

Im: Aspects of Mid-Cretaceous
Regional Geology.

R.A. Rexmont & P. Bengtson

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VENEZUELA

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Abstract This study gives a review of the Cretaceous sedimentary history of Venezuela, with an emphasis on the middle Cretaceous. Correlations of the lithological formations within different depositional areas and palaeogeographic conclusions are discussed.

Introduction

Geological investigations in Venezuela started at the beginning of the nineteenth century, when Alexander von Humboldt visited South America between 1799 and 1804. The famous naturalist was followed by Karsten (1886), who first described and figured ammonites from the Cretaceous, collected in the Venezuelan Andes. Later, Sievers (1888) first mapped parts of the Andes in the State of Lara and constructed a geological cross-section showing the distribution of Cretaceous sediments. At the beginning of the present century, oil was discovered in Venezuela resulting in a detailed geological and geophysical exploration of great parts of the country.

This compilation is based on published literature; the nomenclature of lithological units follows the *Léxico Estratigráfico de Venezuela* (1970).

Deposits of Cretaceous age display very diversified lithogenetic developments within Venezuela. For the present discussion, four representative areas are reviewed (Fig. 1). They are, from west to east:

- 1) north-western Venezuela: Cretaceous in the Maracaibo Lake Basin, the Perijá Range, and the Venezuelan Andes;
- 2) central Venezuela: Barquisimeto Trough (Paleocene–Eocene) with allochthonous masses of Cretaceous age;
- 3) Cretaceous section along the southern foothills of the Cordillera de la Costa in the region between Acarigua and San Carlos; and

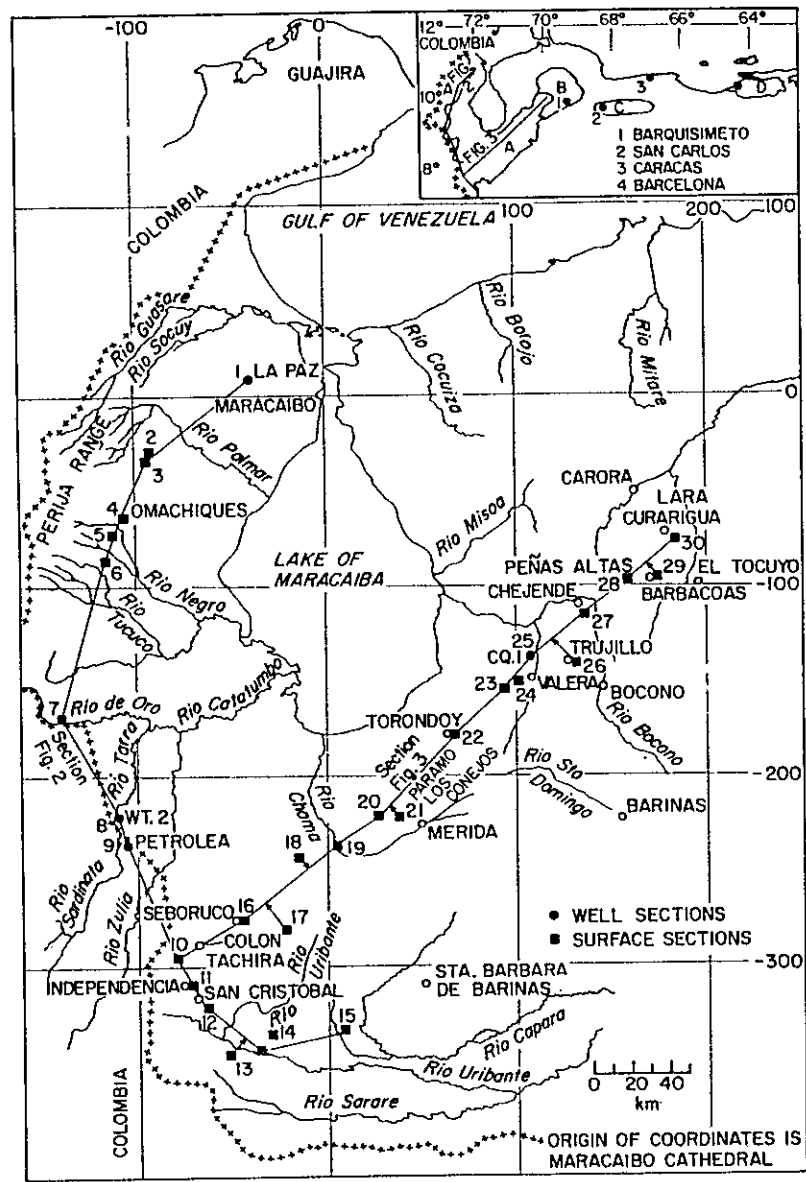
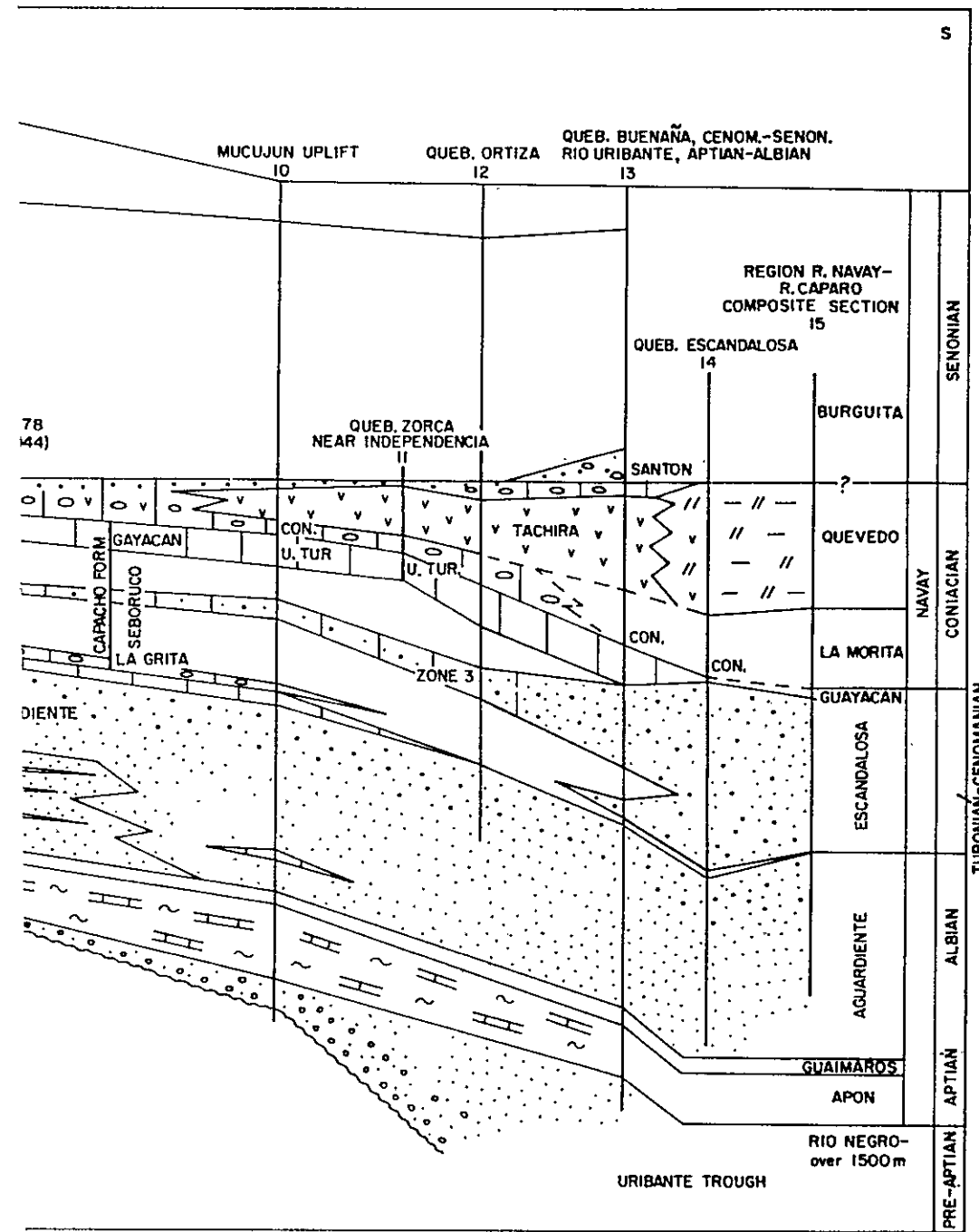


Fig. 1 Location map of well and surface sections of the Cretaceous in western Venezuela.



the south-eastern foothills of the Venezuelan Andes.

