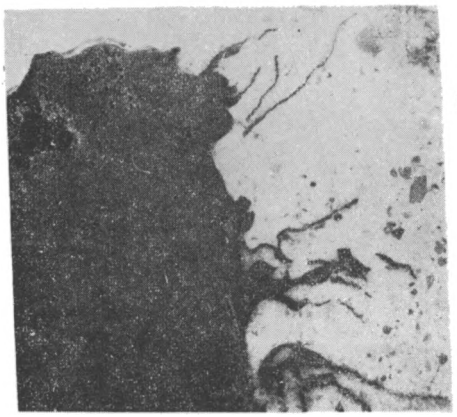
Fig. 1 El Puquén formation (Norian), south of El Puquen area. Flame in sandstones overlying dark plant-bearing shales. The flames indicate clearly a northward sense of sedimentation. (by CECIONI)

Fig. 2 La Caleta formation (? Carboniferous). Isolated angular pebble which apparently tumbled down as a " rain " on the unconsolidated very fine laminated limy-sandy sediment so that in sinking, the laminae were molded around it. This phenomenon suggests rafting, possibly by floating ice. (by CECIONI)

Loc. W 2 ?*Cardinia* cf. *L. listeri* (SOW.), abundant
(?) *Otapiria* cf. *O. ussuriensis* (VORONETZ)

While the questionable *Cardinia* has basal Jurassic affinities, the probable *Otapiria* appears to be closely related with the Lower/Middle Norian eastern Siberian *O. ussuriensis.* However, the genus *Otapiria*, previously unknown from the eastern Pacific realm, has a minimum range





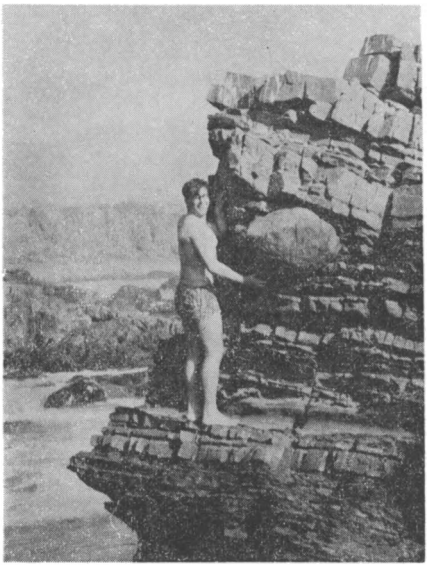


Plate II

Fig. 1a, b *Archaeocalamites goepperti* (ETT.) from the La Caleta formation (?Carboniferous). Fragment of tige with verticils; a) longitudinal section, ×5. b) transverse section, ×5. (by CECIONI)

Fig. 2 Basal flysch series in the Graywackes Member of the El Quereo formation. The well rounded large boulder apparently dropped onto the sea bottom, bent the unconsolidated beds, and was covered by modelling horizontal beds. Significantly, the boulder originated from an old flysch lithologicellar similar to upper Paleozoic beds south of Puerto Manso. The boulder might have been rifted by floating ice or tree roots. (by CECIONI)

from the Lower/Middle Norian to the Upper Hettangian. This fauna could well be of Rhaetian age as suggested by its stratigraphical position.

Jurassic

Los Molles Formation, main part: Approximately 50 m above the *?Cardinia-Otapiria* bed and 100 m above the unquestionably Upper Triassic *Arcestes-Cladiscites* bed, follows within the same Shaly Member the highly fossiliferous and relatively thin (21 m) *P. planorbis* Zone of the Hettangian.

The Hettangian sequence commences with a single bed crowded with crushed ammonites:

Loc. W 5 d *Psiloceras* (*Psiloceras*) cf. *P. planorbis* (SOW.)

12 m higher occur rather abundant but crushed ammonites:

Loc. W 5 e *Psiloceras* (*Psiloceras*) sp. / subsp. nov. (?) aff. *P. planorbis erugatum* (PHILL.), (?) *Entolium* sp.

5 m higher occur again some crushed ammonites:

Loc. W 5 c *Psiloceras* (*Psiloceras*) cf. *P. planorbis* (SOW.)

From 2.5 to 4.5 m higher occur in crowded beds crushed ammonites:

Loc. W 5 a, b *Psiloceras* (*Caloceras* ?) cf. *P. peruvianum* LANGE
rare: ? *Psiloceras* aff. *P.* reissi TILM., (?) *Entolium* sp.

Within this 21 m thick *P. planorbis* Zone which is directly overlain by the *S. angulata* Zone, three successive faunizones can probably be distinguished: characterized by (1) only smooth *P.* cf. *planorbis* (W 5 d), (2) smooth *P.* cf. *planorbis* and nucleoplicate *P.* cf. *planorbis erugatum*

(W 5 e, c), and (3) fully plicate *P.* cf. *peruvianum* (W 5 a, b). (1) and (2) can confidently be correlated with the *P. planorbis* Subzone and (3) with the *P. johnstoni* Subzone of northwestern Europe. Furthermore, (2) may be time equivalent with the "*P. plicatulus* beds" which have only very recently been distinguished in the upper *P. planorbis* Subzone of the Ardéche, France (ELMI and MOUTERDE, 1965).

The *peruvianum* beds probably intergrade through a 0.1–0.2 m range overlap with the superposed approximately 1.0 m thick highly fossiliferous interval containing:

Loc. W 6 *Schlotheimia* sp. ex gr. *S. angulata* (SCHLOTH.)

marking the base of the *S. angulata* Zone of unknown total thickness. From 3 to 5 m above the base occur thin conglomerates (loc. W 7) which contain deformed and worn, but not crushed, fragments of *Psiloceras* (*Caloceras*) cf. *P. peruvianum* LANGE. These are obviously derived from the *P. johnstoni* Subzone prior to its compaction.

Approximately 285 m above the *Schlotheimia* beds in the Sandy Shaly Member, a single arietitid nucleus was found which indicates Sinemurian (loc. W 8). The stratigraphic position of the Hettangian/Sinemurian boundary is therefore unknown.

Approximately 75 m higher is Fuenzalida's locality No. 6 (HF 6) which was reinvestigated by CECIONI and contains abundantly poorly preserved Polymorphitidae, including:

Loc. HF 6 *Polymorphites* sp. [coll. FUENZALIDA]

indicating Lower Pliensbachian. No younger fossils were found in the section, and the boundaries of the stage remain unknown.

Faunistic affinities and age correlations

The central Chilean faunal sequence and its correlation with the European zonal succession were discussed above and are summarized in *Table 1.* The fairly well known Hettangian

Table 1. Correlation of the principal marine faunas of late Triassic and early Jurassic age in the Pacific area with the European ammonoid zones. Knowledge of stratigraphical differentiation of the faunas is limited to the intervals separated by solid and dashed lines.

	European Zones		Central Chile (here)	N. Peru Kummel & Fuchs, 1963 Schindewolf, 1957	Nevada Muller & Ferguson, 1939 Hallam, 1965	New Zealand New Caledonia Marwick, 1953 ; Aviss, 1952
Pliensb.					(absent?)	
Sinemurian	U. jamesoni		Polymorphites	Microderoceras, Asteroceras Vermiceras		
	E. raricostatum				Eoderoceras	?
	O. oxynotum			Vermiceras, Asteroceras	Oxynoticeras Weyla alata	
	A. obtusum			Arnioceras		
	E. turneri					
	A. semicostatum		"Arietites"	Arnioceras	Arietites, Coroniceras, ? Arnioceras, Megarietites	Arnioceras
	A. bucklandi			Verm. cf. spiratissimum		
Hettangian	S. angulata		Schloth. ex. gr. angulata	Schloth. ang. postangulata	Schlotheimia gr. angulata	Schlotheimia ? Saxoceras Laqueoceras ? Discamphic. Waehneroceras Otap. marshalli
	P. planorbis	P. johnstoni	Psil. cf. peruvianum Psil. aff. reissi	Psil. peruvianum (?) Psil. reissi	Psil. cf. johnstoni Waehn. cf. megastoma ?Alsatites	Psiloceras [plicate]
		(P. plicatulus)	Psil. aff. planorbis erugatum			
		P. planorbis	Psil. cf. planorbis	Psil. planorbis tilmanni	Psil. cf. planorbis	?
Rhaet.	C. marshi		(?) Otapiria cf. ussuriensis ? Cardinia cf. listeri	?	Chor. marshi	Clavigera bisulcata Rastelligera elongata Otapiria dissimilis Rhaetavicula contorta Arcestes cf. rhaeticus
Norian	P. metternichi		?Arcestes, Cladiscites, Minetrigonia Oxytoma cf. inaequivalvis			Mon. salvata, M.rauthieri
	C. bicrenatus		Sandlingites spp.	Monotis subcircularis Sandlingites	Mon. subcircularis	Mon. ochotica A.(Sienarcestes) arnouldi
	H. paulckei					