(facing page 198)

4) north-eastern Venezuela: eastern Cretaceous basin in the Serranía del Interior.

Cretaceous in the Maracaibo Lake Basin, the Perijá Range and the Venezuelan Andes

Pre-Cretaceous

North of the Maracaibo platform, which roughly coincides with the Maracaibo lake basin, proven marine Jurassic is known in the Goajira and Paraguaná peninsulas. Further east, thick metamorphosed Jurassic sediments almost certainly occur in the Cordillera de la Costa, and again can be proved in Trinidad by ammonites. Thick continental deposits of Triassic-Jurassic age, associated with porphyritic volcanics (*La Quinta Formation*: Kündig, 1938) accumulated within subsiding troughs, bordering the stable Maracaibo platform. The subsiding areas are known as the Machiques trough (Sutton, 1946) in the Perijá range and the Uribante trough (Renz, 1956) in the Andes (Figs 1-3).

"Neocomian"

During early Cretaceous times the Machiques and Uribante troughs continued to subside and were progressively filled by continental deposits reaching thicknesses exceeding 2000 m. The respective sediments are called the *Río Negro Formation* (Hedberg, 1931). Polygenetic conglomerates predominate, alternating with loose gritty, ungraded sands and light greyish claystones. Shales are very subordinate and do not contain foraminifers. Fossils are restricted to indeterminable carbonized plant remains. Over the Maracaibo platform, the Río Negro is reduced to a thin basal conglomerate consisting mostly of rounded quartz pebbles derived from the metamorphosed basement below. The interval is assumed to represent the "Neocomian".

Aptian

At the close of the Barremian, we assume that western Venezuela gradually came to lie below sea-level. The elevated area of the

metamorphic basement, called the Mérida swell, coinciding with the highest elevation of the Andes, remained longest above sea-level (Fig. 3, sections 20-22).

An extended carbonate platform, with a fairly uniform lithology, covers most of the region under consideration. Predominant are grey, well-bedded, micritic skeletal limestones, interbedded with grey, marly limestones. The sequence is referred to as the *Apón Formation* (Sutton, 1946). The most important fossils allowing an age assignment are the ammonite *Chelonicerias* sp. and *Heminautilus etheringtoni* Durham, occurring in the upper part of the formation in the States of Mérida and Táchira (Fig. 3, section 16). Among the bivalves *Exogyra*

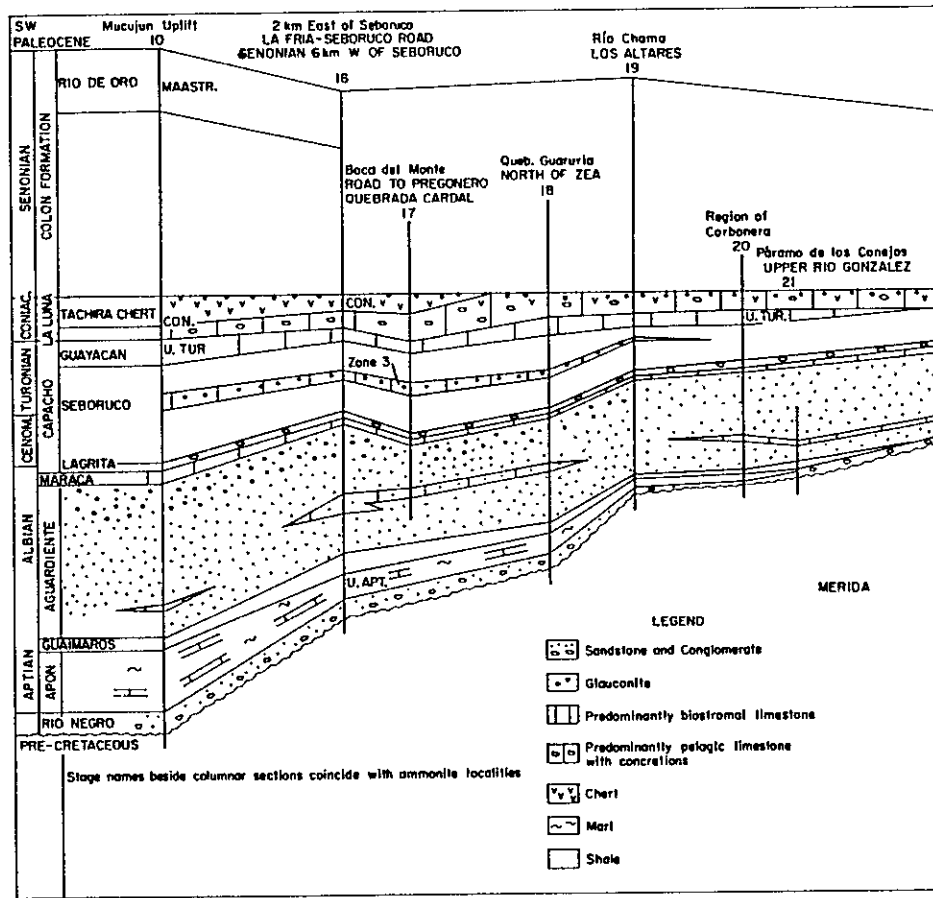
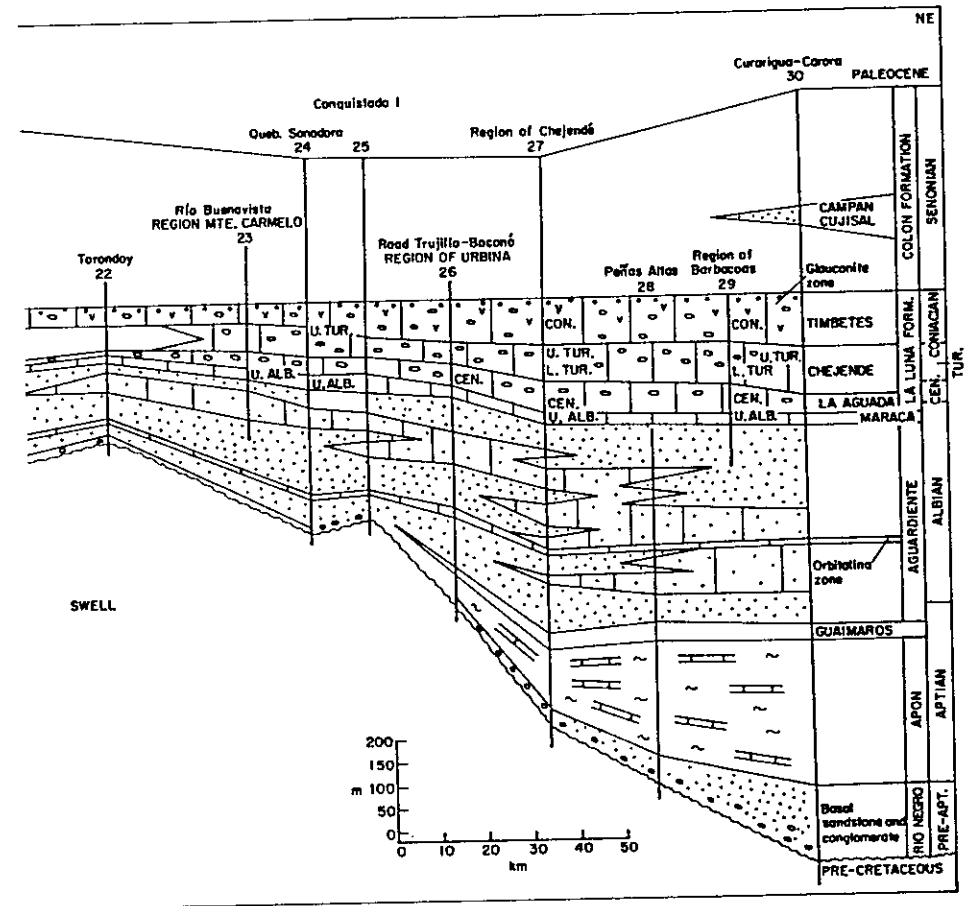