ammonoid faunas first recognized in Chile by G. CECIONI (1960) are probably identical on the specific and possibly subspecific level with their equivalents in northern Peru. The Peruvian faunas, recently revised by SCHINDEWOLF (1957) are better preserved but less known with regard to stratigraphical succession (In *Table 1*, knowledge of stratigraphical differentiation is limited to intervals separated by horizontal lines). Both subzones of the *P. planorbis* Zone appear to be represented and are overlain by the *S. angulata* Zone. Beneath, the Upper Norian is well indicated by *Monotis subcircularis* GABB (WESTERMANN, 1966) and, again, '*Sandlingites*.' However, Rhaetian does not seem to be represented by marine beds.
The Andean Hettangian ammonoid faunas closely resemble their northwestern European equivalents with respect to specific affinities and succession. Most common Andean species can probably be regarded as mere geographical subspecies of their European relatives. The Andean forms are markedly distinguished only by the somewhat more narrowly umbilicate whorls. It appears premature to guess migrational-evolutionary patterns of these almost cosmopolitan genera and possibly, species.
An unusually complete Triassic/Jurassic marine transition with perhaps the best representation of species diagnostic of the European Zones is developed in west-central Nevada (MULLER and FERGUSON, 1939). A slightly revised account of the fauna and zonal sequence has recently been given by HALLAM (1965); however, this important fauna has not yet been described. Above Upper Norian with *Monotis subcircularis*, marine Rhaetian is established by *Choristoceras marshi*, index species of the single Rhaetian ammonoid Zone. In the Hettangian, the *P. planorbis* and *P. johnstoni* subzones as well as the *S. angulata* Zone appear to be represented. This is followed by Lower and Upper Sinemurian which, in turn, is probably directly overlain by Toarcian.
Elsewhere in North America where Hettangian is indicated by plicate *Psiloceras* and, partly also by *Schlotheimia* as in British Columbia (FREBOLD, 1951) and Yukon (LEES, 1934), Rhaetian is either absent or unknown. However, TUCHKOV (1964) has recently suggested that the upper part of the Lewes River group in Yukon and the Sutton member of the Vancouver group on Vancouver Island, B. C. are Rhaetian rather than Norian in age as previously suggested (TOZER, 1958; MCLEARN, 1953). The only well known British Columbian species, *Psiloceras* (*Caloceras*) *canadense* FREBOLD, shows affinities to the Andean *P.* (*C.*) *reissi* TILMANN.
In the Western Pacific realm, probably the most complete marine Upper Triassic/Lower Jurassic sequence is developed in New Zealand (MARWICK, 1953) and, especially, in New Caledonia (AVIAS, 1952). The presence of thick, eugeosynclinal Rhaetian has been fairly well established for most of the " Otapirian ". The sequence overlies latest Norian beds with the smooth *Monotis calvata* and *M. routhieri* and very probably contains *Rhaetavicula contorta* (PORTL.) (C. A. FLEMING, priv. com.). The endemic brachiopod *Clavigera bisulcata* HECTOR is common to the " Otapirian " of both island groups. The " Otapirian " is overlain by thick "Aratauran " with plicate *Psiloceras* of the (upper ?) *P. planorbis* Zone and, above, *Laquaeoceras*, *Waehneroceras*, *Schlotheimia* [+ ? *Saxoceras*, ? *Discamphiceras*] of the (lower and upper) *S. angulata* Zone. Smooth *Psiloceras*, indicative of the *P. planorbis* Subzone have not been reported.
In the Japanese islands, terrestrial facies develops in the upper-most Norian *Monotis zabaikalica* Zone. No marine Rhaetian is known and the Jurassic is usually in fault contact (BANDO, 1964). Lowermost Jurassic beds probably of the Middle Hettangian are present on northeastern Honshu and contain (?) *Alsatites* (*Yebisites*) *onoderai* MATSUMOTO. This sequence commences with a basal conglomerate (MATSUMOTO, priv. com.).
A fossiliferous marine Triassic/Jurassic transition has recently been recorded from the north-

eastern coast of the Sea of Okhotsk, USSR, by TUCHKOV (1964). Upper Norian with *Monotis ochotica* is overlain by a 700–800 m sedimentary sequence bearing a rich brachiopod and pelecypod fauna which includes many characteristical Rhaetian species as well as *Oxytoma inaequivalvis* (SOW.) which makes its first occurrence in the Rhaetian, two ammonoid species previously considered late Norian, and long ranging species. This well established Rhaetian sequence is overlain by the *P. planorbis* Zone of the Hettangian with ' *Psiloceras* spp. including *P.* aff. *planorbis* '. This sequence is said to be developed throughout the eastern part of the Kolyma River basin and the adjacent area of the Okhotsk slope.

The Hettangian ammonoids of central Chile appear to be identical with those of Peru, as stated above. These Andean faunas show, in turn, rather close affinities to their generally poorly known North American and especially to their European counterparts ; i.e. the Andean faunas appear to be somewhat closer related to the European, especially northwestern European, than to the North American Cordilleran faunas. From what little there is known about the Western Pacific Hettangian ammonoid faunas, one can probably assume that they are not closely related to the Andean faunas and perhaps, rather Mediterranean-Tethian in character. However, since most Hettangian genera are probably cosmopolitan, such conclusions have to be based on studies on the species level, which have so far been almost impossible in the western Pacific area because of poor preservation.

Similar faunal relationships were suggested for the early Liassic by AVIAS (1957), especially with regard to close affinities between the Andean and European faunas.

Fossil descriptions

Family CLYDONITIDAE MOJSISOVICS, 1879

' *Sandlingites* ' ex gr. ' *S* '. *lissoni* et *sutanensis* (JAW.)

FUENZALIDA (1938, p. 95) collected and briefly described " *Nevadites* sp." from his fossil locality No. 2 which he said resembles very well the Norian " *Nevadites* " from Peru. " *N.*" *lissoni* and " *N.*" *sutanensis* JAWORSKI spp. originated in the rich late Norian Peruvian fauna with *Rhabdoceras*, *Placites*, *Metasibirites*, *Arcestes* and *Monotis subcircularis* (=" *Entomonotis ochotica* " auct.) and has been placed into *Sandlingites* by KUMMEL and FUCHS (1953, p. 103). However, also this classification appears unsatisfactory (SILBERLING, priv. comm., 1966). In Colombia, the ' *Sandlingites* ' fauna directly underlies the *Monotis* beds (op. cit.). There can be little doubt about the correct comparison by FUENZALIDA of these peculiar Norian forms. No new specimens could be found in spite of intensive search.

Family PTYCHITIDAE MOJSISOVICS, 1882

(?) *Sturia* sp. (**Pl. III, Fig. 1**)

A large whorl fragment from the *Daonella* beds of the Quereo section is tentatively assigned to the genus *Sturia* which has a known Anisian-Karnian range. *Daonella* ex gr. *D. dubia* (GABB) is present on the same slab.

The almost flat, probably somewhat crushed whorl side of 120 mm height has widely spaced blunt spiralic ridges which grade thinner externward and are interspaced with single thin striae.

The specimen had previously been correctly identified by Raul VICENCIO, Universidad de

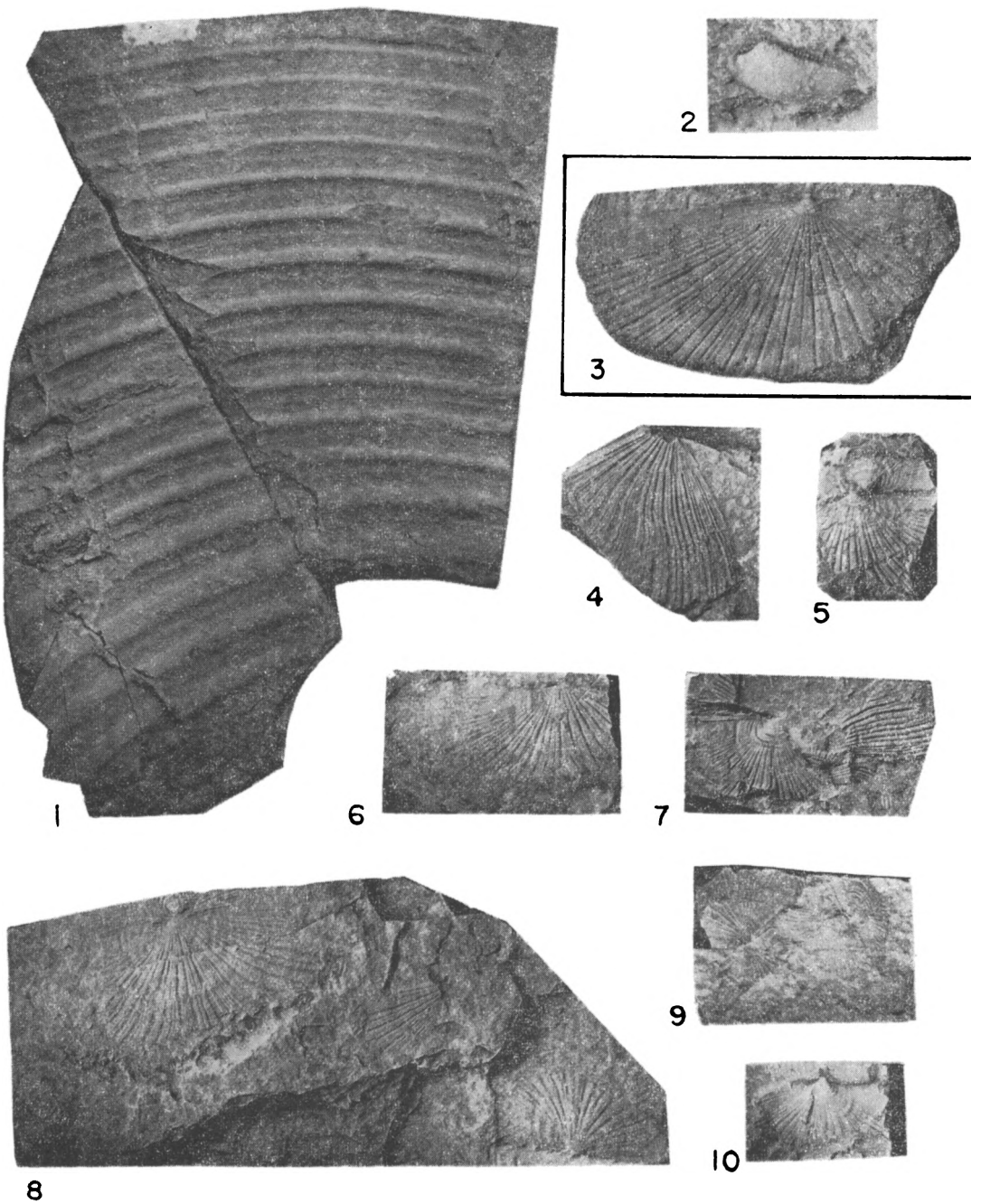


Plate III (All figures natural size, except where indicated)

Fig. 1 (?) *Sturia* sp., large whorl fragment. Upper Anisian *Daonella* beds of the Quereo section. Museo Nac. Hist. Nat. Santiago, cat. on. 10.001

Fig. 2 *Palaeoneilo* cf. *P. elliptica* (GOLDF.). Internal mold of left valve. From loose block, 50-100 mm below upper Anisian *Daonella* beds of the Quereo section. ×2. Dept. Geol. McMaster Univ., cat. no. Tr. 409

Fig. 3 *Daonella dubia* (GABB). "Topotype" from the Upper Anisian of the Humboldt Range, Nevada. Plastotype to J. P. Smith, 1914, pl. 49, Fig. 11. For comparison with the Chilean form.

Figs. 4-10 *Daonella dubia* (GABB). Mostly incomplete and crushed mature and immature valves (fig. 4 distorted). *Daonella* beds (W 7) of the Quereo section, associated with (?) *Sturia* and (?) *Gymnites*. Figs. 4, 6-9, Dept. Geol. McMaster Univ., cat. no. Tr. 404-408; Figs. 5, 10, Museo Nac. Hist. Nat. Santiago, cat. no. 10.002, 10.003

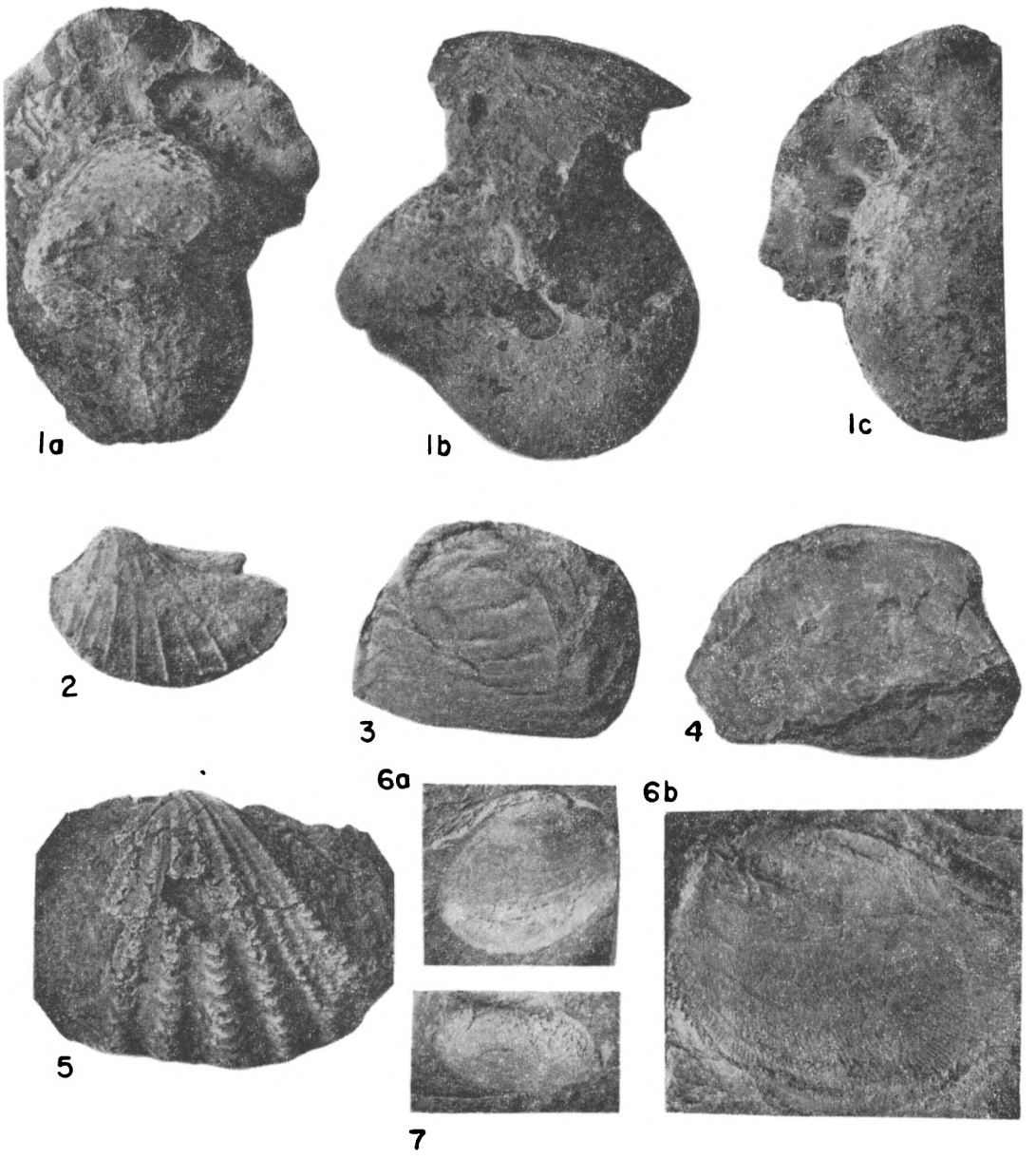


Plate IV (All figures natural size, except where indicated)

Fig. 1a-c *Aycestes* (? *Arcestes*) sp. indet., cf. *A. andersoni* (HYATT & SMITH). Incomplete phragmocone, right side damaged. U. Norian/Rhaetian *Arcestes-Cladiscites* bed (HF 4) of the Los Molles section. Dept. Geol. McMaster Univ., cat. no. Tr. 410.

Fig. 2 *Oxytoma* cf. *O. inaequivalvis* (SOW). Slightly dorsoventrally distorted left valve. U. Norian/Rhaetian *Arcestes-Cladiscites* bed (HF 4) of the Los Molles section. Museo Nac. Hist. Nat. Santiago, cat. no. 10.004

Figs. 3-4 ? *Cardinia* cf. *C. listeri* (SOW.). Somewhat distorted incomplete internal molds of left and right valves. Rhaetian/?Hettangian '*Cardinia*' bed (W 2) of the Los Molles section, associated with (?) *Otapiria*, about 50 m above the *Arcestes-Cladiscites* bed (HF 4) and 50 m below the *Psiloceras* beds. Dept. Geol. McMaster Univ., cat. no. Tr. 413, 414.

Fig. 5 (?) *Minetrigonia* sp. nov. aff. *M. otamitensis* (TRECH.). Incomplete left valve. U. Norian/Rhaetian *Arcestes-Cladiscites* bed (HF 4) of the Los Molles section. Museo Nac. Hist. Nat. Santiago, cat. no. 10.005

Figs. 6a-b, 7 (?) *Otapiria* cf. *O. ussuriensis* (VOR.). Almost complete right valve with internal (6a) and external mold (6b×2), and a dorso-ventrally distorted left valve (7). Rhaetian/?Hettangian '*Cardinia*' bed (W 2) of the Los Molles section (see figs. 3, 4). Dept. Geol. McMaster Univ. cat. no. Tr. 411, 412.