Fig. 3 Section of the Cretaceous along the Venezuelan

scyfax (Coquand), *E. texana* Roemer, *E. couloni* Defrance, *E. boussingaulti* d'Orbigny, *Trigonia tocaimana* Lea and *Cucullea gabrielis* (Leymerie) are abundant in most sections. The echinoids *Toxaster* and *Enallaster* occur especially in Lara. The most abundant foraminifer is *Choffatella decipiens* Schlumberger, present in all sections, mostly in marly intercalations. *Neotrocholina* cf. *valdensis* Reichel and *Pseudocyclammia* sp. occur in oolitic intercalations (Fig. 3, section 29). The fauna indicates a neritic, well aerated, quiet environment. In the direction of the Guayana Shield, intercalations of quartz sandstone increase rapidly in number and thickness.

On the Maracaibo platform, the Apón Formation is followed by



Andes in the States of Táchira, Mérida and Lara.

the Cogollo Formation, in the Machiques trough by the Machiques Formation and in the Andes by the Guáimaras member of the Apón.

Due to subsidence of the Machiques trough area, a closed basin developed, creating euxinic environmental conditions. Live oil is preserved in the interior of the fossils. The *Machiques Formation* (Renz, 1959), was deposited within the basin. It consists of bituminous, dark blue-grey, platy limestones characterized by abundant limestone concretions. The fauna is entirely pelagic, consisting of fish remains, ammonites, inoceramids and some pelagic foraminifers. Sutton (1946) described the following ammonites: *Deshayesites columbianus* Riedel, *D. cf. stutzeri* Riedel, *Cheloniceras cf. cornuelianum* (d'Orbigny), *Parahoplites cf. inconstans* Riedel, indicating Late Aptian. In the upper part of the Machiques Formation, some ammonites belonging to the genus *Engonoceras* occur; they indicate Early Albian. Northwards, in Quebrada Sta. Rosita (Fig. 2, section 4), a lateral transition into the Cogollo Formation, indicated by alternating Cogollo and Machiques limestones, is exposed. Southwards, the euxinic limestones apparently grade laterally into the *Mercedes Member* of the Aguardiente Formation (Notestein *et al.*, 1944) representing an alternation of sandstones and limestones (Fig. 2, sections 7-9).

In the Andes, the Apón Formation is followed by a zone of terrigenous sediments consisting of dark grey silty, often micaceous shales containing exclusively plant remains, among which *Weichselia* is abundant. The conspicuous change in environment might indicate that uplift in the south caused a renewed supply of terrigenous material. The interval is referred to as the *Guáimaras Member* of the Apón Formation (Renz, 1959), regarded as being Late Aptian in age.

Albian

The chronostratigraphic boundary separating the Aptian from the Albian cannot be placed accurately in the sections, owing to the scarcity of diagnostic fossils. On the Maracaibo platform it passes within the lower third of the Cogollo Formation and continues in the Machiques trough within the upper part of the Machiques Formation. In the southern Perijá range and in the Andes, the boundary passes above the Guáimaras Member within the Aguardiente Formation (Figs 2 and 3).

In several sections on the Maracaibo platform, a shale zone (= shale break, Smith, 1951), probably coinciding with the Guáimaras member in the Andes, follows on the Apón Formation. In the

northern Perijá range and on the Maracaibo platform this shale zone is overlain by a thick sequence of massive grey, biostromal limestones interbedded with thin beds of oolite. Garner (1926) named these limestones the *Cogollo Formation*. Its fauna consists predominantly of bivalves, difficult to extract from the hard limestone. According to regional correlations, the Cogollo Formation is predominantly Albian in age. Its lowest part certainly enters the Aptian and its uppermost part is apparently Cenomanian in age. The *Orbitolina conica texana* level in the La Paz oil field probably coincides with that of the Andes.

Within the Machiques trough, the Piché and the Lisure Formations were deposited during the Albian.

The *Piché Formation* (Renz, 1959) is a massive body of micritic skeletal limestone containing abundant *Trigonia* and *Exogyra*. A large *Oxytropidoceras* (*Manuaniceras*) belonging to the *peruvianum* group, indicating Middle Albian, has been found at Quebrada La Luna (Fig. 2, section 3).

An alternation of glauconitic sands, sandy shales and massively bedded, often sandy limestones overlie the Piché Formation. The name *Lisure Formation* was introduced by Rod and Maync (1954) for this interval.

The abundance of clastic material indicates the northern end of an extensive sand inflow derived from the Guayana Shield. A single *Mortoniceras cf. inflatum* (Sowerby), indicating Late Albian, has been observed in glauconite-bearing marls in the uppermost part of the section in Quebrada La Gé (Fig. 2, section 2). Rod and Maync (1954, p. 273) mention the following foraminiferal fauna from this interval: *Haplostiche texana* (Conrad), *Discorbis minima* Vieaux and *Textularia rioensis* Carsey. Sutton (1946) recorded the echinoid *Phymosoma cf. texana* (Roemer).

Towards the Andes, the Lisure Formation grades laterally into sandstones composed of semi-rounded, polished quartz grains, designated as the *Aguardiente Formation* by Notestein *et al.* (1944). In the State of Táchira, glauconitic sandstones with very subordinate limy intercalations predominate. These sands form part of the north-eastern margin of the extensive sand inflow mentioned above. In the Cordillera Oriental of Colombia, those sandstones form a considerable part of the Cretaceous sequence, as is also the case in the Serranía del Cocuy, not far from the Venezuelan-Colombian border. Here, they are referred to as the Une Formation (Albian) and the Guadalupe Formation (Late Cretaceous).

In the Andes, north-east of the Mérida swell, in the States of Trujillo and Lara, the Aguardiente Formation is composed of two

prominent sandstone members composing its lower and upper part. They normally form outstanding morphological features. Here, glauconite is very subordinate. The two members are separated by a thick alternating sequence, of mostly massively layered biostromal limestones with some interbedded sandstones. Conspicuous within this middle member is a zone rich in *Orbitolina concava texana* (Roemer). Among the numerous fossils, bivalves such as rudists, caprinids and oysters predominate (Fig. 3, sections 27-30).

The upper sandstone member of the Aguardiente Formation is locally covered by a hard-ground of iron oxide. It is overlain by a thin bed of black shale, followed by a relatively thin interval of biostromal limestones. The fauna consists mainly of *Exogyra boussingaulti* d'Orbigny, *Ostrea scyfax* (Coquand), *Trigonia hondeana* Lea, *Sphaera corrugata* Sowerby, *Cerithium* and locally rudists as well as *Terebratula* sp. (detailed section in Renz, 1968, Fig. 2). The age of this interval is well documented by a rich ammonite fauna, known since Karsten (1886), and indicating the early Late Albian (*Hysterocheras orbignyi* zone).