Chile. The genus has apparently not yet been reported from the Americas.
Deposited at Museo Hist. Nat. Santiago, Cat. No. 10,001.

Family Arcestidae Mojsisovics, 1875

Arcestes (?*Arcestes*) sp. indet., cf. *A. andersoni* Hyatt & Smith, 1905 (**Pl. IV, Figs. 1a–c**)

One large incomplete phragmocone and one fragment were collected from the *Arcestes-Cladiscites* bed, Fuenzalida's fossil locality No. 4 at " Corral Barrancas ". Fuenzalida's specimens were lost during the war in Germany.
The phragmocone is globose and narrowly umbilicate (D 65 mm, W ca. 85%, H 44%, U ca. 10%); neither costae nor constrictions are visible on the preserved parts. Septum and suture are typically ammonitic with 5 major external elements grading in size from the " ventre " to the umbilical seam.
This form is best referred to *Arcestes* s. str. with a Karnian-Rhaetic range and compares rather closely with *A. andersoni* Hyatt and Smith from the Upper Norian of Nevada. *A. rhaeticus* Clark (1888) from the Rhaetian of the Tyrolian Alps, which has tentatively been identified from the Rhaetian of New Zealand (Trechmann, 1918, p. 182, pl. 17, Fig. 1) is larger umbilicate (U ca. 20%). *A.* (*Stenarcestes*) *arnouldi* (Avias) from the Norian of New Caledonia (Avias, 1952, pl. 25, Fig. 1) is more compressed and obvolute. It is of interest that *Arcestes* cf. *biceps* Mojs. originally described from the Upper Norian of the Alps, has recently been recorded from the Rhaetian of the Okhotsk Sea (Tuchkov, 1964).
Deposited at Dept. Geology, McMaster Univ., Cat. No. Tr 410

Cladiscites sp.

Fuenzalida (1938, p. 82, Pl. 5, Fig. 3) collected and described *Cladiscites* aff. *tornatus* (Bronn) from his fossil locality No. 4 (HF 4) at " Corral Barrancas ", together with *Arcestes* and other Upper Triassic fossils. Like his other ammonoid specimens, however, it was lost during the war in Germany.

Family Psiloceratidae Hyatt, 1867

Psiloceras (*Psiloceras*) cf. *P. planorbis* (J. de C. Sowerby) 1824 (**Pl. V, Figs. 1–7**)

The lectotype of *P. planorbis*, type species of *Psiloceras*, was refigured by Arkell (1956, Pl. 31, Fig. 7). The species is relatively narrow umbilicate and smooth. It may or may not be conspecific with the more evolute *P. psilonotum laeve* (Quenstedt) 1849; however, Quenstedt's trinomial name is a junior objective synonym of *P. sampsoni* (Bean) 1843, and possibly also to *P. erugatum* (Phill.) 1829. The poor, crushed, preservation of the lectotype (and cotypes) of *P. planorbis* has led to much confusion and discussion (see Lange, 1941, p. 74; Donnovan, 1952, p. 634–37). *P. plicatulum* (Quenstedt), a common associate of *P. planorbis* in Europe, is distinguished only by weak but marked plication, may be restricted to the upper part of the *P. planorbis* range zone in England (Donnovan, loc. cit.) and marks a distinct horizon of the upper *P. planorbis* subzone in the exceptionally thick and complete Hettangian of the Ardèche (Elmi and Mouterde, 1965, pp. 149–152).
The only satisfactory described occurrence of smooth *Psiloceras* in the Pacific realm is in northern Peru. The " *P. planorbis* Sow." of Tilmann (1917, p. 648, Pl. 22, Fig. 1) was

distinguished as *P. tilmanni* LANGE (1925, p. 974) on the only grounds that it is narrower umbilicate than *P. psilonotum*, although the similarity to *P. planorbis* was admitted. SCHINDEWOLF (1957, p. 154) reinvestigated the specimens and included the Peruvian form as a subspecies in *P. planorbis*; the sole distinction from the restricted species is in the whorl section, i.e. the more broadly rounded externside and the converging flanks. Septal suture and umbilical width (30–40%) do not differ markedly. The stratigraphical position of the Peruvian *P. planorbis tilmanni* with respect to *Schlotheimia* which occurs in the same area is not known except that it is different (loc. cit.).

Supposed *Psiloceras planorbis* was recorded from the basal Jurassic of Nevada (MULLER and FERGUSON, 1939). The cf. *P. erugatus* (BEAN) from the southern Yukon (LEES, 1934, p. 46, Pl. 6, Figs. 1–4) has fold-like plicae on the inner whorls and its exact stratigraphic position appears to be unknown. The true *P. erugatum* has more compressed and larger umbilicate whorls (see below).

Material. Numerous crushed and mostly incomplete specimens from fossil bed 5d, the lowest ammonoid bearing horizon of the Los Molles Jurassic. Several specimens from fossil bed 5c.

Description. In spite of the poor state of preservation, it can be concluded with some confidence that the whole assemblage belongs to a single moderately involute (U–30–40%) and totally smooth species. The diameter varies between 40 and 60 mm, probably inclusive of the body chamber. The juvenile whorls up to about 15 mm diameter are larger umbilicate and probably subcircular in section. Ornament is regularly absent on all growth stages. Although the septal suture is not preserved, this form is clearly distinct from the much wider umbilicate *Psilophyllites*.

The *P. planorbis* bed is, in turn, overlain by beds with *P.* (*?Caloceras*) and beds with *Schlotheimia* and thus constitutes the first evidence for the development of the *P. planorbis* Subzone for the Americas.

Psiloceras (*Psiloceras*) sp./subsp. nov. (?) aff. *P. planorbis erugatum* (PHILL.) 1829

Pl. V, Figs. 9—10

The European *P. erugatum* is distinguished from *P. planorbis* and its close and doubtfully distinct *P. sampsoni* (BEAN) (=*P. psilonotum* auct.) apparently only in the costation of the innermost whorls. It is therefore here tentatively regarded as a subspecies of *P. planorbis*. *P. plicatulum* (QUENSTEDT) is doubtfully specifically distinct from *P. planorbis* with which it is always associated, by the blunt plication of usually at least the whole phragmocone. All have compressed whorls and the plicated forms are widely umbilicate. The first occurrence of *P. plicatulum* may be slightly higher than that of the smooth *P. planorbis* (DONNOVAN, 1952, p. 634; LANGE, 1941, chart II opposite p. 52) while the exact stratigraphic position of *P. erugatum* within the *planorbis* subzone appears to be unknown.

The " cf. *Psiloceras erugatus* (BEAN) " of LEES (1934, p. 46, Pl. 6, Figs. 1–4) from the southern Yukon is more narrowly umbilicate than the European form and has circular inner whorls.

Material. Several crushed specimens from fossil bed 5e, 12 m above the *P.* cf. *planorbis* bed, Los Molles.

Description. The specimens vary in diameter from 35 to 50 mm and are probably somewhat wider umbilicate than the *P.* cf. *planorbis* from bed 5d. All have 12–15 plications on the innermost whorls up to 15–30 mm diameter while the outer whorls are smooth. Part of the septal suture is preserved on a large whorl fragment of 13 mm whorl height. The lateral saddle

has moderately deep primary and small shallow secondary incisions, as in typical *Psiloceras*. The specimens resemble closely *P. planorbis erugatum* (BEAN) as refigured by BUCKMAN (1921, Pl. 223), which is plicate up to a diameter of only about 10 mm. The closest ally may be the cf. *P. erugatum* from the southern Yukon which is slightly stronger plicate and narrower umbilicate. Exact comparison of the crushed Chilean specimens is, however, impossible.

Psiloceras (*Caloceras*?) cf. *P. peruvianum* LANGE, 1941 (**Pl. VI, Fig. 1–6**)

The type-species of the subgenus *Caloceras*, *P. torus* (ORB.) 1842, has often been regarded as questionably conspecific with the poorly known *P. johnstoni* (SOW.) 1825; yet the former name was upheld because the latter may be regarded as *nomen dubium* (LANGE, 1941, p. 91). However, *P. johnstoni* was usually distinguished in England based on attributed sharper and denser juvenile costation and different stratigraphic range (DONNOVAN, 1952, p. 637). DONNOVAN furthermore distinguishes the somewhat sharper ribbed *P. belcheri* (SIMPSON) in which he includes the common "*P. torus*" described by LANGE (op. cit.) from northwest Germany. To these three supposed species from the *P. johnstoni* Subzone of the *P. planorbis* Zone, Lange added several more names, including *P. cheilon*. This rare form appears to differ only in the smaller size and in the inflated body chamber and may be the microconch if the proposed absence of intergrading forms is correct. More densely ribbed species range upward into the lower *Schlotheimia angulata* Zone (DONNOVAN, loc. cit.).