The ammonites are accumulated in the top layer of the interval. The dark blue-grey limestone has furnished the following assemblage: *Hysterocheras orbignyi* (Spath), *H. carinatum* Spath, *H. bucklandi* Spath, *Prohysterocheras* (*Goodhallites*) *goodhalli* (J. Sowerby), *Mortoniceras* (*M.*) *arietiforme* (Spath), *M. (M.)* aff. *pricei* (Spath), *M. (Rusoceras)* *nothum* (van Hoepen), *M. (Deiradoceras)* *devonense* Spath, *Oxytropidoceras* (*Venezolicerus*) *venezolanum* Stieler, *O. (V.) karsteni* Stieler, *O. (V.) bituberculatum* Collignon, *O. (V.) robustum* O. Renz, *Parengoceras discoides* O. Renz, *Knemiceras* aff. *compressum* Hyatt, *Neophlycticeras madagascariense* (Collignon), *Puzosia* (*Anapuzosia*) *tucuyensis* (v. Buch), *Puzosia* (*Anapuzosia*) *saintoursi* Collignon, *Bhimaites stoliczkai* (Kossmat) and *Desmoceras* (*D.*) *latidorsatum* (Michelin). The interval is at present united with the Maraca Formation from the Machiques trough in the Perijá (Léxico Estratigráfico, 1970). The Maraca Formation exposed in the Perijá, however, is assumed to be Cenomanian in age.

In the Andes (States of Táchira and Mérida), as well as southern Perijá (Fig. 2, section 8), the Maraca Formation of early Late Albian age is followed with a sharp contact by a thin layer of black pelagic limestone. Its facies is indistinguishable from that of the La Luna Formation. Its age, however, is still latest Albian, as indicated by planktic foraminifers, predominantly *Hedbergella* and *Ticinella*. The thin interval, often covered by debris in the field, reflects a sudden

subsidence during Late Albian time, creating euxinic conditions. This lithological unit, allowing important deductions regarding the depositional history of the area, is called the *La Grita Member* of the Capacho Formation (Renz, 1959).

In the State of Trujillo, the La Grita Member merges with the lower part of the Aguada Member of the La Luna Formation (Fig. 3, sections 24-29). In the Barbacoas area (Fig. 3, section 29), ammonites still of Late Albian age occur in the respective lower limestones of the Aguada Member, rich in *Hedbergella*. Here, ammonites are rare and flattened owing to compaction of the sediment. The subgenus *Laraiceras*, assumed to be the latest offspring of the genus *Oxytropidoceras*, is of special palaeontological interest (Renz, 1968).

Cenomanian

On the Maracaibo platform, and in the northern Perijá range, no signs of an unconformity are observed along the boundary separating the Cogollo from the La Luna Formation, which here is Turonian and Coniacian in age. The sediments corresponding to the Cenomanian are therefore apparently represented by the uppermost limestone beds of the Cogollo Formation. So far, there is no palaeontological evidence from the Cogollo to confirm this assumption (Fig. 2, section 1).

Within the Machiques trough, a conspicuous massive limestone body, referred to by Rod and Maync (1954) as the *Maraca Formation*, overlies the Lisure Formation. The above-mentioned *Mortoniceras* of Late Albian age, collected from the top of the Lisure Formation, and Lower Turonian ammonites from above the Maraca in the La Luna Formation, suggest a Cenomanian age for the interval. The fauna consists predominantly of *Exogyra boussingaulti* d'Orbigny. So far, typical Cenomanian ammonites are not known from the Perijá.

Towards the Andes, the chronostratigraphic boundaries delimiting the Cenomanian enter the lower part of the Seboruco Member of the Capacho Formation, which then grades laterally into the upper part of the *Aguada Member* (Renz, 1959) of the La Luna Formation in Trujillo and Lara (Fig. 3). The *Aguada Member* is characterized by its large limestone concretions reaching diameters of over 1 m, especially in the Barbacoas region. The rather poorly preserved ammonites of Cenomanian age are *Mariella* (*M.*) cf. *worthensis* Adkins and Winton and large specimens belonging to the genus *Acanthoceras*.

Rotalipora appenninica (Renz) has been observed from the Chejendé section (Fig. 3, section 27).

Towards the south-eastern foothills of the Andes, the lower Seboruco Member of Cenomanian age grades laterally into the lower part of the *Escandalosa Formation* (Renz, 1959; Gaenslen, 1962), which consists of glauconitic sands alternating with silty shales. Diagnostic fossils are so far not known within this facies (Fig. 2, sections 13-14).

Turonian and Coniacian

On the Maracaibo platform, the massive Cogollo limestone sequence is followed abruptly by the *La Luna Formation* (Garner, 1926). The latter comprises the most important oil-source rocks in Venezuela. The lithology is characterized by bituminous, mostly thin-bedded, black, micritic limestones interbedded with platy, black, argillaceous limestones containing abundant limestone concretions reaching diameters of up to 0.3 m. In the upper Coniacian part of the interval, thin layers and lenses of black chert are intercalated. Ammonites, inoceramids (*I. labiatus* Schlotheim) and fish remains are abundant. The ammonite genera indicating an Early Turonian age are *Vascoceras*, *Hoplitoides*, *Neoptychites*, *Thomasites*, *Pseudaspidoceras* and *?Eucalyoceras*; they come from the first concretion bed exposed above the Cogollo Formation (Sutton, 1946). The upper part of the La Luna Formation of Coniacian age has furnished *Barroisiceras*, *Peroniceras*, *Gauthiericeras*, *Prionocycloceras* and *Prionocyclus*.

The euxinic environment reflected by the La Luna Formation suggests a period of subsidence, which began during late Albian time (La Grita and Aguada Members in the Andes), and progressively expanded over the Maracaibo platform with the beginning of the Turonian, and further northwards to the Goajira peninsula with the beginning of the Coniacian. As a result of this subsidence in the Andes during the later Albian, we may assume a corresponding positive movement along the northern Guayana Shield causing erosion in this area. An extended fan-like feature of terrigenous material, predominantly silty shales followed by massively bedded limestones, was deposited during Cenomanian and Turonian times. The western margin of this fan is found in the subsurface of the Río de Oro oil-field (Fig. 2, section 7) and its eastern margin between the surface sections at Torondoy and Monte Carmelo in the Andes (Fig. 3, sections 22-23). Its three-dimensional shape, and its extension to north-east, can readily be deduced from Figs 2 and 3. Two lithological units can be

distinguished within this fan: the *Seboruco Member* (Renz, 1959) below, and the *Guayacán Member* (Notestein *et al.*, 1944) above, both forming part of the *Capacho Formation* (Sievers, 1888).

The base of the Capacho is formed by the pelagic La Grita Member of late Albian age, followed by the Seboruco Shale, consisting of uniform, massive, black, micaceous, silty shales without age-indicative fossils. Based on our regional picture, a Cenomanian to Early Turonian age is suggested for this interval. The Seboruco Shale has a conspicuous zone of grey, massive limestone with shell fragments and glauconitic sandstones interbedded in it. The limestones become more and more sandy towards the south, where they merge with the Escandalosa Formation (Fig. 2). Notestein *et al.* (1944) designated this intercalation, clearly distinguishable on Schlumberger logs, by the informal name "Zone 3".

The Guayacán Member consists of micritic, partly skeletal limestones containing abundant small bivalves. They are interbedded with dark shales. In the Venezuelan Andes, this interval is relatively thin, but it increases in thickness southwards towards the Colombian border, where, along the road from Rubio to Las Delicias, part of the Seboruco shales are progressively replaced by Guayacán-like limestones. Large *Coilopoceras* indicate a Late Turonian age for this member. In the Andes, the Guayacán limestone correlates with the upper part of the Chejendé Member of the La Luna Formation in Trujillo and Lara, which contains the same large *Coilopoceras*.

Towards the south-eastern foothills of the Andes, the upper part of the Seboruco Shale of Early Turonian age grades laterally into a sandy facies corresponding to the upper part of the Escandalosa Formation (Fig. 2, sections 12-13).

In the Andes, on the south-western slope of the Mérida swell, the La Luna Formation overlying the Capacho Formation is reduced to the Coniacian part of the La Luna at the type section, which contains beds of black chert (Fig. 3, sections 19, 20, 22). From the culmination of the Mérida swell north-eastwards, in the direction of the Tertiary Barquisimeto trough, the La Luna increases in thickness, replacing the Capacho, and ranging in age from Late Albian to Late Coniacian. The interval following on the Aguada Member of Late Albian to Cenomanian age is subdivided into the *Chejendé Member* (Renz, 1959) of Turonian age and the *Timbetes Member* (Renz, 1959) of Coniacian age.

The Chejendé Member is characterized by very abundant, rather small limestone concretions accumulated especially in the upper part of the interval. They contain ammonites, inoceramids (*I. labiatus*) and

fish remains. The rich ammonite assemblage is composed of the genera *Hoplitoides*, *Mammites*, *Benueites*, *Pseudaspidoceras*, *Vascoceras*, *Thomasites*, *Neoptychites* and *Fagesia*. Within the upper part of the Chejendé Member, large specimens of *Coilopoceras* indicating Late Turonian occur.

The Timbetes Member is distinguished by the abundance of seams and lenses of black chert. Characteristic ammonite genera are *Barroisiceras*, *Metatissotia* and *Peroniceras*. Among the foraminifers, *Siphogenerinoides* occurs in the upper part of the member (Fig. 3, section 24).

In the State of Táchira, the Guayacán Member of the Capacho Formation of Late Turonian age is followed by a thin interval of typical La Luna, which here represents the southernmost occurrence of the formation (Fig. 2, sections 10–12). It is still Coniacian in age as proven by the ammonites *Lenticeras andii* (Gabb), *Gauthiericeras lenti* Gerhardt, *Prionocyclus* sp. and *Peroniceras* sp.

Further to the south-east, in the foothills of the Andes, the La Luna grades laterally into dark grey shales distinguished as the *La Morita Member* (Renz, 1959; Gaenslen, 1962) of the *Navay Formation* (Kehrer, 1938; Gaenslen, 1962). In limestone concretions, ammonites of the Coniacian, such as *Barroisiceras* sp., still occur. Among the foraminifers, *Globotruncana fornicata* (Plummer) may be mentioned.

In Táchira, the upper part of the La Luna Formation of Coniacian age is replaced by thin-bedded, black chert referred to as the *Táchira Member* of the La Luna Formation (Hedberg and Sass, 1937; Renz, 1959). Larger fossils are restricted to phosphatized fish remains accumulating toward the top of the formation. Pelagic Foraminifera such as *Globotruncana*, *Guembelina* and *Globigerina* are abundant, but their preservation is generally poor, owing to silicification.

Towards the south-western foothills of the Andes, the Táchira Member grades into light brown, hard, siliceous shales distinguished by the name *Quevedo Member* of the *Navay Formation* (Renz, 1959; Gaenslen, 1962). Pelagic foraminifers are poorly preserved. Gaenslen (1962) mentions remains of *Mosasaurus* (Fig. 2, sections 13–15).

Santonian

Within western Venezuela, the La Luna Formation is overlain by a glauconite-phosphate zone, ranging in thickness from less than one metre to several metres. The palaeontological evidence suggests that this zone might represent a period of reduced deposition (Sutton,

1946). In the south-western Venezuelan Andes (State of Táchira), the glauconitic zone in the Quebrada Buenaña (Fig. 2, section 13) splits into a number of thin glauconitic layers interbedded within black limestones, and calcareous shales with concretions of La Luna type. The ammonite *Texanites texanus* (Roemer) indicates a Santonian age for this interval and probably also for the glauconite zone (cf. Gerhardt, 1897; Sellier de Civrieux, 1952).

Campanian-Maastrichtian

In the foothills of the northern Perijá range, and on the Maracaibo platform, the glauconitic zone is overlain by a sheet of light greyish, micritic limestone, the *Socuy Member* of the Colón Formation (Sellier de Civrieux, 1952). It contains a mixture of pelagic and benthic foraminifers. Some pelagic forms are: *Globotruncana fornicata* (Plummer), *G. cretacea* Cushman, *G. rosetta* Carsey, *Rugoglobigerina rugosa* (Plummer) and *Globigerina cretacea* d'Orbigny. The age of this assemblage is considered by Sellier de Civrieux to be Campanian. The Socuy Member apparently represents the lowermost wedge of the *Guaramai Formation* (Renz, 1959) of the southern Goajira peninsula in Colombia. Its age is Campanian to Maastrichtian. Its equivalent in western Venezuela is the *Colón Formation* (Liddle, 1928) consisting of uniform dark grey shales, becoming gradually silty towards the top. This upper silty part was designated the *Mito Juan Formation* by Garner (1926). The two formations are difficult to separate in the field.

In the oil-fields of the southern Perijá foothills, as well as in Táchira, some light brown limestone intercalations are referred to by Garner (1926) as the *Río de Oro Member* of the Mito Juan Formation. These rocks have furnished the ammonites *Coahuilites* sp. and *Sphenodiscus* sp. indicating Maastrichtian (Fig. 2, section 12).

In the State of Lara, where the Andes plunge beneath the Tertiary of the Barquisimeto trough, the Colón Formation is divided by a wedge consisting of massive quartz sandstones referred to as the *Cujisál Member* (Renz, 1959). In the Colón shales overlying the sandstone, ammonites found east of Cujisál belong to the genera *Baculites* and *Euhomaloceras* (determined by W. S. Adkins), which indicate a Campanian age (Fig. 2, section 30).

Towards the south-western foothills of the Andes, in the State of Táchira, a lateral transition from the shales of the Colón Formation into alternating sands and sandy shales overlies the Quevedo Member

of the Navay Formation. This unit is referred to as the *Burguila Formation* (Renz, 1959; Gaenslen, 1962). *Siphogenerinoides* is the only foraminifer that has been recovered from the type section in the well Burgua 3.

Barquisimeto Trough (Paleocene–Eocene) with allochthonous masses of Cretaceous rocks (State of Lara)

The Barquisimeto trough is a deep depression filled mainly with Paleocene–Eocene sediments predominantly developed in a flysch facies. Thicknesses of between 3000 and 4000 m were observed by Renz *et al.* (1955). To the west, the trough is limited by the plunging Andes composed here mainly of Cretaceous sediments. To the south-east, the complicated Barquisimeto flexure-zone delimits the trough. Eastwards, metamorphosed rocks of mostly unknown age form its limits (regional map in Bellizzia and Rodriguez, 1967, 1968). To the north, Oligocene–Miocene deposits cover the older Tertiary unconformably. The north–south extension of the exposed part of the Barquisimeto trough reaches about 90 km, and its width from west to east about 100 km. Large slip-masses predominantly composed of Cretaceous rocks ranging from block-size up to slabs extending over several kilometres, and displaying diversified lithologies, occur in great numbers within the trough area. These allochthonous masses might have slumped from the north, southwards into the developing Barquisimeto trough. This process possibly correlates with an Early Paleocene orogenic phase, responsible for the metamorphism of the Mesozoic sequences exposed in the Cordillera de La Costa (States of Carabobo and Miranda).