In the Pacific realm, *P.* (*Caloceras*) has been described from Canada, Peru and, probably, Central Chile. The small rather narrowly umbilicate "*P. johnstoni* SOW." described by TILMANN (1917, p. 653, Text-fig. 2, Pl. 22, Figs. 2–3) from northern Peru was distinguished as *P.* (*Caloceras*) *peruvianum* LANGE (1941, p. 96) based on the supposedly different septal suture. According to SCHINDEWOLF (1957, p. 154), who reinvestigated the Peruvian form, the suture resembles closely that of *P. torus* while the coiling is as in *P. cheilon* LANGE. However, the whorl section is more rounded. The Peruvian form was consequently included in *P. cheilon* as a subspecies. Because of our incomplete knowledge of *P. cheilon* which may be only a variant or dimorph of the associated common "*P. torus*", *P. belcheri* according to DONNOVAN, and because the Peruvian form is also poorly known, *P. peruvianum* LANGE is here tentatively upheld.

Psiloceras reissi TILMANN (1917, p. 21, Figs. 4, 4a) from northern Peru is another poorly known probable *Caloceras* which is distinguished in the exceptionally narrow umbilicus (ca. 30%) and long projected costae. The simple septal suture is a strong argument against the placement in the subgenus *Discamphiceras* by CECIONI (1960).

From central Chile, 15 km south of Los Bombas in Atacama, CECIONI (1960, p. 11, Pl. 1)

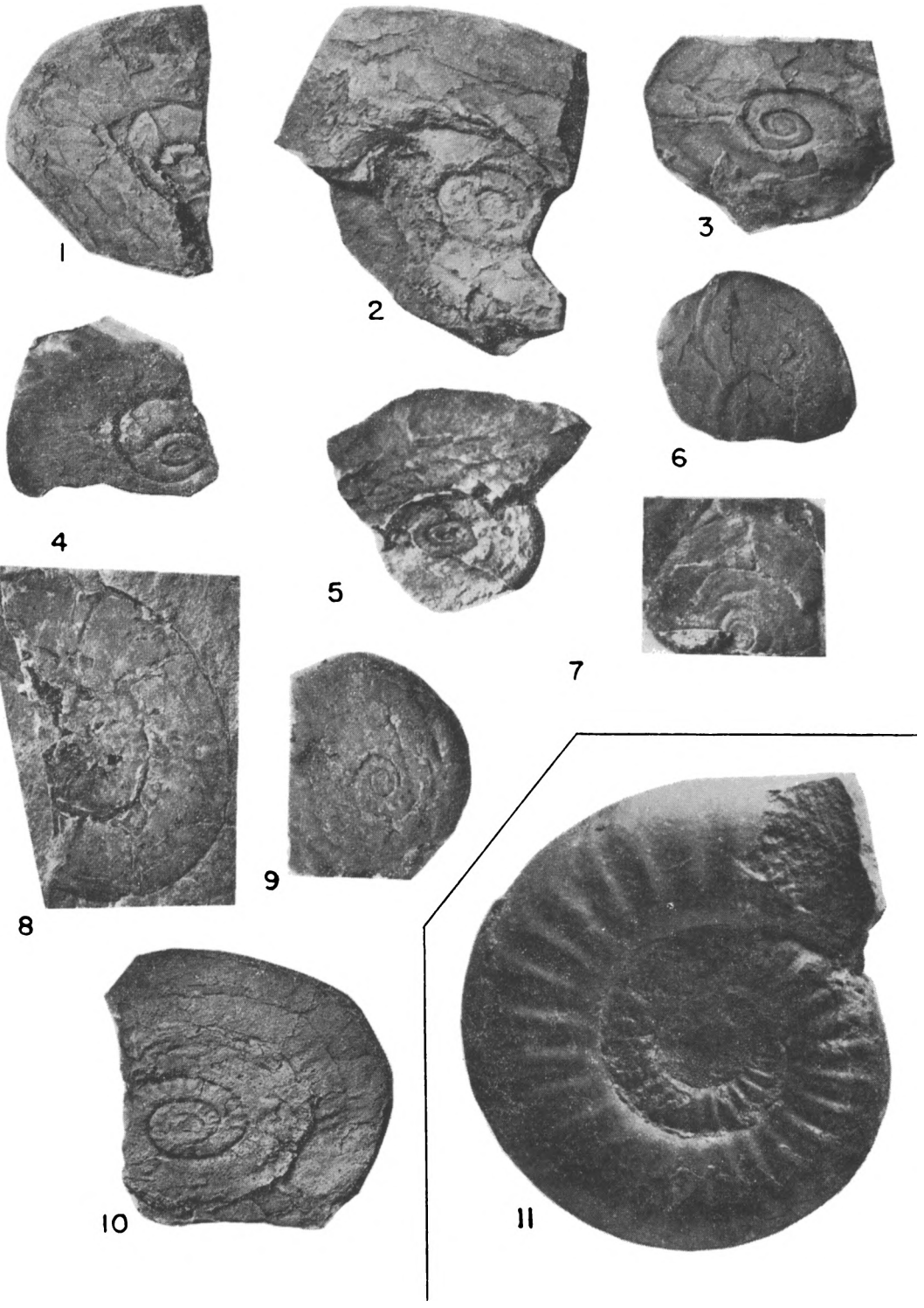
Plate V (All figures natural size)

Figs. 1-7 *Psiloceras* (*Psiloceras*) cf. *P. planorbis* (SOW.). Somewhat distorted incomplete internal molds and rubber casts (figs. 3, 4, 6, 7). All from *Psiloceras* bed (W 5d) of the Los Molles section, except for fig. 7 which is from *Psiloceras* bed (W 5c). *P. planorbis* subzone, Hettangian, Dept. Geol. McMaster Univ., cat. no. J. 1164–1170.

Fig. 8 *Psiloceras* sp. Crushed costate specimen with smooth body chamber. '*Caloceras*' bed (W 5a) of the Los Molles section. Dept. Geol. McMaster Univ., cat. no. J. 116.

Figs. 9-10 *Psiloceras* (*Psiloceras*) sp./subsp. nov. (?) aff. *P. planorbis erugatum* (PHILL.). Rubber casts of crushed and somewhat distorted specimens. *Psiloceras* bed (W 5e), 12 m above the *P.* cf. *planorbis* bed of the Los Molles section. *P. planorbis* Subzone, Lower Hettangian. Dept. Geol. McMaster Univ., cat. no. J. 1172–1173.

Fig. 11 *Psiloceras* (? *Caloceras*) cf. *P. peruvianum* (LANGE). *P. planorbis* Zone of Las Bombas area, Atacama. Reproduction of Cecioni's (1960, pl. 1) original photograph of "*P.* (*Discamphiceras*) *pleuronotum* (COCCHI)". Dept. Geol. Univ. Chile.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has recently described a single specimen of *Psiloceras* which he referred to *P.* (*Discamphiceras*) *pleuronotum* (CANAVARI) [unpublished manuscript name of Cocchi]. As seen from the photographic figure, this is a widely umbilicate (43%), throughout coarsely costate form which differs strongly from the narrowly umbilicate and weakly costate *Discamphiceras*. If the septal suture is rather complicated and retracted like in *D. pleuronotum* this could be a *P.* (*Franziceras*). However, *Franziceras* BUCKMAN appears to be known only in the type specimen of *P.* (*F.*) *ruidum* BUCKMAN, and certainly cannot be distinguished from *P.* (*Caloceras*) because of its slightly stouter whorls. Cecioni's specimen agrees otherwise well with *P. peruvianum* and with the common Los Molles form here described. The "*P.* (*Discamphiceras*) *reissi*" described by CECIONI (op. cit.) from the same locality agrees well with *P.* (*Caloceras*) *reissi* from Peru. Weakly continuous costae are known also from *P.* (*Caloceras*) *canadense* FREBOLD.

From British Columbia, FREBOLD (1951, p. 3; 1964, p. 6) described and profusely illustrated *P.* (*Caloceras*) *canadense*. This is a narrowly umbilicate, coarsely costate large form which much resembles *P. reissi*, as already noticed by FREBOLD. As in Peru, the exact stratigraphic relationship to *Schlotheimia* also present in the area, is unknown.

Material. Numerous (150–200) crushed specimens from beds 5b and 5a of the Los Molles section, directly underlying the *Schlotheimia* beds. Also (c. 100) from locality JCS-56, 1.2 km upstream Estero el Chivato (Coll. CAÑAS).

Description. The diameter of the few complete specimens with aperture varies from 60 to 90 mm. The umbilical width can be roughly estimated as relatively small in the inner whorls (between 25 and 35%) up to 25–40 mm diameter, and increasingly larger in the outer one or two whorls. The whorl section cannot be determined but it appears that the externside was rounded. The simple aperture is strongly obliquely inclined.

The costation consists of simple rectiradiate, sometimes slightly retro—or prosoradiate, costae, 27–32 on the inner whorls, increasing to 32–40 on the last whorl of large specimens. The costae are long and die out rather suddenly, sometimes with short weak projection. All specimens are costate to at least 50–60 mm diameter except for a single one which becomes smooth at 40 mm diameter. Septum and suture are not preserved.