Prior to 1955, these slumped masses of Cretaceous age were considered to be autochthonous, but detailed field work in the surroundings of the town of Carora, in the State of Lara, revealed their allochthonous nature (Fig. 4). Four kilometres south-east of Carora, a submarine channel has been cut into the south-eastern flank of a plunging Andean anticline, exposing the Colón and La Luna Formations. The region is an interesting object for study, well worth visiting. The channel-fill consists of contorted Tertiary shales containing a mixture of blocks and slabs of different Cretaceous ages. The autochthonous Andean Cretaceous, as well as the channel fill, are in turn covered by a major slab composed of siliceous to cherty shales of Senonian age, reaching a length of about 6 km. The

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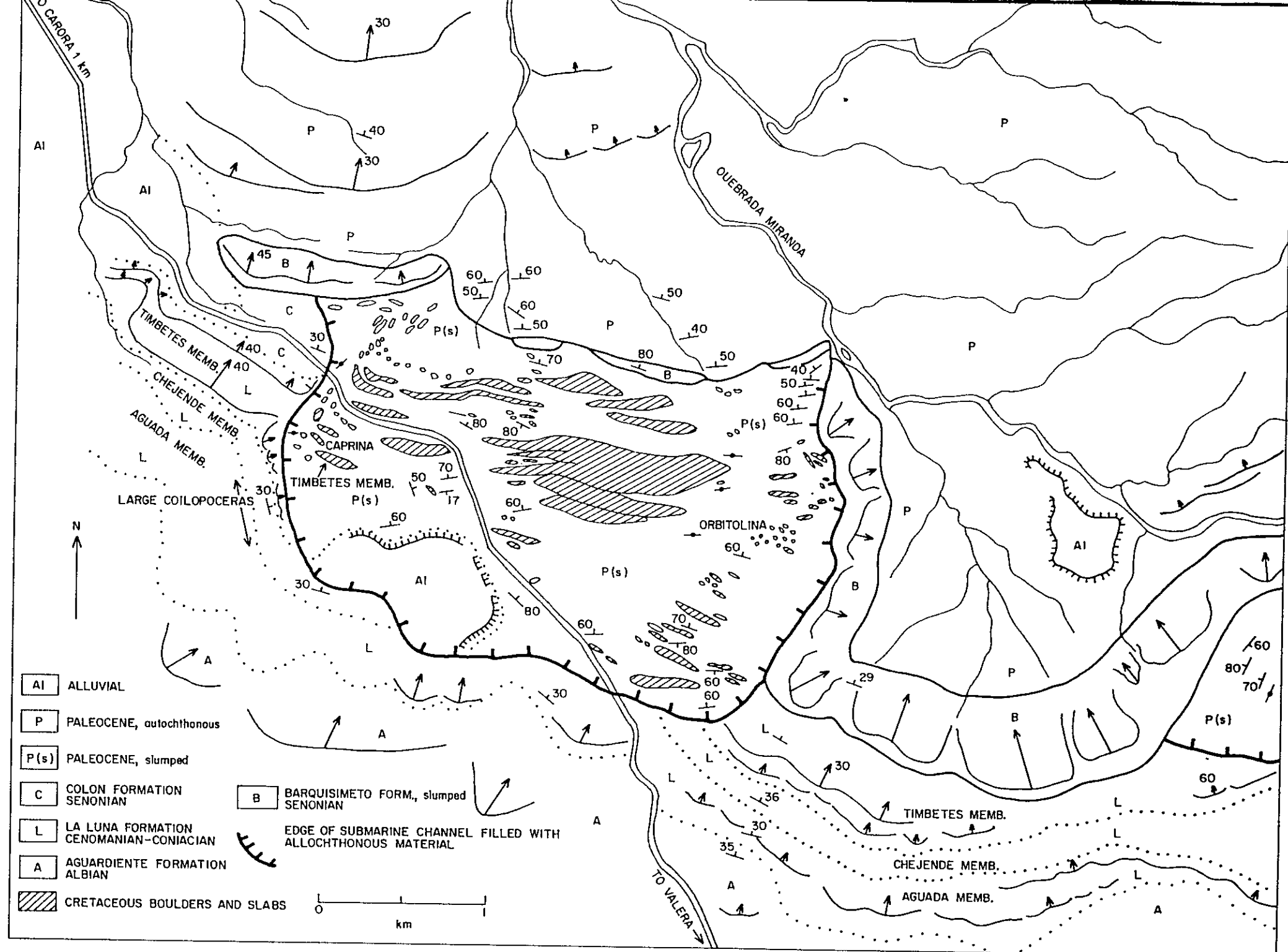


Fig. 4 Submarine channel and submarine slumping of Early Paleocene age south-east of the town Carora (State of Lara).

sequence resembles the Barquisimeto Formation, also of Senonian age. Later, during the Andean orogenesis, the sediments were folded. These conditions have been attributed to large-scale submarine activity slumping during Paleocene-Eocene times (Renz *et al.*, 1955). Similar dislocations of still greater extent can be observed to the south-east along the plunging Andes as far as the town El Tocuyo.

Sorting the innumerable allochthonous blocks and slump-masses present in the Barquisimeto trough area according to their lithology and fauna, leads to the conclusion that material from two quite different depositional areas of the Cretaceous is involved (Renz, 1960).

The sediments attributed to one of these sections are comparable to those exposed in the Andes. They are not altered by metamorphism. The oldest limestone blocks bearing small Pulchelliidae, comparable to those from Trinidad, are of Barremian age. Limestones with *Choffatella decipiens* might indicate the Apón Formation of Aptian age, and bioherms composed of rudists and *Orbitolina* limestones might represent the Albian. Of interest are small blocks consisting of dark grey pelagic limestones containing *Oxytropidoceras (Manuaniceras) peruvianum multifidum* (Steinmann) suggesting Middle Albian age (Renz *et al.*, 1955). The lithology of this limestone closely resembles that of the La Luna Formation, which indicates that Middle Albian in La Luna facies must be developed somewhere around the trough area. Slabs of Cenomanian age with the ammonite *Mariella* sp. and inoceramids display a typical La Luna environment. Extensive masses containing large specimens of *Coilopoceras*, indicating Late Turonian, are rather abundant. The presence of Senonian shales (Colón Formation) remains doubtful. They might be present in the form of diagenetically altered, contorted marls.

Along the south-eastern margin of the Barquisimeto trough, the region north of Barquisimeto has been studied by several workers (Bushman, 1959, 1965; Coronel and Renz, 1960; Bellizzia and Rodriguez, 1968): The latter authors, after having carefully investigated the surroundings of the trough area, came to the conclusion that north of Barquisimeto there is a large allochthonous mass of Cretaceous age, which is not subdivided into individual slip-masses separated by diagenetically altered Tertiary shales, as assumed by Coronel and Renz (1960).

The oldest sediments are greenish-brown to grey-blue, platy limestones containing flattened heteromorphic ammonites, determined by Imlay as *Idiohamites* and *Pseudohelicoceras*. A questionable fragment of an *Oxytropidoceras* has been figured by Coronel and Renz

(1960, Fig. 5). The foraminifer *Neotrocholina* aff. *valdensis* Reichel (Coronel and Renz, 1960, Fig. 4) occurs. The fossils indicate a Middle to Late Albian age. Bushman (1960) introduced the name *Carorita Formation* for these sediments, which reach an exposed thickness of about 500 m.

The next younger formation, within this extended slumped mass, consists of alternating platy siliceous limestones, black chert and finely crystalline, dark grey limestones, which Bushman (1960) referred to as the *Barquisimeto Formation*. It reaches a thickness of about 1700 m. The limestones contain a pelagic fauna composed of *Globigerina cretacea* d'Orbigny, *Guembelina globulosa* (Ehrenberg), *Globotruncana globigerinoides* Brotzen and unilocarinate *Globotruncana*. The sequence is considered to be Cenomanian-Maastrichtian in age.

Cretaceous along the southern foothills of the Cordillera de la Costa (States of Portuguesa and Cojedes)

A section of the Cretaceous, about intermediate between the sequences of the Andes and the eastern Cretaceous basin in the Serranía del Interior, is exposed in the basin extending west of the El Tinaco massif. The Cretaceous sediments within this basin are somewhat affected by slight metamorphism, sufficient to destroy most of the fossils.