Among the many *P.* (*Caloceras*?) cf. *peruvianum* in the Cañas' collection from locality JCS-56, which lies in strike with the coastal *Caloceras* beds, is a single distorted but not crushed probably conspecific specimen (**Pl. II, Fig. 6**).

Psiloceras (*Caloceras*) cf. *P. peruvianum* LANGE, 1941 (**Pl. VI, Figs. 7–8**)

Material. More than 10 fragmentary somewhat distorted specimens came from thin conglomerates of fossil bed 7, in gray siltstones superposed on the *Schlotheimia* beds. The specimens are corroded and obviously reworked, yet their preservation is superior to the crushed fauna from the *Caloceras* beds described above.

Description. The largest specimen measures 50 mm in diameter. The whorl section is slightly compressed oval with rather rounded externside. The umbilical width is moderately large with 1/3–2/5 whorl height overlap, at least of the inner whorls. The rectiradiate costae have the shape of strong plications, at least on the mature whorls above 15–20 mm diameter, and die out at 3/5–2/3 whorl height. The septal suture is simple with short lobes, which distinguishes *P.* (*Caloceras*) from *P.* (*Franziceras*).

Comparison. This form agrees well with the small incomplete holotype of *P. peruvianum* LANGE (TILMANN, Pl. 22, Figs. 2, 3) with which the small "*Psiloceras plicatulum* Qu." of LISSON (1911, Pl. 2) may be identical. The "*P.* (*Discamphiceras*) *pleuronotum*" of CECIOONI

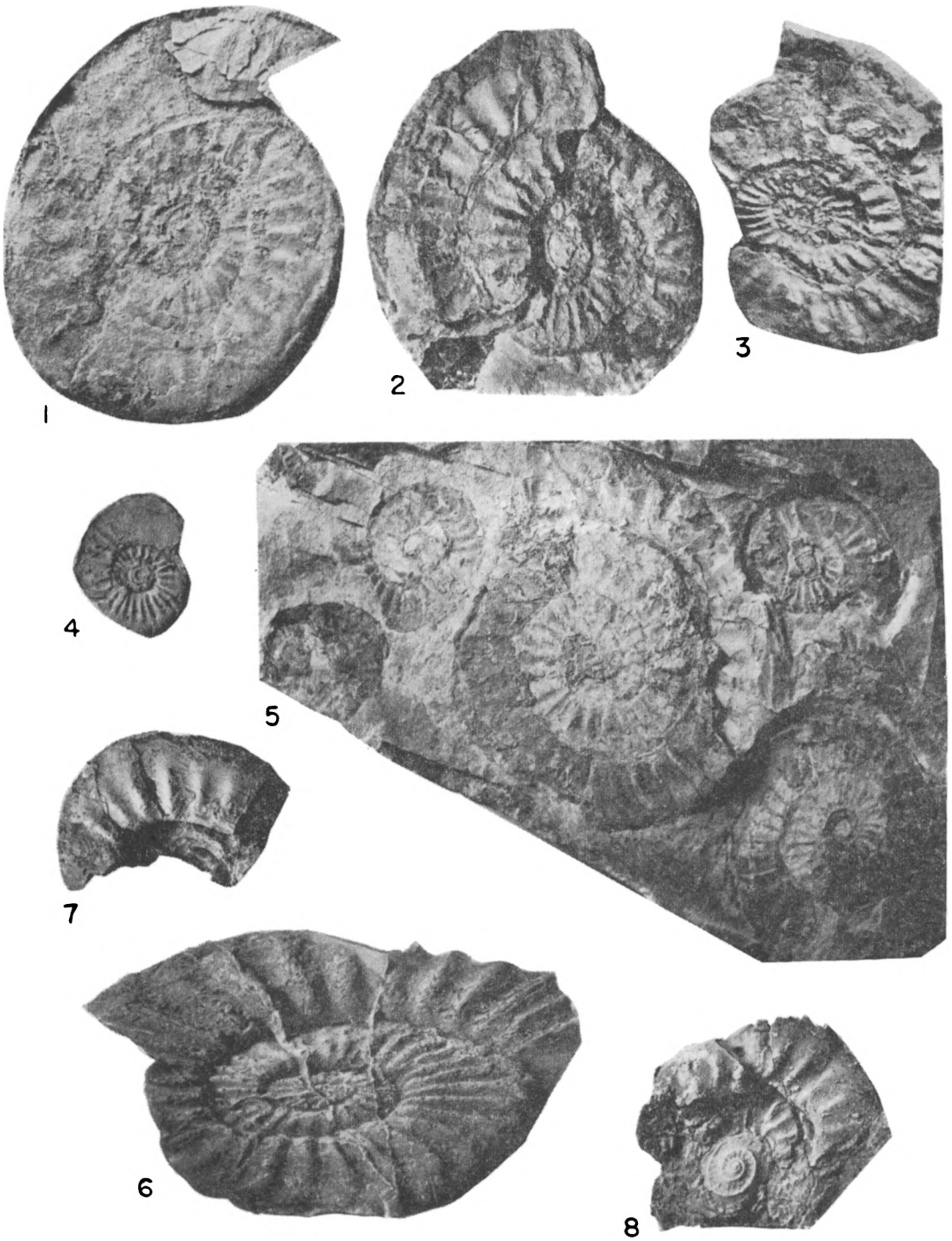

Plate VI (All figures natural size, except where indicated)

Figs. 1-6 *Psiloceras* (? *Caloceras*) cf. *P. peruvianum* LANGE. Crushed specimens, partly complete with aperture (fig. 1, 5 centre ×0.7); the inner whorl (fig. 4) and the strongly distorted, probably conspecific specimen (fig. 6) from rubber casts. From the '*Caloceras*' beds (W 5a and W 5b) of the Los Molles section, except for fig. 6 which is from the '*Caloceras*' bed (JCS-56) of the proximate Estero El Chivato; *P. johnstoni* Subzone of the *P. Planorbis* Zone, Hettangian. Figs. 1–5. Dept. Geol. McMaster Univ., cat. no. J. 1174–1178. Fig. 6, Museo Nac. Hist. Nat. Santiago, cat. no. 10.006.

Figs. 7-8 *Psiloceras* (*Caloceras*) cf. *P. peruvianum* LANGE. Slightly distorted reworked fragments from conglomerate in fossil bed 7 above the *Schlotheimia* beds, Los Molles section, Dept. Geol. McMaster Univ., cat. no. J. 1179–1180.

from the same province appears identical in coiling and costation. The closest foreign ally is probably *P. canadense* FREBOLD from British Columbia.

?*Psiloceras* (?*Caloceras*) aff. *P. reissi* TILMANN

There are 3 or 4 small crushed specimens from the *Caloceras* bed 5b which are much more involute and more finely ribbed than the abundantly associated *P.* cf. *peruvianum*. They could also be *P.* (*Discamphiceras*), yet their poor state of preservation does not permit identification.

Family SCHLOTHEIMIIDAE SPATH, 1923

Schlotheimia (*Schlotheimia*) sp. ex gr. *S. angulata* (SCHLOTH.) 1820 (Pl. VII, Figs. 3, 4)

The cosmopolitan *Schlotheimia angulata*—group has been described from around the Pacific: *S.* cf. *angulata* from New Caledonia (AVIAS, 1953, Pl. 18, Figs. 9), the poorly known *S. jimboi* YOKOYAMA from Japan (YOKOYAMA, 1904, Pl. 1, Fig. 6), *S.* cf. *acuticostata* from British Columbia (FREBOLD, 1951, Pl. 4, Figs. 1a–c), and *S. postangulata* LANGE from Peru (TILMANN, 1917, p. 669).

The Peruvian form, from the famous Utcubamba section, resembles *S. angulata* closely except for slightly different whorl section which is oval rather than trapezoidal. It was therefore identified with the somewhat younger *S. postangulata* LANGE (SCHINDEWOLF, 1957, p. 669) which may, however, better be distinguished only as a chronological subspecies of *S. angulata*. The exact stratigraphical position of the Peruvian *Schlotheimia* is unknown.

Material. A large number of crushed specimens from bed 6, the *Schlotheimia* bed of the Los Molles section, which directly overlies the '*Caloceras*' beds.

Description. Most specimens are 30–40 (45) mm in diameter. The umbilical width is moderate. The whorl section is unknown. The simple costae are strong, rather densely spaced (about 40 on the last whorl) and strongly projected. They are interrupted or build chevrons of much reduced strength on the single preserved externside and comprise approximately a right angle. Septum and suture are unknown.

In no recognizable feature is this poorly known form distinct from *S. angulata*, to which species it is certainly closely allied. The *S. angulata* Zone s.l. of the upper Hettangian is therefore clearly indicated.

Family ARIETITIDAE HYATT, 1874

A small inner whorl or juvenile specimen from bed 8, approximately 110 m above the *Schlotheimia* beds, can only tentatively be referred to this family of the Sinemurian.