The oldest rocks outcropping within the basin are conglomerates and arkoses, referred to as the *Araure Formation* (Renz and Short, 1960; Bushman, 1967). Its contact with a possible granitic basement has not been found. The exposed thickness of the formation attains about 700 m. Fossils are not known. The sequence might be compared with the Río Negro Formation of western Venezuela and with the Barranquín Formation of the Serranía del Interior.

The clastics of the Araure Formation are concordantly followed by a thick sequence of predominantly massively bedded grey limestones, reaching a thickness of about 800 m, for which the name *Agua Blanca Formation* has been used (Garner, 1926; Renz and Short, 1960; Bushman, 1967). The limestones are recrystallized to such a degree that foraminifers, such as *Choffatella*, have been destroyed. Only remains of thick-shelled oysters and colonies of corals suggest a neritic, well aerated environment. Provisionally, an Aptian to ?Albian age might be assigned to these limestones.

In the region under consideration, the Agua Blanca Formation is

succeeded by thickly bedded arkosic conglomerates alternating with massively layered limestones, interbedded with grey phyllites. For this predominantly clastic sequence, attaining a thickness of about 680 m, the term *Cojedes Formation* has been proposed (Renz and Short, 1960; Bushman, 1967). The components of the conglomerates consist of gneiss and granite derived from the El Tinaco basement complex. The fossils observed are foraminifers such as *Orbitolina Cuneolina*, *Coskinolina* and *Miliolidae*, indicating a shallow, well ventilated environment. The age of the interval is assumed to be Albian. Menéndez (1965) correlates the formation with the El Cantil in the Cordillera del Interior.

The Cojedes Formation is followed by a thick sequence composed predominantly of rather uniform calcareous sediments. Characteristic are thin-bedded, partly arenaceous limestones, interbedded with marly limestones reaching a thickness of about 460 m. The succession is referred to as the *Mapuey Formation* (Renz and Short, 1960; Bushman, 1967). Crushed, indeterminate uncoiled ammonites are the most conspicuous fossils. They are similar to those observed in the Carorita Formation of the Barquisimeto trough, which are supposed to be Late Aptian in age. Redeposited limestones containing *Orbitolina* and limestones with *Caprinidae* indicate a younger age than those fossils. According to its position in the stratigraphic column, a Late Albian to Coniacian age is most likely. Possibly, the Mapuey correlates, at least partly, with the Querecual Formation further eastwards.

Concordantly above the Mapuey Formation is a 1000-1500 m thick monotonous sequence, interbedded with thin beds of dark chert, as well as with layers of pelagic limestones rich in foraminifers such as *Globotruncana*, *Rugoglobigerina* and *Guembelina*. This succession of beds has been referred to as the *Mucaria Formation* (Renz and Short, 1960; Oxburgh, 1965; Menéndez, 1965; Jarvis, 1966; Bell, 1968). The age is Coniacian to Maastrichtian. The formation was intruded by basic igneous rocks which contain blocks of *Orbitolina* limestones indicating a post-Albian age for these intrusions. The Mapuey correlates with the San Antonio Formation in eastern Venezuela and the Colón Formation in western Venezuela.

The Cretaceous basin of north-eastern Venezuela (Serranía del Interior)

The present summary is mainly based on the investigations of

Hedberg (1950), Rod and Maync (1954), Rosales (1959), Salvador (1964) and Guillaume (1972).

Lower Cretaceous

The oldest sediments of the Cretaceous exposed in the Serranía del Interior are contained in the *Barranquín Formation* (Liddle, 1928). It consists of sandstones composed of subangular quartz grains, interbedded with black shales and thick layers of biostromal limestones. The lower boundary of the formation against the pre-Cretaceous is not known. Guillaume (1972) indicates variable thicknesses ranging from 1420 to 2460 m. In the upper part of the formation, plant remains determined as *Weichselia*, *Otozamites*, *Equisetites*, *Brachyphyllum* and *Frenelopsis* are present (Royo y Gomez, 1960). Von der Oosten (1957) indicates numerous bivalves and Guillaume (1972), *Choffatella decipiens*. The age of the formation is given as ?Barremian to Early Aptian (Guillaume, 1972).

The Barranquín Formation is overlain by ammonite-bearing marls known as the *García Formation* (Rod and Maync, 1954; Guillaume, 1972). The thickness of these shales increases from 80 to 150 m from the north to the south-east. A rich fauna of ammonites indicates Late Aptian. The *Cheloniceras martini* and the *Ch. subnodosocostatum* zones are indicated by 54 ammonite species determined by Guillaume (1972). Some important genera and species are: *Deshayesites* (4 species), *Cheloniceras martini* and *Ch. subnodosocostatum*, *Colombiceras* (about 3 species), *Gargasiceras* (about 5 species), *Dufrenoyia* (6 species) and *Acanthohoplites*. The microfuna in the García Formation corresponds to the *Biglobigerinella barri* and the *Praeglobotruncana infracretacea* zones (Fig. 5).

The García Formation is followed by the *El Cantil Formation* (Liddle, 1928; Rosales, 1959). Its lithology is variable; typical are massive, partly biostromal limestones interbedded with shales and sandstones, which increase in thickness towards the south (the Guayana Shield). The formation varies in thickness from 300 to 860 m. To the north, the biostromal limestones turn into reefs. Towards the middle part of the sequence, *Orbitolina concava texana* appears frequently. Other foraminifers are *Pseudocyclamina hedbergi* Maync and *Dictyoconus walnutensis* (Carsey). Rudist limestones are common. Based on the presence of the *Cheloniceras martini* zone in the García Formation below, and the *Douvilleicerias mammillatum* zone above in the Chimana Formation, the age of the El Cantil Formation is regarded as Early to Middle Albian.

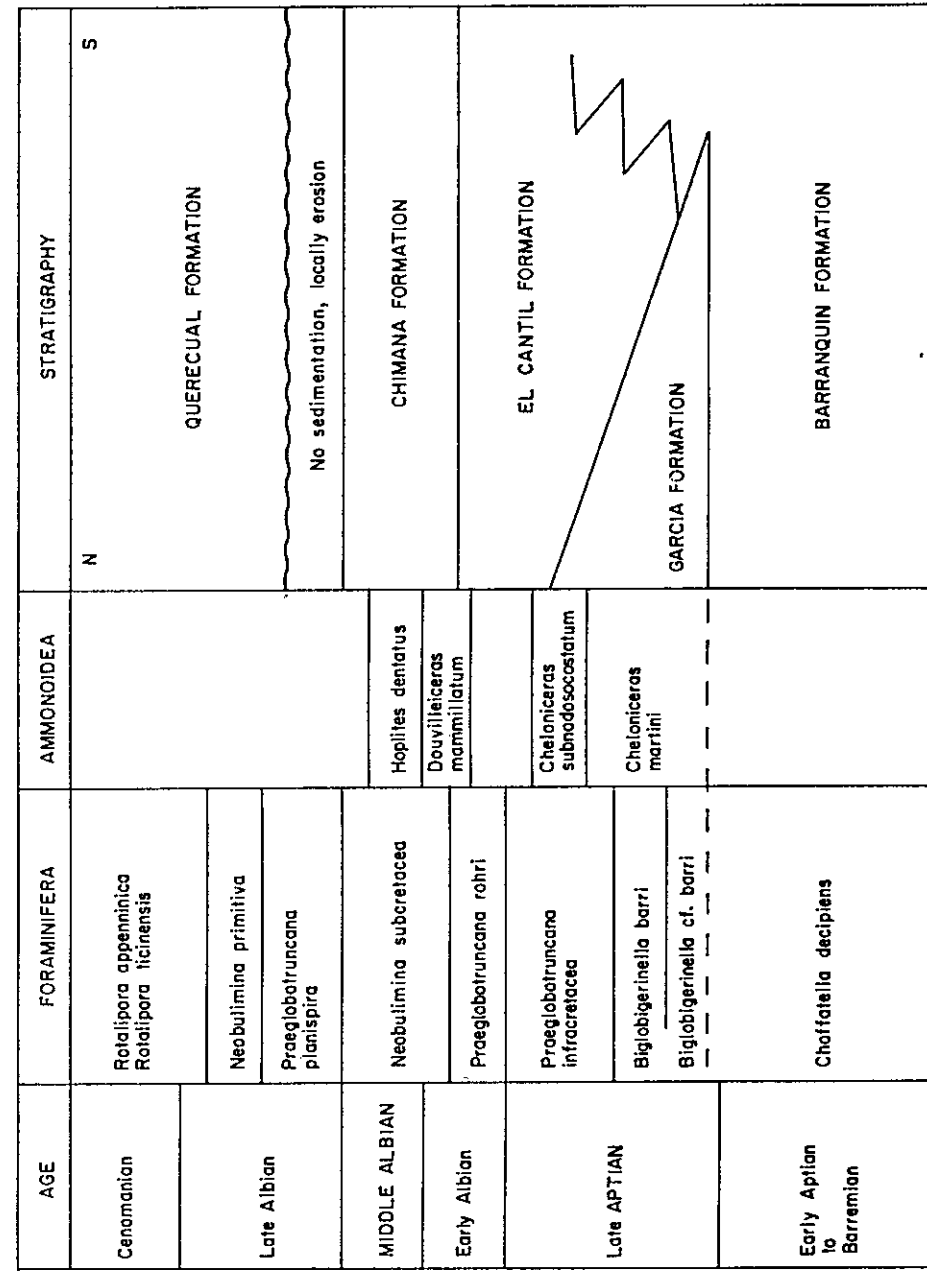


Fig. 5. Stratigraphic correlations of the Cretaceous in the Serranía del Interior (after Guillaume, 1972).

The massive limestones of the El Cantil Formation are overlain by dark, partly glauconitic shales, interbedded irregularly with limestones and sandstones. The interval has been referred to by Hedberg and Pyre (1944) as the *Chimana Formation*. The succession, reaching a maximal thickness of about 800 m, is characterized by abundant ammonite genera, as well as diagnostic foraminifers. In the lower part of the Chimana Formation, Guillaume (1972) collected the following ammonite species indicating the *mammillatum* Zone of the late Early Albian: *Hypophylloceras* cf. *velledae* (Michelin), *Beudanticeras* sp., *Douvilleicerias* cf. *mammillatum* (Schlotheim), *Parengonoceras pernodosum* (Sommermeier), *P. guadaloupaeforme* (Sommermeier), *Knemiceras attenuatum* (Sommermeier). The *Hoplites dentatus* Zone above, indicating the early Middle Albian, furnished a very diversified fauna composed of *Hypophylloceras* cf. *velledae*, *H. subalpinum* (d'Orbigny), *Pictetia astieriana* (d'Orbigny), *Hemitragonites aeolus* (d'Orbigny), *Tetragonites kitchini* (Krenkel), *Puzosia* cf. *androiavensis* Breistroffer, *Anapuzosia provincialis* (Parona and Bonarelli), *Beudanticeras walleranti* (Jacob), *Uhligella rebouli* Jacob, *Desmoceras latidorsatum* (Michelin), *D. applanatum* Jacob, *Eubranoceras* sp., *Mojsisovicsia* aff. *evansi* (Spath), *Oxytropidoceras* (*Manuaniceras*) *carbonarium* (Gabb), *O. douglasi* Knechtel, *O. alticarinatum* Spath, *Prolyelliceras peruvianum* Spath, *Lyelliceras lyelli* (Leymerie), *L. pseudolyelli* (Parona and Bonarelli), *Tegoceras gladiator* (Bayle) and *Hamites* sp.

The *mammillatum* Zone corresponds to the *Praeglobotruncana rohri* Zone, which further yielded *P. infracretacea* (Glaessner), *P. gautierensis* (Brönnimann), *Globigerina kugleri* Bolli, *G. washitensis* Carsey and *Planomalina buxtoni* (Gandolfi). The *Neobulimina subcretacea* Zone yielded *Praeglobotruncana infracretacea* (Glaessner), *P. gautierensis* (Brönnimann) and *P. planispira* (Tappan) (see Bolli and Beckmann, in Guillaume, 1972).

Upper Cretaceous

After the deposition of the Chimana Formation, a period of denudation affected parts of the area. The next younger lithologic unit, the *Querecual Formation* (Hedberg and Sass, 1937), overlaps onto the El Cantil and Chimana Formations (Guillaume, 1972). It is characterized by mostly thin-bedded, bituminous, micritic limestones with discoidal concretions closely resembling those of the La Luna Formation in western Venezuela. The thickness of the interval reaches about 750 m (Rosales, 1960). In the east of the Serranía del

Interior, the *Querecual Formation* begins with the Late Albian indicated by *Praeglobotruncana planispira* (Tappan). To the west, the transgression started with the beginning of the Cenomanian. Here, *Rotalipora ticinensis* Gandolfi and *R. appenninica* (Renz) occur. In the Turonian section of the formation, the ammonite genus *Collignonicerias* occurs with *Inoceramus labiatus* Schlotheim and the foraminifers *Guembelina* and *Globigerina* (Hedberg and Pyre, 1944).

Towards the south, the *Querecual Formation* is followed by the *San Antonio Formation* (Hedberg and Sass, 1937) displaying a similar pelagic facies to the *Querecual*. It consists of thin-bedded, dark grey limestones and shales, interbedded with thin layers of chert and hard quartzitic sandstones. Anastomosing dykes are a characteristic feature similar to those observed in the Colón Formation, near Cujizál, in the Barbacoas area of western Venezuela (Laubscher, 1961). The foraminifer *Siphogenerinoides ewaldi* (Karsten) has been noted. The age of the formation is considered to be post-Turonian.

The youngest lithological unit of the Cretaceous is the *San Juan Formation* (Hedberg and Sass, 1937; Rosales, 1960). It consists of fine to medium-grained, thickly bedded sandstones with some calcareous beds at the base of the succession. The foraminifers *Dorothyia bullata* (Carsey) and *Gaudryina laevigata* Franke have been identified. The age is considered to be Maastrichtian, extending into the Paleocene.

Figure 5 summarizes the stratigraphy of the Serranía del Interior.

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NEW ZEALAND

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Abstract Macrofaunal, foraminiferal and miospore taxa important in the biostratigraphy of the Korangan to Teratan (Late Aptian to Santonian) stages are illustrated and their ranges documented. Molluscs, notably species of *Inoceramus* and *Aucellina*, provide the basic zonation to which the ranges of other taxa are related. Stratigraphic and systematic limitations are discussed.

Geological setting

The Late Jurassic–Early Cretaceous Rangitata Orogeny had a profound effect on the New Zealand region (Wellman, 1950; Fleming, 1970) and did much to obscure the record of pre-Aptian Cretaceous events. Following the main phase of tectonism, the mid-Cretaceous was a period of more localized tectonic mobility with deposition occurring in basins controlled largely by faulting. Later Cretaceous deposition was more widespread, due mostly to extensive subsidence probably related to the separation of New Zealand from Australia–Antarctica in Campanian time (Weissel *et al.*, 1977).

For the purposes of this review the “mid-Cretaceous” is taken to correspond to the period of deposition of the local sequences mentioned above. When related to the chronostratigraphic subdivision of the New Zealand Cretaceous introduced by Wellman (1959) (Fig. 1), the mid-Cretaceous thus includes the Korangan (approximately Late Aptian) to Teratan (Coniacian–Santonian) Stages. Mid-Cretaceous rocks are of two major depositional regimes:

1) largely marine, thick (some exceeding 5000 m), mostly shelf sequences dominated by sandstone, siltstone and alternating sandstone–siltstone units with minor conglomerate, developed in four regions: Northland, the Raukumara Peninsula, Wairarapa and Marlborough (Fig. 2);