Family POLYMORPHITIDAE HAUG, 1887

Polymorphites sp. (Pl. VII, Fig. 2a, b)

Polymorphites and its allied genera *Uptonia*, *Platypleuroceras*, *Jamesonites* and *Peripleuroceras* are all restricted to the *U. jamesoni* Zone of the Lower Pliensbachian. In particular the first two named genera appear morphologically poorly separated on the base of the fine ventrolateral tubercles.

Material. Both fragmentary specimens collected in 1936 at " fossil point 6 " and figured by

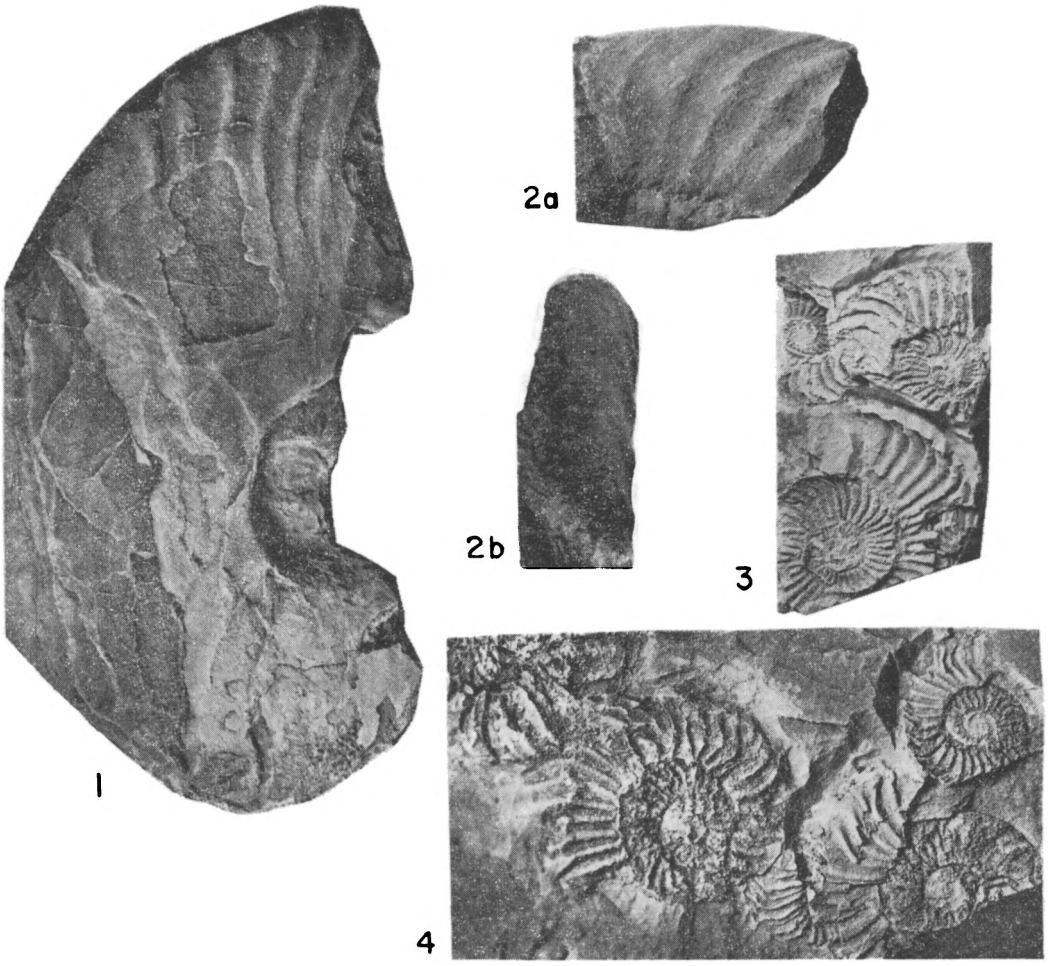

Plate VII (All figures natural size)

Fig. 1 *Juraphyllites* cf. *J. diopsis* (GEMM.). Somewhat distorted incomplete body chamber and part of phragmocone. Jurassic Los Molles section, exact stratigraphical position unknown. Museo Nac. Hist. Santiago, cat. no. 10.007.

Fig. 2a-b *Polymorphites* sp. Newly prepared fragment from Fuenzalida's "fossil point 6" (HF 6) of the Los Molles section, originally figured as unidentified ammonite (Fuenzalida, 1938, p. 85, pl. 5, fig. 2). *U. jamesoni* Zone, Pliensbachian. Museo Nac. Hist. Nat. Santiago, cat. no. 10.008.

Figs. 3-4 *Schlotheimia* (*Schlotheimia*) sp. ex gr. *S. angulata* (SCHLOTH.). Crushed specimens, one showing the externside (fig. 4 right centre). *Schlotheimia* bed (W 6) of the Los Molles section. *S. angulata* Zone, Hettangian. Dept. Geol. McMaster Univ., cat. no. J. 1181-1182.

FUENZALIDA (1938, p. 85, Pl. 6, Figs. 1, 2) were further developed out of the matrix. The bed is approximately 250 m above the *Schlotheimia* beds.

Description. The crushed specimen reproduced by FUENZALIDA in Fig. 1 and very tentatively compared with *Schlotheimia angulata* is undeterminable. It has rectiradiate costae which, high on the flanks, bend suddenly forward. This could belong to Schlotheimiidae as well as to Oxynoticeratidae or Polymorphitidae, such as *Uptonia*.

Fuenzalida's other specimen which is here refigured after the externside was laid free (Pl. 5, Fig. 2a, b) is a widely umbilicate internal mold of a whorl fragment with 25 mm height and a compressed oval section. The widely spaced blunt primaries are slightly prosoradiate, bend suddenly forward at 3/5 whorl height in small tubercles, and pass bluntly over the externside building acute chevrons. Very weak secondaries appear to be intercalated. The weak fastigiation of the externside could be due to deformation.

Family Juraphyllitidae Arkell, 1950

Juraphyllites cf. *J. diopsis* (Gemmellaro) 1884 (Pl. VII, Fig. 1)

Material. A single large, somewhat distorted specimen comes from the Jurassic of the Los Molles section (collection Escuela de Geologia, Universidad de Chile, loc. E G–4–20) but the exact stratigraphical position appears to be unknown.

Description. The diameter of the ½ whorl body chamber is 107 mm. All observable features agree with *J. diopsis*, the type-species of the genus. The phragmocone is smooth. The last septal suture shows a diphyllic lateral saddle. The body chamber becomes coarsely costate towards the end of the preserved part. The strongly projected ribs commence mid-laterally and increase in strength externwardly to form heavy chevrons. The sharp umbilical angle separates a narrow vertical umbilical wall. The umbilical seam of the body chamber egresses strongly (probably not due to distortion).

This appears to be the first record for the genus from the Americas.

Family Nuculidae Gray

Palaeoneilo cf. *P. elliptica* (Goldf.) 1844 (Pl. III, Fig. 2)

One internal mold of a slightly distorted valve with preserved hinge and other incomplete specimens from a loose block, 50–100 m below the *Daonella* bed of the Quereo section.

This compressed, elongate, small form compares well with *P. elliptica* as figured by M. Smith (1928, p. 174, Fig. 389) from the Upper Muschelkalk (Ladinian) of Germany.

Family Halobiidae Kittl, 1912

Daonella dubia (Gabb) 1864 (Pl. III, Figs. 4–10)

The Upper Anisian *D. dubia*, abundant in Nevada and California, is distinguished by near-symmetry, relatively inflated and projecting umboes, the median strong costae which bundle in pairs, and common rugae in the apical region (Gabb, 1864, p. 30; J. P. Smith, 1914, p. 143). Smith (loc. cit.) placed *D. dubia* in close relationship to *D. lindstroemi* Mojs., *D. sturi* (Ben.) and *D. lommeli* (Wiss.).

The first probably Anisian assemblage in Chile was described by Ichikawa (in Zeil, 1958, p. 343) and Barthel (1958) from near Alto de Carmen in Atacama. The described, poorly preserved " *Daonella* ex gr. *D. sturi*, close to *D. dubia* ", is almost certainly identical with the form here described as *D. dubia*.

Material. About 10, in part almost complete and often bivalve (disarticulated) internal molds, mostly crushed, from the *Daonella* beds of the Quereo section. Associated with (?) *Sturia* and (?) *Gymnites*.

Description. The length of the valves varies from 20 to 50 mm. The ventral margins are incomplete so that the shell outline is poorly known. The apex is subcentrally located and projects somewhat above the hinge line which is about as long as the valve. From the mode of crushing, a relatively inflated umbo is inferred. Rugae are present in the apical region of several valves.

The costae consist medially of first- and second-order paired bundles which are often further subdivided by radial striae. Some asymmetry of bifurcation may result, however, in local irregularly bundling threes. Anteriorly and posteriorly the bifurcation is often reduced to first-

order bifurcation and the striae are absent, single ribs are intercalated and the strength decreases toward the hinge margin.

The direct comparison of the specimens with the plastotypes of J. P. Smit's *D. dubia* from Nevada, kindly furnished by the U. S. National Museum, reveals specific identity in all morphological features.

Family Monotidae Fischer, 1887

Otapiria (?) cf. *O. ussuriensis* (Voronetz) 1936 (Pl. IV, Figs. 6a, b, 7)

The genus *Otapiria* has only been known from New Zealand and New Caledonia and recently from northeastern Asia. Trechman (1923, p. 270, Pl. 15, Figs. 6–9) described '*Pseudomonotis*' *marshalli* from questionable Callovian of New Zealand. Marwick (1935, 1953) erected for this species the genus *Otapiria* which was said to be restricted in New Zealand to his " upper Aratauran Stage ". This was correlated with the Sinemurian and lower Pliensbachian on purely stratigraphical grounds, yet the *O. marshalli* occurrence is only slightly above the *Psiloceras* occurrences of the " lower Aratauran Stage ". In New Caledonia, *O. marshalli* was described from the middle and upper Hettangian, in association with *Waehneroceras* and, probably, *Schlotheimia* (Avias, 1954, p. 149, Pl. 20, Figs. 1–4). " *Monotis* " *dissimilis* Cox from New Zealand was probably correctly placed in *Otapiria* by Marwick (1953, p. 59, Pl. 3, Figs. 10–12) who redescribed the species from the " Otapirian " (Rhaetian). The affinity of " *Otapiria* " *masoni* Marwick (1963, p. 95, Pl. 11, Figs. 10, 11) from the uppermost Jurassic of New Zealand is dubious. *O. ussuriensis* (Voronetz) from the " upper Karnian ", i.e. probable Lower to Middle Norian, of northeastern USSR was very recently placed in *Otapiria* by Vozin and Tikhomirova (1964, p. 18, Pl. 7, Fig. 13). The two poorly preserved pelecypods described by Fuenzalida (1938, pp. 76, 77) as " *Lima* sp." and "*Avicula* sp. ind." respectively from localities HF 2 and HF 4 may possibly belong to *Otapiria*. However, both specimens are lost.

Otapiria is strongly reminiscent of early *Monotis* ex gr. *scutiformis et typica*, from which it is distinct mainly in the detailed hinge structure (Marwick, 1935).

Material. A left and a right valve came from the *Cardinia* bed. Both are somewhat deformed by crushing and probably also by cleavage. Both internal and external molds are is present for the right valve.

Description. The shell is obliquely ovate in outline. The left valve shows a short straight hinge line which continues into the short straight antero-dorsal margin. The antero-dorsal angle is sharply rounded, the truncation of the obsolete posterior auricle is highly obtuse. On the right valve, a byssal notch may be indicated but the valve is damaged in the apical region. Strong rugae are present on the right valve. Both valves are covered with extremely fine and numerous subequal costae (or radial striae), 100–110 on the right valve.

Comparison. The costation is finer than in the Hettangian *O. marshalli* and the Rhaetian *O. dissimilis*. The latter species also has a distinctly different, non-costate right valve. Our form resembles closely the probably early Norian *O. ussuriensis*.

The age of the Los Molles specimens, and therefore of the '*Cardinia*' bed, is probably (Norian-) Rhaetian rather than Hettangian.

Family Aviculopectinidae Etheridge Jr., 1906

Oxytoma cf. *O. inaequivalvis* (Sow.) 1819 (**Pl. IV, Fig. 2**)

In a recent study on *O. inaequivalvis* Ichikawa (1958, p. 159) attributed to this common species a range from the Rhaetian to the upper Lower (or ? Middle) Jurassic in southern Germany and England.

The left valve of *O. inaequivalvis* is distinguished from Karnian and Norian species, particularly known from eastern Siberia and Japan, in the strong inflation and large umbo, the relatively short posterior auricle which does not protrude beyond the posterior shell margin, and the simple costation with almost smooth interspaces. The only similar pre-Rhaetian species appears to be the late Norian *O. omolonensis* Kipar. from northeast Siberia. *O. inaequivalvis* is recorded from the Rhaetian of eastern Siberia, Timor and the Carpathians (Tuchkov, 1964).

Material. A single left valve from the *Arcestes-Cladiscites* bed of " fossil point No. 4, Corral Barrancas ", collected and described as " *Pseudomonotis* sp." by Fuenzalida (1938, p. 78, Pl. 3, Fig. 2). The valve is somewhat distorted by dorso-ventral compression and the surface is slightly corroded. It is here pointed out that the specimen in the collection bore Fuenzalida's correct original label " *Pseudomonotis* cf. *inaequivalvis* " and that the specific name was carefully omitted in the publication.

Description. The posterior of the valve is not quite complete but the length can be estimated at 35 mm. The valve is highly inflated (somewhat distorted by the dorsoventral compression) and the large umbo projects well above the hinge line. The posterior auricle is probably complete at about 3/4 posterior length of the shell; the depth of the sinus cannot be determined due to the deformation. The main part of the valve is strongly prosocline and ornamented with 13–14 strong radial costae including one or two of the second order. Between these ribs are only some very faint irregular radial striae.

If identical with *O. inaequivalvis*, the *Arcestes-Cladiscites* beds would probably be post-Norian in age.

Family Trigoniidae Lamarck

Minetrigonia (?) sp. nov., aff. *M. otamitensis* (Trechmann) 1918 (**Pl. IV, Fig. 5**)

Material. A single incomplete left valve, collected by Fuenzalida in 1937 from " fossil point No. 4 ", the *Arcestes-Cladiscites* bed at " Corral Barrancas ".

Description. The large triangulid valve of approximately 45 mm height and 50 mm length is almost certainly conspecific with the right valve described as " *Myophoria* sp. indet. aff. *Jaworskii* Steinmann " by Fuenzalida (1938, p. 78, Pl. 4, Fig. 1) from the same locality. The sides carry extremely strong and widely spaced beaded ribs and two thin beaded ribs in the depressed sector beside the latero-posterior margin. The triangular posterior area is almost plane and covered with fine pustulation arranged lattice-like and weakly along oblique lines.

Affinities. Minetrigonia jaworskii as well as the closely allied or conspecific associated *M. lissoni*, ? *M. pascoensis* (Steinmann) 1929 spp. and *M. baertli* (Boit) from the Upper Norian of Peru (Cox, 1949; Boit, 1966), are distinguished in the concave, non-pustulated posterior area, reduced or absent fine riblets beside the posterolateral margin and at least the two last named species in the somewhat finer costae. Surprisingly similar is *M. nuggetensis* (Trech.)

from the Upper Karnian or Lower Norian of New Zealand. The trigoniid dentition was shown by MARWICK (1953, Pl. 6, Fig. 15). *M. otamitensis* (TRECH.) from beds of the same age is distinct from the Chilean form only in its much smaller size (holotype 14 mm) and the somewhat concave posterior area. The Chilean species belongs probably to the "*Myophoria*" *inaequicostata* group of *Minetrigonia* KOBAYASHI and KATAYAMA, as discussed by KOBAYASHI and ICHIKAWA (1952, p. 70) from the Karnian and Norian of the Pacific region.

(?) Family CARDINIIDAE ZITTEL

Cardinia? cf. *C. listeri* (SOW.) **(Pl. IV, Figs. 3, 4)**

FUENZALIDA (1938, p. 80, Pl. 4, Fig. 3) described '*Cardinia* sp.' from the *Arcestes-Cladiscites* bed of the Los Molles section which he tentatively compared with *C. gleimi* SMITH. The specimen is, however, lost and the reproduction of the photograph insufficient for comparison.

Material. About 12 poorly preserved deformed internal molds of mostly bivalve specimens from fossil locality 2, the '*Cardinia*' bed; approximately 50 m above the *Arcestes-Cladiscites* bed and 50 m below the *Psiloceras* beds in the Los Molles section, associated with *Otapiria* (?) cf. *ussuriensis* (VOR.).

Description. The valve outline is subrectangular with inflated strongly prosogyral umbo. The length varies between 40 and 50 mm and the relative height is about 3/4 of the length. Growth striae are well developed, the major intervals varying between 3 and 4 mm in width on mature valves. Some test remains in the hinge area are moderately thick but the important hinge structure is unknown.

Affinities. Although this form may be a Triassic *Pleurophorus* or *Anodonta*, its reference to *Cardinia* appears more probable. The known age of *Cardinia* ranges throughout the Upper Triassic into the Middle Jurassic, although it abounds in the basal Jurassic (KOBAYASHI and ICHIKAWA, 1952, p. 64). *C. listeri* is common in the (lower) Hettangian of Europe. Most known Triassic species are less inflated and less prosogyral, except for the small *C. gleimi* SMITH from the Upper Karnian of Nevada and possibly for *C. subcircularis* KIPAR. from the Upper Karnian to Middle Norian of northeastern Siberia. All in all, a basal Jurassic age appears as probable as a late Triassic age.

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